

Mould Tooling & Die Industry

The following guidelines are intended to provide examples of “experimental development” projects which would qualify for Canadian SR&ED (Scientific Research & Experimental Development) tax credits.

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901 - Plastics/Metal Hybrids for auto front end module:

Scientific or Technological Objectives:

M e a s u r e m e n t	C u r r e n t P e r f o r m a n c e	O b j e c t i v e
Alignment variance (mm)	5	0.1
Increase Production Speed (Units per hour)	50	75
Increase strength and structural integrity (%)	80	100
max cost of part (\$ per unit)	26	20
maximum cost of production increase (\$ per batch)	12	15

[AUTHOR'S NOTE: THESE EXAMPLES HAVE BEEN ADAPTED FROM THE "PLASTICS MATERIALS, PROCESSING, EQUIPMENT & TOOL MAKING GUIDANCE DOCUMENT & CASE STUDIES" - APRIL, 2004. THIS DOCUMENTS ARE AVAILABLE FOR DOWNLOAD AT (www.cra.gc.ca/sred). THIS DOCUMENT WAS PREPARED BY A JOINT CANADA REVENUE AGENCY (CRA)-INDUSTRY SECTOR COMMITTEE.]

[AUTHOR'S NOTE: IDEALLY THE TAXPAYER WOULD ATTEMPT TO QUANTIFY THE OBJECTIVES THEY ARE TRYING TO ACHIEVE. A QUANTIFIABLE OBJECTIVE HAS BEEN ADDED ABOVE, TO ILLUSTRATE.]

Our objective was development of the design details and process conditions for the manufacture of an automotive front-end module. Since we were only provided with drawings, we needed to develop the required technology and know-how for the correct placement of the metal stampings (as part of the design details) and the process for injecting the plastic. Development of the product and process would increase our company's technology base for the manufacture of plastic / metal hybrids.

Technology or Knowledge Base Level:

Benchmarking methods & sources for citations:

- Internet searches: 23 sites / articles -- No sufficient info found
- Patent searches: 4 patents -- Different environment used for plastics/metal hybrid technology
- Similar prior in-house technologies: 1 products / processes -- Subsequent work needed to adapt the technology for use it in a front-end module.
- Potential components: 2 products -- plastics/metal hybrid technology for different materials
- Queries to experts: 3 responses -- No sufficient method found

This work concerns a proprietary plastics/metal hybrid technology in which nylon is bonded to a metal stamping, to give better strength and structural integrity that can be achieved with the metal stamping alone. Our company is a 'tier 1' supplier, which has licensed the base technology from the multinational corporation who developed it at a location outside Canada. This project covers subsequent work that was needed to adapt the technology for use it in a front-end module. The technology is not yet well established and at this point in time each application requires its own application development to accommodate the special features of the moulding process. The initial design for the part had been carried out at our customer, a U.S. auto OEM (Original Equipment Manufacturer). The work that follows was required to advance the technology to a sufficient degree that we could design a process to manufacture the parts.

Field of Science/Technology:

Materials engineering & metallurgy (2.05.01)

Intended Results:

- Improve existing processes
- Improve existing materials, devices, or products

Work locations:

Commercial Facility

Scientific or Technological Advancement:

U n c e r t a i n t y # 1 : P o s i t i o n i n g f o r t h e m e t a l i n s e r t s

Project Name: Plastics/Metal Hybrids for auto front end module
Project Number: 901

Start Date: 2009-02-27
Completion Date: 2009-05-21

The current base technology only gives an approximate position for the metal inserts. The design details including the proper positioning of the metal stamping are crucial for good adhesion. Poor adhesion can lead to problems with variability on part geometry. The original drawings were based on rules of thumb developed by the resin supplier and we had to modify these with the results acquired from our experimentation. The experimentation was needed to provide the required finesse that was not provided by the rough theoretical guidelines available to us.

The most significant underlying key variables are:
Position, Adhesion, Moulding conditions

A c t i v i t y # 1 - 1 : B u i l d i n g i n i t i a l m o u l d s

Work performed in Fiscal Year 2009:

Methods of experimentation:

- Process trials: 3 runs / samples - 3 runs performed using initial mould prototype.
- Physical prototypes: 1 sample - Initial mould prototype.

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

The initial moulds were building using the drawings provided by our customer. Initial runs gave us parts that had adequate strength, but the alignment was poor.

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD QUANTIFY HOW MANY RUNS AND SPECIFY STRENGTH RANGES OF PARTS AND THEIR ALIGNMENT. REMEMBER THAT THE TAX COURT'S CONTINUALLY REITERATE THE FACT THAT, "SYSTEMATIC INVESTIGATION MUST INVOLVE EXTREMELY ACCURATE MEASUREMENTS AND SUBSEQUENT ANALYSIS OF THOSE MEASUREMENTS." WE SHOULD THEREFORE ATTEMPT TO PROVIDE REVENUE CANADA WITH SUCH EVIDENCE WHENEVER POSSIBLE.]

Results:

- Alignment variance: 3 mm (40% of objective)
- Increase Production Speed: 60 Units per hour (40% of objective)
- Increase strength and structural integrity : 100 % (100% of objective)
- max cost of part: 19 \$ per unit (116% of objective)

Conclusion:

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD CONTAIN A CONCLUSION FOR THE CURRENT ACTIVITY. CAN WE PROVIDE ANY FURTHER TECHNICAL CONCLUSIONS AS TO WHY THESE "RESULTS" AND RELATED "INTEGRATION ISSUES" WERE NOT "READILY PREDICTABLE" TO YOU FROM A TECHNICAL STANDPOINT?]

Key variables resolved: Adhesion, Moulding conditions, Position

A c t i v i t y # 1 - 2 : M o d i f i c a t i o n o f m o u l d s

Work performed in Fiscal Year 2009:

Methods of experimentation:

- ... Prototype revisions: 2 revisions - The moulds were modified empirically in two iterations to give the required alignment.

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD BE MORE SPECIFIC AS TO WHAT AND HOW MUCH CHANGED IN EACH ITERATION].

Results:

- Alignment variance: 0.1 mm (100% of objective)
- Increase Production Speed: 77 Units per hour (108% of objective)
- max cost of part: 20 \$ per unit (100% of objective)
- maximum cost of production increase: 14 \$ per batch (66% of objective)

Conclusion:

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD CONTAIN A CONCLUSION FOR THE CURRENT ACTIVITY.]

ADDITIONAL CRA COMMENTS REGARDING ELIGIBILITY:

The base technology had clearly been developed outside Canada. Much of the final development was performed in Canada. The final design and production development (this term includes both product and process development) required further work to advance the technology and remove the technological uncertainty around the shrinkage of the materials in this process. As long as the work carried out in Canada meets the SR&ED criteria, it can form basis for a valid claim, even though the underlying technology was developed outside the country.

Project Name: Plastics/Metal Hybrids for auto front end module
Project Number: 901

Start Date: 2009-02-27
Completion Date: 2009-05-21

Key variables resolved: Adhesion, Moulding conditions, Position

901 - Plastics/Metal Hybrids for auto front end module

Benchmarks: Internet searches: 23 sites / articles
 Patent searches: 4 patents
 Similar prior in-house technologies: 1 products /
 Potential components: 2 products
 Queries to experts: 3 responses

Objectives: Alignment variance: 0.1 mm
 Increase Production Speed: 75 Units per hour
 Increase strength and structural integrity : 100 %
 max cost of part: 20 \$ per unit
 maximum cost of production increase: 15 \$ per batch

Uncertainty: 1 - Positioning for the metal inserts		Key Variables: Adhesion, Moulding conditions, Position					
Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Building initial moulds	Process trials: 3 runs / samples Physical prototypes: 1 samples	Alignment variance: 3 mm (40 %) Increase Production Speed: 60 Units per hour (40 %) Increase strength and structural integrity : 100 % (100 %) max cost of part: 19 \$ per unit (116 %)	Adhesion Moulding conditions Position	0.00	0.00	0.00	2009
2 - Modification of moulds	... prototype revisions: 2 revisions	Alignment variance: 0.1 mm (100 %) Increase Production Speed: 77 Units per hour (108 %) max cost of part: 20 \$ per unit (100 %) maximum cost of production increase: 14 \$ per batch (66 %)	Adhesion Moulding conditions Position	0.00	0.00	0.00	2009

902 - Plastic Injection Moulding and Extrusion Dies:

Scientific or Technological Objectives:

M e a s u r e m e n t	C u r r e n t P e r f o r m a n c e	O b j e c t i v e
Rejection rate (%)	30	2
Increase Extrusion production speed (inches per hour)	24	35
Maintain Part geometry tolerance (%)	94	100
minimize cost of production (\$ per inches)	15	10
cost of die (\$ per unit)	2500	1500

[AUTHOR'S NOTE: THIS EXAMPLE HAS BEEN ADAPTED FROM THE CANADA REVENUE AGENCY'S "PLASTICS MATERIALS, PROCESSING, EQUIPMENT & TOOL WAS MAKING GUIDANCE DOCUMENT & CASE STUDIES" - APRIL, 2004. THIS DOCUMENTS ARE AVAILABLE FOR DOWNLOAD AT (www.cra.gc.ca/sred). THIS DOCUMENT WAS PREPARED BY A JOINT CANADA REVENUE AGENCY (CRA)-INDUSTRY SECTOR COMMITTEE.]

[AUTHOR'S NOTE: IDEALLY THE TAXPAYER WOULD ATTEMPT TO QUANTIFY THE OBJECTIVES THEY ARE TRYING TO ACHIEVE. A QUANTIFIABLE OBJECTIVE HAS BEEN ADDED ABOVE, TO ILLUSTRATE.]

Our objective was development of the know-how required to design a PVC housing that would meet our customer's functional requirements, the design of very large extrusion dies for shaping and forming the extruded parts, and the development of manufacturing methods for large extrusion dies too large for EDM manufacture. The initial purpose of the project was the design of an injection mould for the manufacture of unusually large PVC parts with a complex profile. The part had a thick exterior wall, four interior chambers and a flange on one end. The project evolved into the development of extrusion dies and the technology required for manufacturing both the dies and the parts. To develop an understanding of the flow characteristics of extruding plastic and to apply this understanding to develop the processing parameters for large extrusion dies with multiple internal chambers, thick wall stock and external flanges.

Technology or Knowledge Base Level:

Benchmarking methods & sources for citations:

- Internet searches: 23 sites / articles -- limited info on technology needed to produce the extrusion dies
- Patent searches: 3 patents -- different environment for extrusion dies
- Similar prior in-house technologies: 1 product / processes -- This would be our first attempt at designing and producing extrusion dies of this size.

Our company is a leader in the design and manufacture of plastic injection moulds, which make up the bulk of our business. We had won a contract to design and build tooling to produce complex moulded PVC housings that were over 57" wide, 12" high and had a wall stock of 3/8-1/2". These very large parts had multiple internal cavities with internal and external flanges.

This example describes a project that began as an injection mould design that was expected to contain only a limited amount of work meeting the SR&ED criteria. At some point the direction of the project changed, when we realized that we had to develop the manufacturing technology needed to produce the extrusion dies.

After the initial design work it became apparent that injection moulding would not give parts that could meet the functional requirements for rigidity and impact resistance. We decided that the parts would have to be extruded. This would be our first attempt at designing and producing extrusion dies of this size.

The size of the available extrusion machines provided a constraint. This impacted on the size of the dies since only a limited amount of space was available for the plastic to expand from the 3" extruder head to the 57" product width. As a result the extruded material had to flow through an angle of 135 degrees, compared to the typical 10 to 20 degrees. There were also concerns that the moulding pressure might blow apart the dies. The dies were therefore designed with a single piece outer construction to obtain maximum strength.

Dies of this nature are normally wire-EDM (Electrical Discharge Machine) manufactured, but because of the complexity of the flow patterns, and the large size of dies this was not possible. Since typical methods of manufacture would not work in this application, a new approach had to be developed. The compound angles of the receiving block and its four interior chambers would have to be separately manufactured. This could only be done using CNC (Computer Numeric Controlled) contoured milling of the outer single-piece receiving block.

Project Name: Plastic Injection Moulding and Extrusion Dies
Project Number: 902

Start Date: 2009-03-01
Completion Date: 2010-07-09

Field of Science/Technology:

Materials engineering & metallurgy (2.05.01)

Intended Results:

- Develop new materials, devices, or products
- Improve existing processes

Work locations:

Analysis, Commercial Facility

Scientific or Technological Advancement:

U n c e r t a i n t y # 1 : P a r t D e s i g n

We had to design a part that could be produced with the extrusion process and still meet the functional requirements of the customer. Our base technology did not allow us to be confident that this could be done, since our experience with extrusion was limited and as far as we knew, the dies would be the largest of this type in production on the industry.

The most significant underlying key variables are:
speed, material, tolerance

A c t i v i t y # 1 - 1 : M u l t i p l e m o d e l p i e c e s

Work performed in Fiscal Year 2009:

Methods of experimentation:

- Analysis / simulation: 3 alternatives - Different piece configurations analyzed.
- Physical prototypes: 5 samples - Models used to test fit of pieces.

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

The finished product was made from a number of pieces. We designed these pieces and build models to ensure that the finished pieces would fit together to give a part that met our customer's requirements. We then designed the dies required to manufacture the parts.

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD QUANTIFY HOW MANY PIECES THE FINISHED PRODUCT WAS MADE WITH.]

Results:

No results have been recorded for this Activity.

[NOTE: IF THERE WERE ANY TEST RESULTS FROM THIS ACTIVITY THAN THESE SHOULD BE STATED HERE]

Conclusion:

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD CONTAIN A CONCLUSION FOR THE CURRENT ACTIVITY. CAN WE PROVIDE ANY FURTHER TECHNICAL CONCLUSIONS AS TO WHY THESE "RESULTS" AND RELATED "INTEGRATED ISSUES" WERE NOT "READILY PREDICTABLE" TO YOU FROM A TECHNICAL STANDPOINT?]

Key variables resolved: material, speed, tolerance

U n c e r t a i n t y # 2 : D e s i g n a n d P r o c e s s f o r d i e s c o n s t r u c t i o n

The dies would have to be constructed of a single outer shell to prevent the die from blowing apart under extruding pressures related to flow requirements. Typically extrusion dies are produced with wire-EDM (electric discharge machining). The present dies could not be produced using conventional machining methods for two reasons:

- a) The large overall size meant that the parts could not fit into any wire-EDM machine.
- b) The requirement for a 135 degrees angle over an 18" distance.

The most significant underlying key variables are:
angle vs. distance, number of components of die, cooling, assembly method

A c t i v i t y # 2 - 1 : C o n s t r u c t i o n o f t h e d i e s

Project Name: Plastic Injection Moulding and Extrusion Dies
Project Number: 902

Start Date: 2009-03-01
Completion Date: 2010-07-09

Work performed in Fiscal Year 2009:

Methods of experimentation:

- Physical prototypes: 4 samples - One fixture for each of the four interior chamber components.
- ... prototype revisions: 2 revisions

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

Upon completion of the design of the dies we realized that there were additional technical problems that we had not considered at the beginning of the project. The greatest of these was how to manufacture the dies. To produce the four interior chamber components, fixtures were building for each component. They were then manufactured using CNC contoured milling and sink EDM. These interior chamber components were then mounted using flow dividers to fasten them to the main receiving block. Finally the extrusion die, which was wire EDM and had interior chamber components mounted with flow dividers, was assembled to the receiving block.

Results:

No results have been recorded for this Activity.

[NOTE: SIMILARLY, IF THERE WERE ANY TEST RESULTS FROM THIS ACTIVITY THAN THESE SHOULD BE STATED HERE]

Conclusion:

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD CONTAIN A CONCLUSION FOR THE CURRENT ACTIVITY.]

Key variables resolved: angle vs. distance, assembly method, cooling, and number of components of die

U n c e r t a i n t y # 3 : F l o w a n d f i l l i n g o f p l a s t i c

We expect that extrusion of plastic from a 3" extruder head to 57" in a span of less than 18" would lead to poor flow and filling difficulties.

The most significant underlying key variables are:
material, speed, length, Temp, density

A c t i v i t y # 3 - 1 : T e s t i n g o f d i e

Work performed in Fiscal Year 2010:

Methods of experimentation:

- Physical prototypes: 1 samples
- ... Prototype revisions: 13 revisions - It was necessary to rework the contoured shape of the receiving block many times over the next few months before finally obtaining a successful result.

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

Upon "first test" the dies functioned as designed, however there were problems with the receiving plate and in particular the flow of the plastic being extruded. The dies did withstand the high processing pressure; however the angles called for in the design were not sufficiently contoured to provide the required flow of plastic. It was necessary to rework the contoured shape of the receiving block many times over the next few months before finally obtaining a successful result. The problem was developing a shape that would force the material in a lateral direction.

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD SPECIFY THE PROCESSING PRESSURE AND QUANTIFY HOW MANY TIMES IT WAS NECESSARY TO REWORK THE CONTOURED SHAPE. REMEMBER THAT THE TAX COURT'S CONTINUALLY REITERATE THE FACT THAT, "SYSTEMATIC INVESTIGATION MUST INVOLVE EXTREMELY ACCURATE MEASUREMENTS AND SUBSEQUENT ANALYSIS OF THOSE MEASUREMENTS." WE SHOULD THEREFORE ATTEMPT TO PROVIDE REVENUE CANADA WITH SUCH EVIDENCE WHENEVER POSSIBLE.]

Results:

- Rejection rate: 2 % (100% of objective)
- Increase Extrusion production speed: 34 inches per hour (90% of objective)
- Maintain Part geometry tolerance: 100 % (100% of objective)
- minimize cost of production: 11 \$ per inches (80% of objective)
- cost of die: 1600 \$ per unit (90% of objective)

Conclusion:

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION FOR THE CURRENT ACTIVITY WOULD CONTAIN A CONCLUSION AS TO THE OPTIMAL SHAPE OF THE DIE.]

Project Name: Plastic Injection Moulding and Extrusion Dies
Project Number: 902

Start Date: 2009-03-01
Completion Date: 2010-07-09

ADDITIONAL CRA COMMENTS REGARDING ELIGIBILITY:

In the course of carrying out SR&ED, new information is often acquired that can have a significant impact on the scope, direction or duration of a project. In this case resolving the technological uncertainties required to design the die, resulted in die that could not be manufactured with routine techniques. It was necessary to take a new approach to die manufacture and assembly. Normally it is relatively easy to accommodate changes in scope or direction into an SR&ED claim, since the claim is written after the work has been done. The additional technological advancement required and / or the associated technological uncertainties can be included, even if they were not obvious at the beginning of the project. In this case "a method to cut metal in complex shapes that are not possible with EDM" would be added to the list of technological advancements. If the project is split in two and submitted in two or more tax years, then the changes will be made to the advancements and uncertainties in the second or subsequent years work, with an explanation as to what had generated the need for change. This project provided an opportunity for the mould maker to design and manufacture unique extrusion dies, expanding their technology base from that required for the design and manufacture of injection moulds that formed the bulk of their business. They took a new approach to die manufacture and assembly, drawing on the experience of their designers to develop the die design, and to learn about the flow characteristics of extruded plastic.

Key variables resolved: density, length, material, speed, Temp

902 - Plastic Injection Moulding and Extrusion Dies

Benchmarks:	Internet searches: 23 sites / articles Patent searches: 3 patents Similar prior in-house technologies: 1 products /	Objectives:	Rejection rate: 2 % Increase Extrusion production speed: 35 inches per hour Maintain Part geometry tolerance: 100 % minimize cost of production: 10 \$ per inches cost of die: 1500 \$ per unit
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Uncertainty:	1 - Part Design	Key Variables:	material, speed, tolerance				
Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Multiple model pieces	Analysis / simulation: 3 alternatives Physical prototypes: 5 samples	(none)	material speed tolerance	0.00	0.00	0.00	2009

Uncertainty:	2 - Design and Process for dies construction	Key Variables:	angle vs. distance, assembly method, cooling, number of components of die				
Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Construction of the dies	Physical prototypes: 4 samples ... prototype revisions: 2 revisions	(none)	angle vs. distance assembly method cooling number of components of die	0.00	0.00	0.00	2009

Uncertainty:	3 - Flow and filling of plastic	Key Variables:	density, length, material, speed, Temp				
Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Testing of die	Physical prototypes: 1 samples ... prototype revisions: 13 revisions	Rejection rate: 2 % (100 %) Increase Extrusion production speed: 34 inches per hour (90 %) Maintain Part geometry tolerance: 100 % (100 %) minimize cost of production: 11 \$ per inches (80 %) cost of die: 1600 \$ per unit (90 %)	density length material speed Temp	0.00	0.00	0.00	2010

903 - Automotive Exterior Trim:

Scientific or Technological Objectives:

M e a s u r e m e n t	C u r r e n t P e r f o r m a n c e	O b j e c t i v e
Durability (solar) (hr)	1000	3000
Resin to have High gloss surface finish (%)	0	100
Process output (Units per hour)	2	6
Part geometry tolerance (%)	95	100
Part to have Abrasion resistance as paint (%)	0	100
Surface Durability as paint (%)	0	100
Chemical Environmental Resistance as paint (%)	0	100
Maximum cost of parts (\$ per part)	75	85

[THESE EXAMPLES HAVE BEEN ADAPTED FROM THE "PLASTICS MATERIALS, PROCESSING, EQUIPMENT & TOOL MAKING GUIDANCE DOCUMENT & CASE STUDIES" - APRIL, 2004. THIS DOCUMENTS ARE AVAILABLE FOR DOWNLOAD AT (www.cra.gc.ca/sred). THIS DOCUMENT WAS PREPARED BY A JOINT CANADA REVENUE AGENCY (CRA)-INDUSTRY SECTOR COMMITTEE.]

[AUTHOR'S NOTE: IDEALLY THE TAXPAYER WOULD ATTEMPT TO QUANTIFY THE OBJECTIVES THEY ARE TRYING TO ACHIEVE. A QUANTIFIABLE OBJECTIVE HAS BEEN ADDED ABOVE, TO ILLUSTRATE.]

This example describes the shared effort of three groups to bring a new product to market for automotive exterior trim. This system is being developed to replace painted plastic parts used for exterior trim panels and moldings, with non-coated raw plastic parts that provide the same appearance and durability as paint. The resulting cost savings to the OEM will be significant if the project succeeds. The three companies involved are Resin-Us Inc., the resin supplier, Mould-R Inc., the mould maker and Process-R, the company that will manufacture the parts.

Resin - Us Inc.

The objective is the creation of a new plastic that can be used in applications such as the exterior panels of automobiles.

Techniques to resolve the following issues:

- Obtain the required gloss level and surface consistency to provide an acceptable appearance.
- Achieve this at the same time as surface strength or impact resistance requirements are met.
- Ensure that the manufactured parts have the required long-term resistance to the elements.

Process-R Inc.

The objective is the creation of process technology that will enable our company to make exterior panels and other automotive parts from a new plastic. Technological advancements will be required so that:

- The new plastic can be processed in injection moulding applications.
- The properties of the plastic will facilitate the production of a part with the required geometry.
- New techniques can be developed for post mould handling of parts made from the new plastic.

Mould-R Inc.

The objective is the creation of a mould that is capable of acquiring and maintaining the high level lens quality surface finish required to mould a "wet look" paint-like part.

Can an SPI A-1 lens quality finish be applied to an automotive mould consistently over a large surface area?

Is there a tool steel available to support this type of mould finish?

If both tool steel and polish criteria can be met, will the surface last through the moulding process?

How will the surface tension effects created by the smooth surface associated with the high finish effect the flow of plastic?

Can a runner system be developed to compensate for any flow problems, and if so how?

Technology or Knowledge Base Level:

Benchmarking methods & sources for citations:

- Internet searches: 25 sites / articles -- info on required technology was insufficient
- Patent searches: 8 patents -- did not reveal a suitable solution
- Similar prior in-house technologies: 3 products / processes -- Although all 3 groups have prior experience, as described below, this will require a new material.
- Queries to experts: 3 responses -- No new info was provided

Project Name: Automotive Exterior Trim
Project Number: 903

Start Date: 2009-01-14
Completion Date: 2010-09-16

Resin-Us was asked by their customer, the processor for a resin that could be molded to give a part that has the same: High gloss appearance, Abrasion resistance, Surface Durability and Chemical Environmental Resistance as paint. The resin supplier has never supplied a material that meets these criteria before and therefore must create a new plastic that it hopes may be used in applications such as the exterior panels of automobiles. It was expected that the resin supplier would provide samples to the supplier.

Process-R Inc's goal is to develop a process that will use the new resin to manufacture automotive body sidemoldings. They plan to work with the resin supplier to develop specifications for the plastic and a process that can use this material to obtain a product that meets the technical specifications for the part.

Mould-R needs to take the part geometry and plastic material specifications and create a mould that will produce a part that will meet the conditions specified for use in automotive exterior trim.

[AN IDEAL DESCRIPTION WOULD SPECIFY VALUES FOR PROPERTIES OF THE MATERIAL AND TECHNICAL SPECIFICATIONS FOR THE PART.]

Field of Science/Technology:

Materials engineering & metallurgy (2.05.01)

Intended Results:

- Develop new materials, devices, or products
- Improve existing processes

Work locations:

Commercial Facility

Scientific or Technological Advancement:

U n c e r t a i n t y # 1 : P r o d u c t i o n o f C o m p o u n d M a t e r i a l

Plastic parts are used routinely for exterior panels of cars and other vehicles. They are usually painted to achieve the required gloss levels, surface strength and impact resistance. The challenge is to produce a compounded material that will give parts with the required mechanical properties, which has a uniform surface that will be durable enough to withstand the environment to which it is exposed.

The most significant underlying key variables are:
gloss level, surface strength, impact resistance, durability

A c t i v i t y # 1 - 1 : F o r m u l a t i o n a n d T e s t i n g o f p l a s t i c

Work performed in Fiscal Year 2009:

Methods of experimentation:

- Process trials: 18 runs / samples - 3 series of 6 tests to develop appropriate resin formulation.

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

The plastic was formulated based on what was known about the materials using the principles of chemical science and engineering combined with past experience. The supplier molded it into sheet form for use in testing.

A series of tests were then performed to satisfy the conditions spelled out by the OEM for vehicle exteriors. The results of these tests were analyzed and adjustments were made to the formula for re-testing.

The resin was released to the plastics processor. Although it met only part of the required conditions for durability, it met most of the requirements for mouldability.

The plastics supplier continued work on the resin to complete all of its chemical requirements for things like weather resistance. Communication is maintained with the mould maker and the processor, and modifications are made to the formulation both to resolve weatherability issues and to contribute to resolving part appearance issues.

Project Name: Automotive Exterior Trim
Project Number: 903

Start Date: 2009-01-14
Completion Date: 2010-09-16

[AUTHOR'S NOTE: QUANTIFY HOW MANY TESTS AND SPECIFY THE REQUIRED CONDITIONS OF PARTS AND THEIR MOULDABILITY. REMEMBER THAT THE TAX COURT'S CONTINUALLY REITERATE THE FACT THAT, "SYSTEMATIC INVESTIGATION MUST INVOLVE EXTREMELY ACCURATE MEASUREMENTS AND SUBSEQUENT ANALYSIS OF THOSE MEASUREMENTS." WE SHOULD THEREFORE ATTEMPT TO PROVIDE REVENUE CANADA WITH SUCH EVIDENCE WHENEVER POSSIBLE.]

Results:

- Durability (solar): 2000 hr (50% of objective)

Conclusion:

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD CONTAIN A CONCLUSION FOR THE CURRENT ACTIVITY SPECIFYING WHAT THE OPTIMAL MATERIAL IS AND WHY? CAN WE PROVIDE ANY FURTHER TECHNICAL CONCLUSIONS AS TO WHY THESE "RESULTS" AND RELATED "INTEGRATED ISSUES" WERE NOT "READILY PREDICTABLE" TO YOU FROM A TECHNICAL STANDPOINT?]

Key variables resolved: durability, gloss level, impact resistance, and surface strength

U n c e r t a i n t y # 2 : P a r t P r o d u c t i o n

Having resolved the material selection issue the next challenge is to produce a part that does not need to be painted to obtain the desired surface and durability.

The most significant underlying key variables are:
surface, durability

A c t i v i t y # 2 - 1 : S a m p l e P a r t s T e s t i n g

Work performed in Fiscal Year 2009:

Methods of experimentation:

- Process trials: 7 runs / samples - Trials required to determine correct processing parameters.
- Physical prototypes: 1 samples - Part handling system.
- ... Prototype revisions: 3 revisions - Revisions required preventing damage to the parts during cooling process.

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

Sample parts of the new plastic were made utilizing existing moulds with geometry similar to the intended body side molding required for the specific application. The processing requirements were extrapolated from the indications of part appearance obtained in these initial tests. Part handling systems were developed and the initial parts were used to evaluate the process. The moulds utilized for these initial tests are set aside. Tests are carried out on them, with changes being made to the processing system to obtain the best results. These results were recorded and copies were sent both to the plastics processor's engineering department and the mould maker's engineering department. The plastics processor analyses the data and prepares for the next test. The moulds are then sent back to the mould maker. After some time the moulds returned. The plastic processor analyzed the first sample part, and made further changes to the processing parameters attempting to correct problems with part appearance. The moulds were returned to the mould maker a number of times before it were determined that the requirements can or cannot be met.

[AUTHOR'S NOTE: QUANTIFY HOW MANY TESTS, SPECIFY THE CHANGES MADE TO THE SYSTEM, THEIR RESULTS AND HOW MANY TIMES WERE THE MOULDS RETURNED TO THE MOULD MAKER.]

Results:

No results have been recorded for this Activity.

[NOTE: IF THERE WERE ANY TEST RESULTS FROM THIS ACTIVITY THAN THESE SHOULD BE STATED HERE]

Conclusion:

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD CONTAIN A CONCLUSION FOR THE CURRENT ACTIVITY. CAN WE PROVIDE ANY FURTHER TECHNICAL CONCLUSIONS AS TO WHY THESE "RESULTS" AND RELATED "INTEGRATED ISSUES" WERE NOT "READILY PREDICTABLE" TO YOU FROM A TECHNICAL STANDPOINT?]

Key variables resolved: durability, surface

U n c e r t a i n t y # 3 : M o l d P r o d u c t i o n

The third major challenge is to produce a mould that can be used with the new resin system to obtain parts with the required mechanical properties.

The most significant underlying key variables are:

Project Name: Automotive Exterior Trim
Project Number: 903

Start Date: 2009-01-14
Completion Date: 2010-09-16

materials, Strengths, Angles

A c t i v i t y # 3 - 1 : M o l d T e s t i n g

Work performed in Fiscal Year 2009:

Methods of experimentation:

- Process trials: 9 runs / samples - 3 types of steel tested, each under 3 different polishing conditions.
- Physical prototypes: 1 samples - Set of moulds.
- ... Prototype revisions: 3 revisions - Revisions required ensuring surface smoothness and correcting finished product dimensions.

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

Candidate samples of tool steel were acquired for tests on surface polishing. The results of these tests were used to select steel for the mould. Moulds were designed and built utilizing the chosen steel.

The moulds were then tested under simulated production conditions. The mould maker then released the moulds to the plastic processor for initial production mould process testing. They were returned to the mould maker along with sample parts and the data from the processor's tests.

[AUTHOR'S NOTE: SPECIFY THE GRADE AND REASON FOR THE STEEL USED. QUANTIFY HOW MANY TESTS AND SPECIFY KEY DATA.]

Results:

[NOTE: SIMILARLY, IF THERE WERE ANY TEST RESULTS FROM THIS ACTIVITY THAN THESE SHOULD BE STATED HERE]

Conclusion:

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD CONTAIN A CONCLUSION FOR THE CURRENT ACTIVITY.]

Key variables resolved: Angles, materials, Strengths

A c t i v i t y # 3 - 2 : A n a l y z i n g o f T e s t P a r t s

Work performed in Fiscal Year 2010:

Methods of experimentation:

- Analysis / simulation: 30 alternatives - Samples analyzed for problems in part appearance.

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

Analyze the test sample parts to determine what changes can be made to the mould or the handling system to correct problems in part appearance.

[AUTHOR'S NOTE: SPECIFY THOSE CHANGES. REMEMBER THAT THE TAX COURT'S CONTINUALLY REITERATE THE FACT THAT, "SYSTEMATIC INVESTIGATION MUST INVOLVE EXTREMELY ACCURATE MEASUREMENTS AND SUBSEQUENT ANALYSIS OF THOSE MEASUREMENTS." WE SHOULD THEREFORE ATTEMPT TO PROVIDE REVENUE CANADA WITH SUCH EVIDENCE WHENEVER POSSIBLE.]

Conclusion:

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD CONTAIN A CONCLUSION FOR THE CURRENT ACTIVITY.]

Key variables resolved: Angles, Strengths

A c t i v i t y # 3 - 3 : I n s p e c t i o n o f t h e M o l d

Work performed in Fiscal Year 2010:

Methods of experimentation:

- Analysis / simulation: 3 alternatives - Inspect the mould for a number of performance characteristics including surface finish, durability and determine coating requirements for surface protection.

[AUTHOR'S NOTE: SPECIFY THE SURFACE FINISH, DURABILITY AND THE COATING REQUIREMENT. REMEMBER THAT THE TAX COURT'S CONTINUALLY REITERATE THE FACT THAT, "SYSTEMATIC INVESTIGATION MUST INVOLVE EXTREMELY ACCURATE MEASUREMENTS AND SUBSEQUENT ANALYSIS OF THOSE MEASUREMENTS." WE SHOULD THEREFORE ATTEMPT TO PROVIDE REVENUE CANADA WITH SUCH EVIDENCE WHENEVER POSSIBLE.]

Project Name: Automotive Exterior Trim
Project Number: 903

Start Date: 2009-01-14
Completion Date: 2010-09-16

Results:

- Durability (solar): 2500 hr (75% of objective)
- Resin to have High gloss surface finish: 100 % (100% of objective)
- Process output : 5 Units per hour (75% of objective)
- part geometry tolerance: 99 % (80% of objective)
- Surface Durability as paint: 100 % (100% of objective)
- Chemical Environmental Resistance as paint: 100 % (100% of objective)
- Maximum cost of parts: 86 \$ per part (110% of objective)

Conclusion:

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD CONTAIN A CONCLUSION FOR THE CURRENT ACTIVITY. CAN WE PROVIDE ANY FURTHER TECHNICAL CONCLUSIONS AS TO WHY THESE "RESULTS" AND RELATED "INTEGRATED ISSUES" WERE NOT "READILY PREDICTABLE" TO YOU FROM A TECHNICAL STANDPOINT?]

Key variables resolved: Angles, materials, Strengths

903 - Automotive Exterior Trim

Benchmarks:	Internet searches: 25 sites / articles Patent searches: 8 patents Similar prior in-house technologies: 3 products / Queries to experts: 3 responses	Objectives:	Durability (solar): 3000 hr Resin to have High gloss surface finish: 100 % Process output : 6 Units per hour part geometry tolerance: 100 % Part to have Abrasion resistance as paint: 100 % Surface Durability as paint: 100 % Chemical Environmental Resistance as paint: 100 % Maximum cost of parts: 85 \$ per part
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Uncertainty:	1 - Production of Compound Material	Key Variables:	durability, gloss level, impact resistance, surface strength				
Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Formulation and Testing of plastic	Process trials: 18 runs / samples	Durability (solar): 2000 hr (50 %)	durability gloss level impact resistance surface strength	0.00	0.00	0.00	2009

Uncertainty:	2 - Part Production	Key Variables:	durability, surface				
Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Sample Parts Testing	Process trials: 7 runs / samples Physical prototypes: 1 samples ... prototype revisions: 3 revisions	(none)	durability surface	0.00	0.00	0.00	2009

Uncertainty:	3 - Mold Production	Key Variables:	Angles, materials, Strengths				
Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Mold Testing	Process trials: 9 runs / samples Physical prototypes: 1 samples ... prototype revisions: 3 revisions	(none)	Angles materials Strengths	0.00	0.00	0.00	2009
2 - Analyzing of Test Parts	Analysis / simulation: 30 alternatives	(none)	Strengths Angles	0.00	0.00	0.00	2010
3 - Inspection of the Mold	Analysis / simulation: 3 alternatives	Durability (solar): 2500 hr (75 %) Process output : 5 Units per hour (75 %) part geometry tolerance: 99 % (80 %) Maximum cost of parts: 86 \$ per part (110 %) Surface Durability as paint: 100 % (100 %) Chemical Environmental Resistance as paint: 100 % (100 %) Resin to have High gloss surface finish: 100 % (100 %)	materials Strengths Angles	0.00	0.00	0.00	2010

904 - In-line Compounding:

Scientific or Technological Objectives:

M e a s u r e m e n t	C u r r e n t P e r f o r m a n c e	O b j e c t i v e
Avg. glass fibre length (mm)	3000	7000
Maximum material cost (\$ per batch)	250	275
Increase production speed (Units per hour)	250	350
Increase pert strength (psi)	1200	1500
Maximum cost of line (\$)	55000	60000

AUTHOR'S NOTE: THIS EXAMPLE HAS BEEN ADAPTED FROM THE "PLASTICS MATERIALS, PROCESSING, EQUIPMENT & TOOL MAKING GUIDANCE DOCUMENT & CASE STUDIES" - APRIL, 2004. THIS DOCUMENT IS AVAILABLE FOR DOWNLOAD AT (www.cra.gc.ca/sred). THIS DOCUMENT WAS PREPARED BY A JOINT CANADA REVENUE AGENCY (CRA)-INDUSTRY SECTOR COMMITTEE.]

[AUTHOR'S NOTE: IDEALLY THE TAXPAYER WOULD ATTEMPT TO QUANTIFY THE OBJECTIVES THEY ARE TRYING TO ACHIEVE. A QUANTIFIABLE OBJECTIVE HAS BEEN ADDED ABOVE, TO ILLUSTRATE.]

Our objective was to develop a capability for the direct compounding of a glass-filled polypropylene resin in an injection moulding machine and improve the physical properties of glass-filled moulded parts by increasing the length of the glass fibers.

Technology or Knowledge Base Level:

Benchmarking methods & sources for citations:

- Internet searches: 12 sites / articles -- Limited info on capabilities for the direct compounding of a glass-filled polypropylene resin
- Similar prior in-house technologies: 1 products / processes -- Current process used pre-compounding, which limits the length of fibres.
- Queries to experts: 3 responses -- No new info on direct compounding of a glass-filled polypropylene resin discovered.

Normally, filled resins are precompounded prior to the injection moulding process. There are limits to the length of the fibers that can be introduced and in many cases better product performance would be achieved if longer fibers could be used. A company wanted to develop a capability for the direct compounding of a glass-filled polypropylene resin in an injection moulding machine.

Field of Science/Technology:

Composites (including laminates, reinforced plastics, cermets, combined natural and synthetic fibre fabrics) (2.05.04)

Intended Results:

- Improve existing processes
- Improve existing materials, devices, or products

Work locations:

Commercial Facility

Scientific or Technological Advancement:

U n c e r t a i n t y # 1 : E q u i p m e n t

- The twin screw extruder, which was designed for continuous extrusion operation, was required to run discontinuously (start / stop). It was not known what effect this would have on the uniformity of the resin properties and the distribution of the glass fibers.

- The twin screw extruder normally experienced little or no resistance to the outflow of resin. It was not known how much backpressure would be created by transferring the compounded resin to a shooting pot and how this might affect the

Project Name: In-line Compounding
Project Number: 904

Start Date: 2009-03-05
Completion Date: 2010-06-08

operation of the extruder. It was also not known if the extruder could exert sufficient pressure to fill the shooting pot.

- Shooting pots in two stage injection units are usually filled quickly at the end of the plasticizing cycle of the injection screw. It was not known how the continuous filling of the shooting pot during plasticizing by the twin screw extruder would affect the uniformity of the melt.

The most significant underlying key variables are:
uniformity of the resin, distribution of the glass fibers, backpressure, uniformity of the melt

A c t i v i t y # 1 - 1 : C h a n g e s t o t h e E q u i p m e n t

Work performed in Fiscal Year 2009:

Methods of experimentation:

- Process trials: 2 runs / samples - Runs required to test the below equipment modifications.
- Physical prototypes: 4 samples - Design and/or redesign of: injection unit, barrel head, feed of roving to barrel head, and machine controls.

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

- Design changes to the injection unit to allow the standard, single, injection moulding screw to be replaced by a standard intermeshing twin screw extruder intended for extrusion processing.
- Redesign of the injection unit barrel head to interface with the extruder and feed in the continuous glass woven roving.
- Design of a mechanism and structure to feed the glass woven roving from containers to the barrel head.
- Modifications to the machine controls to control the operation of the twin screw extruder.

[AUTHORS NOTE: WHAT TESTING WAS DONE FOLLOWING THESE EQUIPMENT CHANGES?]

Results:

- Maximum cost of line: 62000 \$ (140% of objective)

Conclusion:

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD CONTAIN A CONCLUSION FOR THE CURRENT ACTIVITY.]

Key variables resolved: backpressure, distribution of the glass fibers, uniformity of the melt, and uniformity of the resin

U n c e r t a i n t y # 2 : P r o c e s s

- Relationship between throughput (operating speed) and fiber length.
- Relationship between throughput and uniformity (homogeneity) of fiber distribution.
- Relationship between the amount of glass and the uniformity of fiber distribution.
- Compounded resin property changes resulting from increased length of glass fibers.
- Sensitivity of properties to glass fiber length distribution.
- Sensitivities of material properties to screw speed, injection speed, melt temperature, mould temperature and hold pressure.

The most significant underlying key variables are:
throughput, fiber length, uniformity of fiber distribution, amount of glass, screw speed

A c t i v i t y # 2 - 1 : I n f l u e n c e o f m o u l d i n g p r o c e s s p a r a m e t e r s

Work performed in Fiscal Year 2010:

Methods of experimentation:

- Process trials: 20 runs / samples - Varied 5 parameters (amount of glass fiber, resin melt temperature, screw speed, injection speed & hold pressure) each over 4 settings.

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

We had to determine the influence of moulding process parameters such as the amount of glass fiber, resin melt temperature, screw speed, injection speed and hold pressure. **Measured the strength, heat deflection temperature of moulded parts and the glass fiber length distribution.**

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[AUTHOR'S NOTE: QUANTIFY OR SPECIFY THESE PARAMETERS. REMEMBER THAT THE TAX COURT'S CONTINUALLY REITERATE THE FACT THAT, "SYSTEMATIC INVESTIGATION MUST INVOLVE EXTREMELY ACCURATE MEASUREMENTS AND SUBSEQUENT ANALYSIS OF THOSE MEASUREMENTS." WE SHOULD THEREFORE ATTEMPT TO PROVIDE REVENUE CANADA WITH SUCH EVIDENCE WHENEVER POSSIBLE.]

Results:

- Avg. glass fibre length: 7500 mm (112% of objective)
- Maximum material cost: 277 \$ per batch (108% of objective)
- Increase production speed: 342 Units per hour (92% of objective)
- Increase pert strength: 1500 psi (100% of objective)

Conclusion:

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD CONTAIN A CONCLUSION FOR THE CURRENT ACTIVITY. CAN WE PROVIDE ANY FURTHER TECHNICAL CONCLUSIONS AS TO WHY THESE "RESULTS" AND RELATED "INTEGRATED ISSUES" WERE NOT "READILY PREDICTABLE" TO YOU FROM A TECHNICAL STANDPOINT?]

ADDITIONAL CRA COMMENTS REGARDING ELIGIBILITY:

In this example the work carried out in the project meets the requirements of experimental development. The technological advancement sought is the "know-how" required to compound glass-filled polypropylene resin directly in an injection moulding machine. The technology involves both the development of machinery and process control.

This example also illustrates the relationship between technological advancement and technological uncertainty, i.e. the attempt at technological advancement, in this case the technological "know-how", becomes obvious when the work is directed to resolve the technological uncertainties involved in the equipment, the process and the material.

[NOTE: FOR ADDITIONAL EXAMPLES FOR THE MOULD TOOL & DIE INDUSTRY PLEASE LOG-IN AT WWW.RDBASE.NET, USERNAME: user@mtd password: user]

Key variables resolved: amount of glass, fiber length, screw speed, throughput, and uniformity of fiber distribution

904 - In-line Compounding

Benchmarks:	Internet searches: 12 sites / articles Similar prior in-house technologies: 1 products / Queries to experts: 3 responses	Objectives:	Avg. glass fibre length: 7000 mm Maximum material cost: 275 \$ per batch Increase production speed: 350 Units per hour Increase pert strength: 1500 psi Maximum cost of line: 60000 \$
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Uncertainty: 1 - Equipment **Key Variables:** backpressure, distribution of the glass fibers, uniformity of the melt, uniformity of the resin

Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Changes to the Equipment	Process trials: 2 runs / samples Physical prototypes: 4 samples	Maximum cost of line: 62000 \$ (140 %)	uniformity of the resin distribution of the glass fibers backpressure uniformity of the melt	0.00	0.00	0.00	2009

Uncertainty: 2 - Process **Key Variables:** amount of glass, fiber length, screw speed, throughput, uniformity of fiber distribution

Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Influence of moulding process parameters	Process trials: 20 runs / samples	Avg. glass fibre length: 7500 mm (112 %) Maximum material cost: 277 \$ per batch (108 %) Increase production speed: 342 Units per hour (92 %) Increase pert strength: 1500 psi (100 %)	throughput fiber length uniformity of fiber distribution amount of glass screw speed	0.00	0.00	0.00	2010

905 - Bottle Filling - Product Range Extension:

Scientific or Technological Objectives:

M e a s u r e m e n t	C u r r e n t P e r f o r m a n c e	O b j e c t i v e
Shelf life (months)	6	12
container that would be hotfillable (Deg C)	50	85
Must withstand headspace depth (mm)	0	15
the threaded part of the bottle (mm ³)	0	43
max production cost of bottle (\$ per unit)	0.05	0.035

[AUTHOR'S NOTE: THESE EXAMPLES HAVE BEEN ADAPTED FROM THE "PLASTICS MATERIALS, PROCESSING, EQUIPMENT & TOOL MAKING GUIDANCE DOCUMENT & CASE STUDIES" - APRIL, 2004. THIS DOCUMENTS ARE AVAILABLE FOR DOWNLOAD AT (www.cra.gc.ca/sred). THIS DOCUMENT WAS PREPARED BY A JOINT CANADA REVENUE AGENCY (CRA)-INDUSTRY SECTOR COMMITTEE.]

[AUTHOR'S NOTE: IDEALLY THE TAXPAYER WOULD ATTEMPT TO QUANTIFY THE OBJECTIVES THEY ARE TRYING TO ACHIEVE. A QUANTIFIABLE OBJECTIVE HAS BEEN ADDED ABOVE, TO ILLUSTRATE.]

Our objective is the development of a small single serve container that would be hotfillable and provide the required shelf life for juice, isotonic and sauce applications.

Also, determination of the relative impact of condensation and thermal contraction on vacuum formation in a single-serve hotfilled PET bottle.

Technology or Knowledge Base Level:

Benchmarking methods & sources for citations:

- Internet searches: 12 sites / articles -- Limited info on Hot filling was found
- Patent searches: 4 patents -- Hot filling patents use different material
- Similar prior in-house technologies: 1 products / processes -- The smaller size of this container introduces technical challenges.
- Queries to experts: 2 responses -- Material suppliers did not reveal a solution.

With the wider consumer acceptance of plastics containers in the food and beverage market, there is an on-going trend to replace glass containers with plastic. A plastics container company embarked on a program to develop a small single serve container that would be hotfillable and provide the required shelf life for juice, isotonic and sauce applications.

Hot filling is employed to sterilize the internal surface of the container and closure and not to reduce microbial counts in the product. Bottles from any reputable manufacturer will have very low microbial loads since the melt and reheat-blow processing sterilizes them. In most modern processes, the product with which the bottle is filled has already been pasteurized by a thermal treatment before filling. Subsequent handling should maintain this cleanliness.

In the filling process the hot liquid, typically at 185°F (85°C), is introduced into the bottle by a fill tube, which is withdrawn leaving a headspace, and the bottles are conveyed to a capper where more headspace is created by sloshing. Our industry specification is that bottles must be able to withstand a headspace of 15 mm depth.

After capping, the bottle cools and the water vapour in the headspace condense contributing to a vacuum. The liquid also thermally contracts. The bottles must be designed to withstand the hot filling and the subsequent vacuum that forms when the liquid cools. The vacuum level also determines the amount of residual oxygen in the bottle, which impacts on the shelf life of oxygen sensitive products.

The bottle generally has an industry standard finish (the threaded part of the bottle) of 43 mm³, a size that imposes severe challenges on bottle design. To withstand this partial vacuum, PET bottles are made with panels and domes. The panels are designed to flex on cooling and take up the vacuum, while the rest of the bottle remains rigid so as to meet toplayer, shrinkage and ovalization specifications.

Since the company had been manufacturing larger size (1L and 2L) hotfill containers for the beverage market for a number of years, the engineer who prepared the technical descriptions included in the company's SR&ED claims was concerned because the project appeared to be a routine design and engineering procedure at first glance. Since he felt that there was a significant

Project Name: Bottle Filling - Product Range Extension
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Completion Date: 2010-10-11

amount of technical uncertainty that would have to be resolved in order to successfully completes the project, he contacted his local CRA office for advice on how to prepare his claim.

Field of Science/Technology:

Chemical process engineering (2.04.02)

Intended Results:

- Develop new materials, devices, or products

Work locations:

Commercial Facility

Scientific or Technological Advancement:

U n c e r t a i n t y # 1 : P a r a m e t e r s t h a t c o n t r o l t h e v a c u u m

Without knowing the parameters that control the vacuum formed in the headspace of a hotfilled bottle, it is not possible to calculate the stresses on the bottle or to determine the shelf life of the product.

The most significant underlying key variables are:
geometry, finish size, filling liquid temperature, filling speed, types of nozzles, cooling speeds

A c t i v i t y # 1 - 1 : A n a l y z i n g a n d E v a l u a t i n g t e s t r e s u l t s

Work performed in Fiscal Year 2009:

Methods of experimentation:

- Analysis / simulation: 4 alternatives - Bottle and vacuum panel designs were evaluated using finite element analysis to determine the optimize design for building a prototyping mould.
- Process trials: 64 runs / samples - 2-level factorial design with 6 variables.
- Physical prototypes: 1 samples
- ... Prototype revisions: 3 revisions - Modifications were done on the panel design and material distribution to optimize the structural performance of the bottle.

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

Several bottle and vacuum panel designs were evaluated using finite element analysis to determine the optimize design for building a prototyping mould.

Bottles made with the optimized design were filled at 85°C and tested using the standard hotfilled container procedures and specifications. Modifications were done on the panel design and material distribution to optimize the structural performance of the bottle.

Overall volume change of the bottles was measured using the displacement method in a graduated cylinder. The change was compared to the calculated value of liquid contraction and vapour condensation. A series of experimental runs were carried out on the filling line to determine the major factors that impacted on the pressure and amount of the headspace gasses. These were two level factorial designs that looked at the impact of bottle shape (two potential designs) with differences in geometry, finish size, filling liquid temperature, filling speed and two different types of nozzles. These runs were repeated during two separate shifts (one a day shift the other a night shift, to provide different cooling speeds due to different ambient temperatures).

The pressure in the headspace was measured. The rate of oxygen transmission through the bottle wall was also measured using a proprietary method. The results were analyzed to determine the effect of each of the variables on pressure and product shelf life.

[AUTHOR'S NOTE: QUANTIFY HOW MANY BOTTLE/VACUUM PANEL DESIGNS, EXPERIMENTS AND RUNS WERE EVALUATED AND SPECIFY THESE RESULTS. REMEMBER THAT THE TAX COURT'S CONTINUALLY REITERATE THE FACT THAT, "SYSTEMATIC INVESTIGATION MUST INVOLVE EXTREMELY ACCURATE

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MEASUREMENTS AND SUBSEQUENT ANALYSIS OF THOSE MEASUREMENTS." WE SHOULD THEREFORE ATTEMPT TO PROVIDE REVENUE CANADA WITH SUCH EVIDENCE WHENEVER POSSIBLE.]

Results:

- Shelf life: 10 months (66% of objective)
- container that would be hotfillable : 85 Deg C (100% of objective)
- Must withstand headspace depth: 15 mm (100% of objective)
- the threaded part of the bottle: 43 mm³ (100% of objective)
- max production cost of bottle: 0.04 \$ per unit (66% of objective)

Conclusion:

The project was concluded successfully. The company had always believed that the major factor in creating vacuum pressure was the condensation in the headspace, but closer examination reveals some surprises. The work showed that the major cause of vacuuming was simply from cooling the liquid from 85 to 23°C. The work showed that there is a significantly higher oxygen/liquid ratio in the headspace for the single serve containers when compared to the larger size containers; this has very serious implications for oxygen sensitive liquids.

Based on this study, it was concluded that smaller finish sizes are necessary if we are to design successful smaller-volume containers for hotfill applications. This will lead to lighter-weight (lower cost) containers and lower cost closures.

ADDITIONAL CRA COMMENTS REGARDING ELIGIBILITY:

Work to extend a product line is not automatically SR&ED. In this case the work meets the criteria for SR&ED since a technological advancement is required and the work is carried out systematically. The CRA R&T advisor recommended that the project description should be modified to clarify the number of experimental runs required to advance the technology, their length and the amount of material that was scrapped in these experiments. The review process was facilitated by this additional information.

Key variables resolved: cooling speeds, filling liquid temperature, filling speed, geometry, finish size, types of nozzles

Uncertainty #2: Container satisfying required properties

In the following example, our company had production problems with the manufacture of a bottle that had been developed in our plant.

In order to reduce material cost and improve cycle time during the preform injection process, the company had decided to reduce the weight of an existing plastics bottle by 5% for a juice application. Since it was uncertain whether the lighter weight container could still satisfy all physical properties and specifications, it was necessary to proceed with a prototyping injection mould to manufacture the new preforms. The lighter weight preforms were subsequently blown into the same juice container for testing. During the development of this lighter weight container, it was found that the bottle satisfied all the specified requirements, except the top load condition, i.e. the bottle was collapsing when the specified force was applied to the top of the container.

The most significant underlying key variables are:

Type of design variables, Filling liquid temperature (unresolved), Material distribution

A c t i v i t y # 2 - 1 : P e r f o r m i n g T e s t s

Work performed in Fiscal Year 2010:

Methods of experimentation:

- Process trials: 12 runs / samples - We ran several experiments to resolve the poor top load condition. Using Design of Experiment techniques, the poor top load condition was eventually rectified with a new preform design to allow material to be distributed in the desirable area during the blow moulding process. The technology to produce the lighter weight preform and container was then transferred to a production plant.

A few months after the bottle had been in production, the process operator found that the bottle had failed the specified top load requirement during his routine quality check. With the help of the Quality Assurance technician, the process operator was able to run several experiments and determined that the preform heating profile had drifted and had to be adjusted to achieve the original material distribution. The operator already knew that the bottle could achieve the top load condition when processed properly, so there was no technological uncertainty when the experiments were run.

[AUTHOR'S NOTE: THERE IS A LACK OF UNCERTAINTY. IT SEEMS LIKE ROUTINE SOLUTION: NOT ELIGIBLE FOR R&D WORK.]

Results:

No results have been recorded for this Activity.

Conclusion:

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD CONTAIN A CONCLUSION FOR THE CURRENT ACTIVITY.]

Project Name: Bottle Filling - Product Range Extension
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Completion Date: 2010-10-11

ADDITIONAL CRA COMMENTS REGARDING ELIGIBILITY:

The original work described in the previous example that was required to reduce the weight of the soft drinks bottle qualified as SR&ED. When the operator later had problems with achieving the top load condition, she already knew that the bottle could achieve the required specification when processed properly, so there was no technological uncertainty when the experiments were run.

Although the work required to return the bottle making process to its original specified conditions was carried out in a systematic manner, it is not considered to be SR&ED, since there was no need to advance the technology. It was quite clear to all parties concerned that the work only required the application of known process technology. If the operator had to develop the technology further in order to achieve the specified heating profile, a technological advancement would have been made and the work could qualify as SR&ED.

Key variables resolved: Material distribution, Type of design variables

905 - Bottle Filling - Product Range Extension

Benchmarks:	Internet searches: 12 sites / articles Patent searches: 4 patents Similar prior in-house technologies: 1 products / Queries to experts: 2 responses	Objectives:	Shelf life: 12 months container that would be hotfillable : 85 Deg C Must withstand headspace depth: 15 mm the threaded part of the bottle: 43 mm3 max production cost of bottle: 0.035 \$ per unit
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Uncertainty:	1 - Parameters that control the vacuum	Key Variables:	cooling speeds, filling liquid temperature, filling speed, geometry, finish size, types of nozzles
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Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Analyzing and Evaluating test results	Analysis / simulation: 4 alternatives Process trials: 64 runs / samples Physical prototypes: 1 samples ... prototype revisions: 3 revisions	Shelf life: 10 months (66 %) container that would be hotfillable : 85 Deg C (100 %) Must withstand headspace depth: 15 mm (100 %) the threaded part of the bottle: 43 mm3 (100 %) max production cost of bottle: 0.04 \$ per unit (66 %)	cooling speeds filling liquid temperature filling speed geometry, finish size types of nozzles	0.00	0.00	0.00	2009

Uncertainty:	2 - Container satisfying required properties	Key Variables:	Filling liquid temperature, Material distribution, Type of design variables
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Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Performing Tests	Process trials: 12 runs / samples	(none)	Material distribution Type of design variables	0.00	0.00	0.00	2010

906 - Ejection Detection:

Scientific or Technological Objectives:

M e a s u r e m e n t	C u r r e n t P e r f o r m a n c e	O b j e c t i v e
Stoppage frequency (times/shift)	3	0
Increase production speed (units per minute)	420	520
minimize maintenance requirement (hrs per week)	20	5
minimize reject rate (Units per batch)	5	1

[AUTHOR'S NOTE: THIS EXAMPLE HAS BEEN ADAPTED FROM THE "PLASTICS MATERIALS, PROCESSING, EQUIPMENT & TOOL MAKING GUIDANCE DOCUMENT & CASE STUDIES" - APRIL, 2004. THIS DOCUMENT IS AVAILABLE FOR DOWNLOAD AT (www.cra.gc.ca/sred). THIS DOCUMENT WAS PREPARED BY A JOINT CANADA REVENUE AGENCY (CRA)-INDUSTRY SECTOR COMMITTEE.]

[AUTHOR'S NOTE: IDEALLY THE TAXPAYER WOULD ATTEMPT TO QUANTIFY THE OBJECTIVES THEY ARE TRYING TO ACHIEVE. A QUANTIFIABLE OBJECTIVE HAS BEEN ADDED ABOVE, TO ILLUSTRATE.]

Our objective is to correct a problem of frequent "stoppages" on an injection moulding machine by identifying its root cause.

Technology or Knowledge Base Level:

Benchmarking methods & sources for citations:

- Internet searches: 25 sites / articles -- limited info found on mass-production moulding
- Patent searches: 3 patents -- insufficient info on plastic moulding ejection
- Similar prior in-house technologies: 1 products / processes -- Existing process was resulting in occasional mis-ejection.
- Potential components: 2 products -- ejection mechanisms for different environment

Getting moulded parts out of the tool and "down the spout" is a critical part of any mass-production moulding operation, including the more esoteric processes like rotational moulding and hand lay-up. But in injection moulding, failure to eject reliably is more than an inconvenience.

The eight-cavity mould produced a dimensionally non-critical (this was before Six Sigma) small cylinder which was ejected conventionally then blown into a hopper which gravity fed into a small conveyor for the "second op" process. Sprues fell into a barrel where they could be carted away periodically.

The system worked well enough but every once in a while, mis-ejection would cause a "stoppage". The operator would have to hit the panic button when the mould made that characteristic dull thud that suggested ejector pins that were not cycling in a straight line. If they didn't, it usually meant a crash, bent pins, and lots of expensive downtime.

After re-startup, the machine always checked out O.K. Run the process at or near an economically viable speed, however, and the problems reappeared.

Field of Science/Technology:

Mechanical engineering (2.03.01)

Intended Results:

- Improve existing processes

Work locations:

Commercial Facility

Project Name: Ejection Detection
Project Number: 906

Start Date: 2009-09-22
Completion Date: 2009-10-04

Scientific or Technological Advancement:

U n c e r t a i n t y # 1 : O v e r c o m i n g t h e r o o t c a u s e

Whether we can find the root cause, and then overcome it.

The most significant underlying key variables are:
cause of stoppage, Moulding conditions, material properties, processing speed

A c t i v i t y # 1 - 1 : L o o k i n g f o r t h e p r o b l e m

Work performed in Fiscal Year 2009:

Methods of experimentation:

- Process trials: 5 runs / samples - An iterative process was used to try to determine the cause of the problem, as outlined below.

The first step was to manually check for binding or roughness. The parts slid freely.

Loading the cavity with spray-on mould release and adding a little heat showed there was no kind of build-up or gumming action.

The pins were removed for a visual check that showed that the heads had sufficient clearance to keep them floating behind the retainer plate.

There were no witness marks on the parts and ejection seemed trouble-free at moderate speeds. Use of a strobe or high-speed camera to watch the action was considered but there seemed to be no way to adequately see the pins cycle.

The short-term solution was simply to slow the machine down, since the investigation consumed production time too.

A little later the tool went back to the mould shop for a slight modification. After the mild rework, the mould behaved perfectly. It turned out that the bores for the worst offenders were short, very short, at what seemed like not much more than the diameter of the already slender pins.

Results:

- Stoppage frequency: 0 times/shift (100% of objective)
- Increase production speed: 495 units per minute (75% of objective)
- minimize maintenance requirement: 6 hrs per week (93% of objective)
- minimize reject rate: 1 Units per batch (100% of objective)

Conclusion:

At a later date the engineer noticed that serious bellmouthing on the parts had been ignored. This telltale sign should have given away the cause; "It came like that and the other shop says it made 1.2 million parts with no problem".

Rebushed, with new drylubed pins, the mould worked as advertised. Manually sliding those nails back and forth and wiggling side to side failed to produce the lash that was not noticed because at the extremes of the pin's motion, the head gave it extra lateral support, which isn't a realistic operating condition.

ADDITIONAL CRA COMMENTS REGARDING ELIGIBILITY:

Despite the engineer's oversight, the work described here is clearly carried out in a systematic manner, meeting one of the criteria for SR&ED eligibility. The problem was solved using existing technology so there is no technological advancement and the work does not qualify as SR&ED. Again, as in the previous example, if the operator had had to develop the technology further in order to solve his problem, then the work could have qualified as SR&ED.

Key variables resolved: cause of stoppage, material properties, Moulding conditions, processing speed

Project Name: Ejection Detection
Project Number: 906

Start Date: 2009-09-22
Completion Date: 2009-10-04

906 - Ejection Detection

Benchmarks: Internet searches: 25 sites / articles
 Patent searches: 3 patents
 Similar prior in-house technologies: 1 products /
 Potential components: 2 products

Objectives: Stoppage frequency: 0 times/shift
 Increase production speed: 520 units per minute
 minimize maintenance requirement: 5 hrs per week
 minimize reject rate: 1 Units per batch

Uncertainty: 1 - Overcoming the root cause

Key Variables: cause of stoppage, material properties, Moulding conditions, processing speed

Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Looking for the problem	Process trials: 5 runs / samples	Stoppage frequency: 0 times/shift (100 %) minimize reject rate: 1 Units per batch (100 %) minimize maintenance requirement: 6 hrs per week (93 %) Increase production speed: 495 units per minute (75 %)	cause of stoppage material properties Moulding conditions processing speed	0.00	0.00	0.00	2009

907 - Compression moulding of abrasion resistant liners:

Scientific or Technological Objectives:

M e a s u r e m e n t	C u r r e n t P e r f o r m a n c e	O b j e c t i v e
Thickness tolerance (mm)	1	0.1
Production rates (feet per hour)	350	420
Improve thickness tolerance requirements (inches)	0.05	0.04
Reduce production cost (\$ per foot)	55	45

[AUTHOR'S NOTE: THESE EXAMPLES HAVE BEEN ADAPTED FROM THE "PLASTICS MATERIALS, PROCESSING, EQUIPMENT & TOOL MAKING GUIDANCE DOCUMENT & CASE STUDIES" - APRIL, 2004. THIS DOCUMENTS ARE AVAILABLE FOR DOWNLOAD AT (www.cra.gc.ca/sred). THIS DOCUMENT WAS PREPARED BY A JOINT CANADA REVENUE AGENCY (CRA)-INDUSTRY SECTOR COMMITTEE.]

[AUTHOR'S NOTE: IDEALLY THE TAXPAYER WOULD ATTEMPT TO QUANTIFY THE OBJECTIVES THEY ARE TRYING TO ACHIEVE. A QUANTIFIABLE OBJECTIVE HAS BEEN ADDED ABOVE, TO ILLUSTRATE.]

Our objective is the development of a steel filled UHMW-PE abrasion resistant liner for the pulp & paper industry.

- To use steel powder as filler in a UHMW-PE sheet intended as an abrasion resistant liner.
- To develop a mixing process for high density fillers such as steel powder.
- To control the thickness of steel filled UHMW-PE liners and meet the tolerance requirements through the use of process conditions (temperature, pressure) to control the shrinkage.

Technology or Knowledge Base Level:

Benchmarking methods & sources for citations:

- Internet searches: 25 sites / articles -- Limited info on abrasion resistant lining material
- Patent searches: 5 patents -- abrasion resistant lining materials for different application and conditions
- Competitive products or processes: 6 products -- Alternative liners for the pulp & paper industry
- Similar prior in-house technologies: 1 products / processes -- The company has experience with fillers but the high-density of the steel filler may pose challenges

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD ILLUSTRATE THE COMPANY'S CURRENT STATE OF STANDARD PRACTICE. AN EXAMPLE BENCHMARK HAS BEEN ENTERED ABOVE TO ILLUSTRATE.]

In an attempt to expand its market share and better meet its customer's needs by offering a broader product line, the plastic company embarked on the development of a new steel filled UHMW-PE4 for use as an abrasion resistant lining material in the pulp and paper industry.

Field of Science/Technology:

Composites (including laminates, reinforced plastics, cermets, combined natural and synthetic fibre fabrics) (2.05.04)

Intended Results:

- Improve existing materials, devices, or products

Work locations:

Commercial Facility

Scientific or Technological Advancement:

Uncertainty #1: Effects on properties and processing

The addition of even a small quantity of an additive to UHMW-PE can have large unpredictable adverse effects on the

Project Name: Compression moulding of abrasion resistant liners
Project Number: 907

Start Date: 2008-11-01
Completion Date: 2008-12-31

properties and processing of the polymer.

Steel powder is extremely dense and has very different properties from any filler that we have previously used with this polymer.

The most significant underlying key variables are:
Quantity of additive, Steel powder amount, Thickness

A c t i v i t y # 1 - 1 : E x p e r i m e n t a t i o n a n d R e s u l t A n a l y s i s

Work performed in Fiscal Year 2009:

Methods of experimentation:

- Process trials: 22 runs / samples - 4 experiments to select material, 6 experiments to determine processing requirements, 5 experiments to resolve mixing issues, 4 experiments on removing product from moulds, 3 experiments on thickness.

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

A set of designed experiments were conducted on small scale compression moulding equipment to determine the effects of the addition of several types of metal powders (material and morphology) on the properties of UHMW-PE (Ultra High Molecular Weight Polyethylene).

Once a material was selected that could be added to UHMW-PE to give the required properties and economics, another series of experiments were carried out to evaluate the processing requirements.

During production trials several processing problems were encountered. The unusually high bulk density of the additive gave rise to mixing problems that had to be overcome.

The new formulation had a much lower coefficient of thermal expansion and therefore did not shrink as much as standard UHMW-PE material would upon cooling. This made it difficult to remove the product from the moulds. We therefore had to experiment to find a way to remove the finished product from the moulds. This was achieved by modifying the temperature profiles.

To obtain the required thickness, standard practice is to mill the material down. This new product could not be milled as it quickly wore the carbide tipped milling blades away. Experimentation was initiated to determine how to meet the thickness specification.

[AUTHOR'S NOTE: QUANTIFY AND SPECIFY VALUES OF PARAMETERS ENCOUNTERED. REMEMBER THAT THE TAX COURT'S CONTINUALLY REITERATE THE FACT THAT, "SYSTEMATIC INVESTIGATION MUST INVOLVE EXTREMELY ACCURATE MEASUREMENTS AND SUBSEQUENT ANALYSIS OF THOSE MEASUREMENTS." WE SHOULD THEREFORE ATTEMPT TO PROVIDE REVENUE CANADA WITH SUCH EVIDENCE WHENEVER POSSIBLE.]

Results:

- Thickness tolerance: 0.7 mm (33% of objective)
- Production rates: 430 feet per hour (114% of objective)
- Improve thickness tolerance requirements : 0.045 inches (50% of objective)
- Reduce production cost: 44 \$ per foot (110% of objective)

Conclusion:

The required thickness tolerances were not met for this type of steel filled UHMW-PE lining material. It was not possible to mill the material even with carbide tips. Currently modifications to the compression moulding process are being developed to allow processing of tighter tolerance sheet. This would eliminate the need for subsequent milling to meet the thickness tolerances.

ADDITIONAL CRA COMMENTS REGARDING ELIGIBILITY:

This experimental work to produce steel filled liners is carried out in a systematic manner in an attempt to remove uncertainty and advance the technology. It is thus SR&ED. In this case one business project is presented as a sequence of technological problems. In other cases it may be more appropriate to break the project into a number of sub-projects.

Key variables resolved: Quantity of additive, steel powder amount, Thickness

Project Name: Compression moulding of abrasion resistant liners
Project Number: 907

Start Date: 2008-11-01
Completion Date: 2008-12-31

907 - Compression moulding of abrasion resistant liners

<p>Benchmarks: Internet searches: 25 sites / articles Patent searches: 5 patents Competitive products or processes: 6 products Similar prior in-house technologies: 1 products /</p>	<p>Objectives: Thickness tolerance: 0.1 mm Production rates: 420 feet per hour Improve thickness tolerance requirements : 0.04 inches Reduce production cost: 45 \$ per foot</p>
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Uncertainty: 1 - Effects on properties and processing		Key Variables: Quantity of additive, Steel powder amount, Thickness	
Activity	Testing Methods	Results - % of Objective	Variables Concluded
			Hours Materials \$ Subcontractor \$ Fiscal Year
1 - Experimentation and Result Analysis	Process trials: 22 runs / samples	Production rates: 430 feet per hour (114 %) Improve thickness tolerance requirements : 0.045 inches (50 %) Reduce production cost: 44 \$ per foot (110 %) Thickness tolerance: 0.7 mm (33 %)	Quantity of additive Steel powder amount Thickness 0.00 0.00 0.00 2009

908 - Material Substitution:

Scientific or Technological Objectives:

M e a s u r e m e n t	C u r r e n t P e r f o r m a n c e	O b j e c t i v e
Part width (cm)	8	10
Reduce cost of extrusion (\$ per feet)	75	60
Improve strength of part (psi)	900	1100
Minimize shrinkage rate (deg C per sec)	15	10
Improve production rates (feet per hour)	15	25

[AUTHOR'S NOTE: THESE EXAMPLES HAVE BEEN ADAPTED FROM THE "PLASTICS MATERIALS, PROCESSING, EQUIPMENT & TOOL MAKING GUIDANCE DOCUMENT & CASE STUDIES" - APRIL, 2004. THIS DOCUMENTS ARE AVAILABLE FOR DOWNLOAD AT (www.cra.gc.ca/sred). THIS DOCUMENT WAS PREPARED BY A JOINT CANADA REVENUE AGENCY (CRA)-INDUSTRY SECTOR COMMITTEE.]

[AUTHOR'S NOTE: IDEALLY THE TAXPAYER WOULD ATTEMPT TO QUANTIFY THE OBJECTIVES THEY ARE TRYING TO ACHIEVE. A QUANTIFIABLE OBJECTIVE HAS BEEN ADDED ABOVE, TO ILLUSTRATE.]

Our objective is to identify a lower cost alternative to ABS as part of our cost reduction program, and to develop a process that produces extruded profiles for the appliance market using lower cost mass polymerized ABS in place of ABS produced by compounding technology. The initial application was for breaker strips for a refrigerator. Decorative extruded profiles can be manufactured in a similar process.

Technology or Knowledge Base Level:

Benchmarking methods & sources for citations:

- Internet searches: 25 sites / articles -- Several materials contemplated for extruded profiles
- Patent searches: 4 patents -- Insufficient info on possibility of using a mass polymerization.
- Similar prior in-house technologies: 1 products / processes -- Current in-house process uses a more costly material.
- Queries to experts: 3 responses -- We decided to investigate the possibility of using a mass polymerization grade material

Our company is producing extruded profiles for the appliance market from ABS (Acrylonitrile-butadiene-styrene) produced with compounding technology. As a result of cost pressures in this extremely competitive market, the company was looking for alternative materials, which would provide a similar property balance at a lower price. After looking at several alternatives, and talking to our suppliers we decided to investigate the possibility of using a mass polymerization grade of ABS. Since a similar grade was chosen, the initial expectation was that the resin switch would be seamless. As part of the manufacturing routine the new profiles were put through the testing procedures to ensure performance was achieved. Although the resins had almost identical specifications, the shrinkage behaviour of the parts made from the new resin was different.

Field of Science/Technology:

Materials engineering & metallurgy (2.05.01)

Intended Results:

- Improve existing processes
- Improve existing materials, devices, or products

Work locations:

Commercial Facility

Scientific or Technological Advancement:

U n c e r t a i n t y # 1 : M a s s P o l y m e r i z a t i o n

We are presently using ABS produced via compounding technology to manufacture extruded profiles for the appliance

Project Name: Material Substitution
Project Number: 908

Start Date: 2009-02-02
Completion Date: 2009-05-14

market. Our supplier has suggested that we can obtain similar results with ABS produced in a different process (mass polymerization). Although we chose a material with similar specifications, as in this case, they will often behave differently.

thermal properties: die swell, thermal conductivity, shrinkage, flow

The most significant underlying key variables are:

Type of Material, molecular weight, die swell, thermal conductivity, shrinkage, flow

A c t i v i t y # 1 - 1 : T e s t i n g o f n e w m a t e r i a l

Work performed in Fiscal Year 2009:

Methods of experimentation:

- Process trials: 3 runs / samples - To test the 3 die prototypes.
- Physical prototypes: 3 samples

The new ABS (Acrylonitrile-butadiene-styrene) was chosen because it had a similar molecular weight and was expected to have similar thermal properties (die swell, thermal conductivity, shrinkage, flow).

400 meters of product were produced in an experimental run that took four hours. This time was required to stabilize the line and allow the production of consistent material.

Testing of the parts produced showed that they met the mechanical requirements, but that the shrinkage was different from that which was predicted and hence the size of the parts was not correct.

The dies had to be modified by trial and error, since there was no way to predict the shrinkage with the accuracy required.

In the third trial, parts were obtained which consistently had the correct dimensions.

Results:

- Part width: 10 cm (100% of objective)
- Reduce cost of extrusion: 59 \$ per feet (106% of objective)
- Improve strength of part: 1100 psi (100% of objective)
- Minimize shrinkage rate: 11 deg C per sec (80% of objective)
- Improve production rates: 27 feet per hour (120% of objective)

Conclusion:

[AUTHOR'S NOTE; AN IDEAL DESCRIPTION WOULD CONTAIN A CONCLUSION FOR THE CURRENT ACTIVITY. CAN WE PROVIDE ANY FURTHER TECHNICAL CONCLUSIONS AS TO WHY THESE "RESULTS" AND RELATED "INTEGRATED ISSUES" WERE NOT "READILY PREDICTABLE" TO YOU FROM A TECHNICAL STANDPOINT.]

[ADDITIONAL CRA COMMENTS REGARDING ELIGIBILITY:
REPLACEMENT OF ONE RESIN BY ANOTHER OR USING THE SAME RESIN PRODUCED IN A DIFFERENT PROCESS WILL OFTEN REQUIRE EXPERIMENTAL DEVELOPMENT. SUBSTITUTING A RESIN FOR A COMPETITIVE MATERIAL PRODUCED BY A DIFFERENT SUPPLIER (OR MANUFACTURED BY THE SAME SUPPLIER AT A DIFFERENT LOCATION) CAN REQUIRE SR&ED BUT IS MUCH LESS LIKELY.

IN THIS CASE SR&ED WAS REQUIRED. IN THE ABSENCE OF SCIENTIFIC PREDICTIONS, A SYSTEMATIC PROCESS OF TRIAL AND ERROR WAS USED TO MODIFY THE EXTRUSION DIES.

THE PROJECT CLAIM SHOULD INCLUDE THE LABOUR REQUIRED TO RUN THE TRIALS AND CARRY OUT THE PRODUCT TESTING. THE RESIN USED IN THESE TRIALS SHOULD ALSO BE PART OF THE CLAIM AS "MATERIALS CONSUMED". DISPOSAL COSTS OF SCRAPPED MATERIAL MIGHT ALSO BE INCLUDED IN THE CLAIM.

WHETHER OR NOT THE PROJECT IS SUCCESSFUL, WORK ON THE DIES CAN BE CLAIMED AS PART OF THE PROJECT. ANY DIES THAT ARE SCRAPPED AS PART OF THE SR&ED WORK CAN ALSO BE INCLUDED IN THE CLAIM AS "MATERIALS CONSUMED". IF THE DIES THEMSELVES ARE USED IN PRODUCTION THEN THEY BECOME "MATERIALS TRANSFORMED".]

Key variables resolved: die swell, molecular weight, shrinkage, flow, thermal conductivity, Type of Material

Project Name: Material Substitution
Project Number: 908

Start Date: 2009-02-02
Completion Date: 2009-05-14

908 - Material Substitution

Benchmarks: Internet searches: 25 sites / articles
 Patent searches: 4 patents
 Similar prior in-house technologies: 1 products /
 Queries to experts: 3 responses

Objectives: Part width: 10 cm
 Reduce cost of extrusion: 60 \$ per feet
 Improve strength of part: 1100 psi
 Minimize shrinkage rate: 10 deg C per sec
 Improve production rates: 25 feet per hour

Uncertainty: 1 - Mass Polymerization

Key Variables: die swell, molecular weight, shrinkage, flow, thermal conductivity, Type of Material

Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Testing of new material	Process trials: 3 runs / samples Physical prototypes: 3 samples	Part width: 10 cm (100 %) Reduce cost of extrusion: 59 \$ per feet (106 %) Improve strength of part: 1100 psi (100 %) Minimize shrinkage rate: 11 deg C per sec (80 %) Improve production rates: 27 feet per hour (120 %)	die swell molecular weight shrinkage, flow thermal conductivity Type of Material	0.00	0.00	0.00	2009

909 - Dual Injection:

Scientific or Technological Objectives:

M e a s u r e m e n t	C u r r e n t P e r f o r m a n c e	O b j e c t i v e
Passing impact test (%)	70	100
Improve surface finish (scratches per in sq)	25	1
Improve production rates (Units per minute)	25	35
maximum cost of part (\$ per unit)	45	36
Minimize maintenance requirement (hours per week)	15	2

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[AUTHOR'S NOTE: IDEALLY THE TAXPAYER WOULD ATTEMPT TO QUANTIFY THE OBJECTIVES THEY ARE TRYING TO ACHIEVE. A QUANTIFIABLE OBJECTIVE HAS BEEN ADDED ABOVE, TO ILLUSTRATE.]

Our objective is to develop the capability of dual injection to allow the use of recycled polymer in the core of a product, and virgin material on the outside. A second objective is to develop an understanding of the capabilities and limitations of dual injection technology.

Technology or Knowledge Base Level:

Benchmarking methods & sources for citations:

- Internet searches: 12 sites / articles -- Insufficient info on dual injection found
- Patent searches: 4 patents -- Different environment for dual injection
- Competitive products or processes: 1 product -- Dual injection is a known technology, but there are no known instances of it being used in this way.
- Potential components: 3 products -- Machines used with dual injection designed for different environment

A company wished to make use of a new technology called dual injection, which they had never used before. They believed that this technology would allow them to use recycled polymer in the core of a product, and virgin material on the outside. Performance requirements are that the outside material must be of sufficient quality to pass impact tests without surface blemish or cracking.

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD ILLUSTRATE THE COMPANY'S CURRENT STATE OF STANDARD PRACTICE.]

Field of Science/Technology:

Materials engineering & metallurgy (2.05.01)

Intended Results:

- Improve existing processes

Work locations:

Commercial Facility

Scientific or Technological Advancement:

Uncertainty #1: To achieve objectives with present technology

We did not know how to achieve our objectives with our present technology.

Project Name: Dual Injection
Project Number: 909

Start Date: 2009-05-03
Completion Date: 2009-09-09

The most significant underlying key variables are:
 machine speed, feed, belt speed, cycle time

Activity #1-1: Determine the parameters for minimum cost

Work performed in Fiscal Year 2009:

Methods of experimentation:

- Process trials: 381 runs / samples - A Taguchi L9 set of experiments to establish optimum conditions, followed by a 300-piece trial.

In order to assess the technical and commercial feasibility of this new technology, the company needed to determine the necessary machine parameters to obtain an acceptable product at minimum cost. A number of trials were performed in a standard format for designed experiments; in this case a Taguchi L9 (a statistical experimental design technique) was used. Optimum conditions were estimated and used in a final confirming experiment. A 300-piece trial was conducted at the optimum conditions to determine process capability. All 300 pieces were scrapped after the trial.

Results:

- Passing impact test: 80 % (33% of objective)
- Improve surface finish: 1 scratches per in sq (100% of objective)
- Improve production rates: 35 Units per minute (100% of objective)
- maximum cost of part: 40 \$ per unit (55% of objective)
- Minimize maintenance requirement: 5 hours per week (76% of objective)

Conclusion:

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD CONTAIN A CONCLUSION FOR THE CURRENT ACTIVITY. CAN WE PROVIDE ANY FURTHER TECHNICAL CONCLUSIONS AS TO WHY THESE "RESULTS" AND RELATED "INTEGRATED ISSUES" WERE NOT "READILY PREDICTABLE" TO YOU FROM A TECHNICAL STANDPOINT?]

ADDITIONAL CRA COMMENTS REGARDING ELIGIBILITY:

This example illustrates how the use of new technology enabled the company to reach its technical objectives and such work often involves technological uncertainty. The work was driven by a need to reduce costs. A systematic process of experimentation was used to carry it out. If a company is using a technology for the first time it does not automatically mean that they are carrying out SR&ED. When describing a project like this one, it is therefore important to identify the parts of the technology that are generally available and distinguish these from the "know-how" that the company needs to develop experimentally. In this case the technical content requirement was satisfied with the performance of a designed experiment using accepted methods, and the completeness of the work in performing the 300-piece process validation.

Key variables resolved: belt speed, cycle time, feed, machine speed

909 - Dual Injection

Benchmarks:	Internet searches: 12 sites / articles Patent searches: 4 patents Competitive products or processes: 1 products Potential components: 3 products	Objectives:	Passing impact test: 100 % Improve surface finish: 1 scratches per in sq Improve production rates: 35 Units per minute maximum cost of part: 36 \$ per unit Minimize maintenance requirement: 2 hours per week
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Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Determine the parameters for minimum cost	Process trials: 381 runs / samples	Passing impact test: 80 % (33 %) Improve production rates: 35 Units per minute (100 %) maximum cost of part: 40 \$ per unit (55 %) Minimize maintenance requirement: 5 hours per week (76 %) Improve surface finish: 1 scratches per in sq (100 %)	belt speed cycle time feed machine speed	0.00	0.00	0.00	2009

910 - Different Equipment:

Scientific or Technological Objectives:

M e a s u r e m e n t	C u r r e n t P e r f o r m a n c e	O b j e c t i v e
"Predictability" accuracy (%)	60	98
Consistent vertical and horizontal wall dimensions (%)	80	99
Production consistency between locations (%)	90	100
Minimize manufacturing cost (\$ per unit)	5.5	4.9
Improve production speed (units per hour)	45	55

[AUTHOR'S NOTE: THIS EXAMPLE HAS BEEN ADAPTED FROM THE "PLASTICS MATERIALS, PROCESSING, EQUIPMENT & TOOL MAKING GUIDANCE DOCUMENT & CASE STUDIES" - APRIL, 2004. THIS DOCUMENT IS AVAILABLE FOR DOWNLOAD AT (www.cra.gc.ca/sred). THIS DOCUMENT WAS PREPARED BY A JOINT CANADA REVENUE AGENCY (CRA)-INDUSTRY SECTOR COMMITTEE.]

[AUTHOR'S NOTE: IDEALLY THE TAXPAYER WOULD ATTEMPT TO QUANTIFY THE OBJECTIVES THEY ARE TRYING TO ACHIEVE. A QUANTIFIABLE OBJECTIVE HAS BEEN ADDED ABOVE, TO ILLUSTRATE.]

The purpose of the project was to develop procedures that can be used to design and manufacture blow moulds for the production of bottles that have a fill line to indicate the amount of product to be sold in them. These bottles need to have the same dimensions when produced in North America, Europe or South East Asia. The critical requirements were stable and consistent vertical and horizontal wall dimensions as well as consistently located fill lines.

The technological advancement was the establishment of design and manufacture parameters which would ensure that the strict dimensional requirements would be obtained in production, regardless of where either the mould or the bottle was produced. The technological advancement identified the critical parameters and provided a means of determining the variables that were used during the design of the mould to control its volume. The experimental work would provide improved "predictability".

Technology or Knowledge Base Level:

Benchmarking methods & sources for citations:

- Internet searches: 13 sites / articles -- limited info on manufacture of blow-moulded containers
- Competitive products or processes: 4 products -- manufacture of blow-moulded containers
- Similar prior in-house technologies: 1 products / processes -- The company must develop a process for improving final product dimension consistency.
- Potential components: 3 products -- machine components for interchangeability between regions

One of the critical issues in the manufacture of blow-moulded containers is ensuring that any fill lines on the finished container are correctly located to control the volume of the product in the container with sufficient accuracy. A blow mould company has been supplying blow moulds for bottles for many years and is now expanding into international markets. Their new customers are expecting moulds of similar configuration to conform to strict packaging criteria, regardless of where in the world the tool is produced. The company must develop methods to design and manufacture moulds that can be used to produce bottles with consistent dimensions.

Field of Science/Technology:

Mechanical engineering (2.03.01)

Intended Results:

- Improve existing processes

Work locations:

Commercial Facility

Project Name: Different Equipment
Project Number: 910

Start Date: 2009-08-14
Completion Date: 2009-12-23

Scientific or Technological Advancement:

Uncertainty #1: Obtaining Products Requirements

Blow moulding machines can produce different results with the same mould. Humidity, temperature, cooling, cycle, resins and settings parameters can all impact on the shrinkage factors of the material, and hence the dimensions of the plastic products produced in them. It was not certain that verifiable design and manufacturing parameters could be identified that would allow sufficient control over the process to provide products that would meet the strict requirements, independent of the location, the blow mould machine used for production, the resin supply, as well as the local technological capabilities and the climate.

The most significant underlying key variables are:
Humidity, temperature, cooling, cycle, resins

Activity #1-1: Design and Manufacture of a Prototype Mould

Work performed in Fiscal Year 2009:

Methods of experimentation:

- Physical prototypes: 1 samples
- ... prototype revisions: 3 revisions

The project began with the design and manufacture of a prototype mould. The mould design was based on the final product design. However it was modified to include measurement indicators, which during test runs could provide precise data about vertical and horizontal shrinkage as well as changes in volume. The prototype mould was built and sent to the first site for testing. Data gathered included information about the resin and the machine used the resin as well as processing temperatures and other processing parameters. This data was analyzed along with test results from the samples produced.

The mould was then returned to Canada and modifications were made to the mould based on these results. The modifications included changes to the design indicator locations and cnc machining. The mould was retested at the same Canadian site with the same conditions. Further data was collected during the production of samples. The samples were again analyzed and variables determined based on the results of this second test.

A third iteration was carried out before satisfactory results were obtained. Mould tryouts in this experiment were conducted at 4 locations in North America, Europe and Asia as identified above, although all design, machining work and preliminary testing was completed in Canada. Each time the data was collected and modifications made to establish the reliability of the predictions. It was learned from these experiments that variations inherent to processing of a product in various locations through out the world could be predicted in advance with the help of a number of parameters.

Results:

- "Predictability" accuracy: 99 % (102% of objective)
- consistent vertical and horizontal wall dimensions: 98 % (94% of objective)
- Production consistency between locations: 100 % (100% of objective)
- Minimize manufacturing cost: 4.85 \$ per unit (108% of objective)
- Improve production speed: 57 units per hour (120% of objective)

Conclusion:

The data collected from the prototype helped to develop a database for model classification based on location, equipment application and material supplied. Much was learned from the project, and the data now provides the ability to predetermine what variables must be applied prior to the design of new tooling.

ADDITIONAL CRA COMMENTS REGARDING ELIGIBILITY:

The description of the work carried out explains how the experimental mould was modified and reused for experimentation in the establishment of the dimensional variation database. The development of design procedures can be SR&ED, although only the work carried out in Canada can be claimed. The use of these procedures in subsequent projects to design production moulds may not be SR&ED. In this project the prototype mould met the CRA definition of a prototype. It was a piece of equipment designed and built for the sole purpose of experimentation and data collection. Upon completion of the experiment it was not usable for commercial production.

Key variables resolved: cooling, cycle, Humidity, resins, temperature

Project Name: Different Equipment
Project Number: 910

Start Date: 2009-08-14
Completion Date: 2009-12-23

910 - Different Equipment

Benchmarks: Internet searches: 13 sites / articles
 Competitive products or processes: 4 products
 Similar prior in-house technologies: 1 products /
 Potential components: 3 products

Objectives: "Predictability" accuracy: 98 %
 consistent vertical and horizontal wall dimensions: 99 %
 Production consistency between locations: 100 %
 Minimize manufacturing cost: 4.9 \$ per unit
 Improve production speed: 55 units per hour

Uncertainty: 1 - Obtaining Products Requirements

Key Variables: cooling, cycle, Humidity, resins, temperature

Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Design and Manufacture of a Prototype Mould	Physical prototypes: 1 samples ... prototype revisions: 3 revisions	"Predictability" accuracy: 99 % (102 %) consistent vertical and horizontal wall dimensions: 98 % (94 %) Production consistency between locations: 100 % (100 %) Minimize manufacturing cost: 4.85 \$ per unit (108 %) Improve production speed: 57 units per hour (120 %)	cooling cycle Humidity resins temperature	0.00	0.00	0.00	2009

911 - Extrusion Process:

Scientific or Technological Objectives:

M e a s u r e m e n t	C u r r e n t P e r f o r m a n c e	O b j e c t i v e
Minimize Dimension variation (mm/m)	10	1
Obtain production speed (Feet per minute)	12	15
maximum cost of die (\$ per unit)	750	800
improve die life (feet of production)	2500	3000

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Our objective is the development of technology that will provide a process to produce a PP sheet that meets the technical requirements for a number of novel applications. Additionally:

- To identify a grade of polypropylene that can be processed to produce a performing product.
- To modify the processing equipment so that a product can be obtained that meets all critical dimensional requirements.
- To develop a dependable process to produce a PP sheet that will consistently meet customer requirements.

Technology or Knowledge Base Level:

Benchmarking methods & sources for citations:

- Internet searches: 14 sites / articles -- extensive market research and an economic trend analysis
- Patent searches: 5 patents -- Different environment and application
- Similar prior in-house technologies: 1 products / processes -- Experience with polymers, but no experience with PP in this type of application.
- Potential components: 1 products -- cooling bath, its inlet and outlet temperatures and flow patterns
- Queries to experts: 2 responses -- producers of PP sheet could not meet technical requirements

Extrusion processes are used to produce a wide variety of products, such as coated wire, blown film, extruded sheet, pipes, tubes and extruded profiles.

The components of the extrusion process usually consist of an extruder (drive, gearbox and screws), the extrusion die, a cooling medium, calibration units, haul-off equipment, a saw or other cutting device and finally devices that provide any treatment required for final finishing.

In the extruder, material is added to the hopper as either powder or pellets. The hopper continuously feeds the material to a heated barrel, which contains a rotating screw. This screw simultaneously heats, mixes, pressurizes and meters the material as it transports the polymer to the die head. At the die, the polymer takes up the approximate shape of the part and is then cooled either with water or air to give the final shape. As the polymer cools, haul-off devices draw it along so that the product can either be coiled or cut to length.

The material selection process requires balancing a number of properties of the resin. These might include density, tensile strength, flexural modulus, UV Stabilizer levels, coefficient of thermal expansion, coefficient of friction, melt index, shrinkage and gloss levels. At the start of the project it is not always clear what are the important performance criteria and the levels of these are required. Experimentation is often required to determine these.

The performance of the product usually depends on the conditions under which the material was processed. Relevant process parameters can include melt temperature, barrel temperatures, die zone temperatures, back pressure, velocity and mass flow rate.

The type of equipment used to process the polymer can also impact on product performance. For example the cooling bath, its inlet and outlet temperatures and flow patterns, can modify the product performance.

Project Name: Extrusion Process
Project Number: 911

Start Date: 2009-01-01
Completion Date: 2009-05-28

After extensive market research and an economic trend analysis, the company has decided to produce a polypropylene (PP) sheet product which they hope will fulfill its customers' needs and allow them to expand their market share. Since they had no experience of the use of PP in this type of application, extensive experimentation is required so that they can develop a viable manufacturing process and gain control the many parameters and their interactions.

Field of Science/Technology:

Materials engineering & metallurgy (2.05.01)

Intended Results:

- Develop new materials, devices, or products
- Improve existing processes

Work locations:

Commercial Facility

Scientific or Technological Advancement:

Uncertainty #1: Variable Product and Unstable Process

The resin system and process conditions that were chosen based on previous experience gave a product that was too variable. The process was unstable.

The most significant underlying key variables are:

Stability, balancing a number of properties of the resin, process parameters, type of equipment

Activity #1-1: Performing Experiments to Meet Criteria

Work performed in Fiscal Year 2009:

Methods of experimentation:

- Process trials: 13 runs / samples - Varied composition & melt index.

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

In conjunction with material suppliers, several experiments were conducted on the production line with various compositions and melt index to identify a grade that could meet dimensional criteria at an acceptable mass flow rate.

Traditional processing techniques were not satisfactory because variations in melt strength and coefficient of thermal expansion caused freezing of the material, variation in hardness of the material and irregular shrinkage. These variations gave an inherently unstable process.

Rolls were replaced with flame hardened rolls that were annealed at higher temperatures to prevent damage caused from the freezing of the new material on the rolls.

The corona treater roll was replaced with a smaller roll to allow for the higher shrinkage of the new material and the amperage of the treater was increased as the PP material proved to be more difficult to treat than the conventional material run on these lines.

[AUTHOR'S NOTE: QUANTIFY HOW MANY EXPERIMENTS AND SPECIFY THE MATERIAL COMPOSITIONS. REMEMBER THAT THE TAX COURT'S CONTINUALLY REITERATE THE FACT THAT, "SYSTEMATIC INVESTIGATION MUST INVOLVE EXTREMELY ACCURATE MEASUREMENTS AND SUBSEQUENT ANALYSIS OF THOSE MEASUREMENTS." WE SHOULD THEREFORE ATTEMPT TO PROVIDE REVENUE CANADA WITH SUCH EVIDENCE WHENEVER POSSIBLE.]

Results:

- Minimize Dimension variation: 0.8 mm/m (102% of objective)
- Obtain production speed: 14 Feet per minute (66% of objective)
- maximum cost of die: 790 \$ per unit (80% of objective)
- improve die life: 3100 feet of production (120% of objective)

Conclusion:

Project Name: Extrusion Process
Project Number: 911

Start Date: 2009-01-01
Completion Date: 2009-05-28

The processing issues have been resolved and the first product in the new range has been accepted in the marketplace. Further SR&ED work is anticipated in order to produce sheets with different thickness for similar applications.

ADDITIONAL CRA COMMENTS REGARDING ELIGIBILITY:

This experimental work to develop a process to manufacture polypropylene sheets meets the criteria for SR&ED since it is carried out in a systematic manner attempting to remove uncertainty and advance the technology.

Simple selection of materials without the development of new technology is not SR&ED. In this case the required know-how is not available in the public domain and must be developed by the claimant.

The claimant correctly recognizes that the market research and an economic trend analysis (which are certainly an essential part of the business project) are not part of the SR&ED project.

Although there are three separate technological advancements required, the interactions between the materials, the equipment, the process conditions and the final end product properties means that this work must be treated as a single project. This does not however mean that all expenses will be accepted as eligible.

The labour required to identify the best grade of PP is clearly a part of the SR&ED project; the material that is scrapped as a result of the trials and which cannot be recycled is "consumed".

The work on the rolls is also a part of the SR&ED project, but the rolls themselves will be used in production and so cannot be claimed as part of the SR&ED project. An exception would be if experimental rolls are ordered for a trial and are scrapped after the trial.

Key variables resolved: balancing a number of properties of the resin, process parameters, Stability, type of equipment

911 - Extrusion Process

Benchmarks:	Internet searches: 14 sites / articles Patent searches: 5 patents Similar prior in-house technologies: 1 products / Potential components: 1 products Queries to experts: 2 responses	Objectives:	Minimize Dimension variation: 1 mm/m Obtain production speed: 15 Feet per minute maximum cost of die: 800 \$ per unit improve die life: 3000 feet of production
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Uncertainty:	1 - Variable Product and Unstable Process	Key Variables:	balancing a number of properties of the resin, process parameters, Stability, type of equipment
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Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Performing Experiments to Meet Criteria	Process trials: 13 runs / samples	Minimize Dimension variation: 0.8 mm/m (102 %) Obtain production speed: 14 Feet per minute (66 %) maximum cost of die: 790 \$ per unit (80 %) improve die life: 3100 feet of production (120 %)	balancing a number of properties of the resin process parameters Stability type of equipment	0.00	0.00	0.00	2009

912 - Screw Design:

Scientific or Technological Objectives:

M e a s u r e m e n t	C u r r e n t P e r f o r m a n c e	O b j e c t i v e
Increase Regrind content (%)	5	20
Increase impact resistance (%)	95	100
Improve production speed (Units per hour)	35	45
maintain or reduce production cost (\$ per unit)	6	3
reduced variations in part weight (+- grams)	5	2
Improve color consistency (%)	95	100

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Our objective is the development of an improved screw design that will allow us to increase the impact resistance of the product and at the same time increase productivity without increasing production costs.

A new screw design that will offer: Improved dispersion without changing the process conditions, consistently improved impact properties, shot repeatability with reduced variations in part weight, the ability to include a higher percentage of regrind materials without sacrificing performance properties and enhanced particulate dispersion without irregularities of colour.

Technology or Knowledge Base Level:

Benchmarking methods & sources for citations:

- Internet searches: 16 sites / articles -- No sufficient info on Mixing found
- Patent searches: 2 patents -- Screw designs must provided some info on the best combination of distributive and dispersive mixing
- Similar prior in-house technologies: 1 products / processes -- If a product can be made with a higher impact resistance, then a new application would be possible.
- Queries to experts: 3 responses -- No relevant info from injection moulding to manufacturers

Mixing plays a critical role in plastics processing. At low stress, distributive mixing occurs. When more stress is applied, dispersive (intensive) mixing occurs. Dispersive mixing ruptures the cohesive forces that cause components to agglomerate into droplets or particles and thus gives more uniform distribution of the components.

Design of a screw for a specific application will depend on the requirements, which will vary according to the composition of the compound, the equipment and the end application. A host of technological uncertainties may arise during this design process. For example if we need to introduce new mixing elements into a screw designed for an injection machine, special challenges can arise because the plasticizing unit (the plastic melting and conveying section) of an injection machine is relatively short. Moreover, the new screw design may fail to produce the expected dispersion, to the detriment of the end product.

Screw designs must provide the best combination of distributive and dispersive mixing in order to produce the required properties in the product. The screw of an injection-moulding machine is typically a single stage and single flighted conveying screw. Studies have shown that the shear flow generated by screws of this type is inefficient for dispersive mixing. Instead, generation of elongational flow, in which particles such as filler agglomerates undergo a stretching type of deformation without rotational movement, helps in efficient dispersive mixing.

The company is using injection moulding to manufacture a product for the construction market. If a product can be made with a higher impact resistance, then a new application would be possible, which would result in a new product line and increased sales.

Field of Science/Technology:

Project Name: Screw Design
Project Number: 912

Start Date: 2009-10-02
Completion Date: 2010-12-31

Mechanical engineering (2.03.01)

Intended Results:

- Improve existing processes
- Improve existing materials, devices, or products

Work locations:

Commercial Facility

Scientific or Technological Advancement:

U n c e r t a i n t y # 1 : P e r f o r m a n c e o f t h e S c r e w D e s i g n

The use of all polymers requires the addition of materials that confer the required performance properties. These can include thermal and UV stabilizers, plasticizers, organic or inorganic pigments regrind or even physical blowing agents to produce evenly distributed uniform cell structures. To be as effective as possible, these additives need to be dispersed as evenly as possible within the polymer matrix. The technological challenge of uniform pigment and additive dispersion can be addressed by systematically modifying screw designs.

Our new product line demands parts with better impact resistance. This means that a new ingredient must be mixed efficiently. For this injection moulding application, we would like to insert the mixing elements into the screw of the injection moulding machine. Although this new design might improve mixing, the process conditions could thereby be changed, giving a process window that might not allow cycle time adjustments. The use of regrind use might be restricted and costs might rise.

The current process produces a commercially viable product, but variations in part weight and inconsistent impact properties have been reducing productivity. Mixing elements are available that can improve the relative amounts of dispersive and distributive mixing. The available technology allows us to make directional predictions, but the science is not available to make quantitative predictions. Thus experimental development work is required to improve the performance of the screw in this application.

The most significant underlying key variables are:
process window, part weight, Processing conditions, Formulation of confer materials, screw designs

A c t i v i t y # 1 - 1 : D e s i g n o f t h e N o n - R e t u r n V a l v e

Work performed in Fiscal Year 2009:

Methods of experimentation:

- Process trials: 350 runs / samples - Sample parts produced in the course of the experimentation outlined below.
- Physical prototypes: 1 samples - Prototype injection screw.
- ... Prototype revisions: 2 revisions - The design of the non-return valve (NRV) was changed to improve mixing.

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

Results:

- Improve production speed: 40 Units per hour (50% of objective)
- reduced variations in part weight: 3 +- grams (66% of objective)
- Improve color consistency: 95 % (no improvement)

Conclusion:

The output of the injection screw was found to be much less than its theoretical (calculated) output. Possible reasons for this discrepancy included: a feed problem, wear of the screw or barrel, or insufficient melting of the ingredients at high screw speeds.

Measurements of the barrel and screw did not uncover any wear related issues. Changing the barrel temperature settings did not improve the output or the variability of the parts.

Different chemical measurements (viscosity, solvent extractions and thermo-gravimetric analysis) and measurements of surface properties on different sample parts showed that the dispersion of solids was not uniform. Un-melted resin pellets were even observed occasionally.

Project Name: Screw Design
Project Number: 912

Start Date: 2009-10-02
Completion Date: 2010-12-31

The design of the non-return valve (NRV) was changed to improve mixing. This was achieved by adding a CRD (Chris Rauwendaal Device) mixing element to an injection screw as follows: mixing pins were placed inside the slide ring of the NRV. The pins were elongated in the axial direction in order to accelerate the melt fluid as it passed between two pins. This gave elongational flow, which resulted in effective dispersive mixing. Adding similar pins to the outside of the stop subjected the mixture a second time to elongational flow. The large number of pins induced many splitting and reorientation events and the result was efficient mixing.

Key variables resolved: Formulation of confer materials, part weight, process window, Processing conditions, screw designs

A c t i v i t y # 1 - 2 : U s i n g P r e c i p i t a t e d C a l c i u m

Work performed in Fiscal Year 2010:

Methods of experimentation:

- Process trials: 12 runs / samples - GCC and PCC each tested at 6 different levels.

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

Instead of ground calcium carbonate (GCC), precipitated calcium carbonate (PCC) was used in the composition. Although PCC is costlier than GCC, PCC's particles are much finer and their high specific area and controlled structures make them more effective nucleating agents. A set of experiments was designed and carried out, in which the percentages of PCC and GCC were varied in a systematic way to discern their effects on product properties. After incorporating the CRD mixer onto the NRV, several runs were carried out and the resulting impact properties were measured. Using more pins allowed the proportion of regrind to be doubled and surface gloss improved considerably. To check weatherability, specimens were placed under QUV panel and their impact properties determined after various exposure times. Samples containing GCC showed marked loss in impact properties while samples containing PCC did not.

[AUTHOR'S NOTE: QUANTIFY HOW MANY EXPERIMENTS AND HOW MANY RUNS WERE CARRIED OUT. REMEMBER THAT THE TAX COURT'S CONTINUALLY REITERATE THE FACT THAT, "SYSTEMATIC INVESTIGATION MUST INVOLVE EXTREMELY ACCURATE MEASUREMENTS AND SUBSEQUENT ANALYSIS OF THOSE MEASUREMENTS." WE SHOULD THEREFORE ATTEMPT TO PROVIDE REVENUE CANADA WITH SUCH EVIDENCE WHENEVER POSSIBLE.]

Results:

- Increase Regrind content: 10 % (33% of objective)
- Increase impact resistance: 300 % (4100% of objective)
- Improve production speed: 40 Units per hour (50% of objective)
- maintain or reduce production cost: 4 \$ per unit (66% of objective)
- reduced variations in part weight: 2 +- grams (100% of objective)
- Improve color consistency: 100 % (100% of objective)

Conclusion:

As a result of this work we were able to improve the impact resistance of parts. In addition we produced less scrap and regrind content was doubled from 5 to 10%. Since the work has taught us that mixing can be improved, we anticipate continuing this work in the next year to further increase the regrind cycled content.

ADDITIONAL CRA COMMENTS REGARDING ELIGIBILITY:

The description shows that work was carried out in a systematic manner to advance both screw design technology and to improve the technology available to use regrind in our processes. The work meets the criteria for Experimental Development.

Key variables resolved: Formulation of confer materials, part weight, process window, Processing conditions, screw designs

Project Name: Screw Design
Project Number: 912

Start Date: 2009-10-02
Completion Date: 2010-12-31

912 - Screw Design

Benchmarks: Internet searches: 16 sites / articles
 Patent searches: 2 patents
 Similar prior in-house technologies: 1 products /
 Queries to experts: 3 responses

Objectives: Increase Regrind content: 20 %
 Increase impact resistance: 100 %
 Improve production speed: 45 Units per hour
 maintain or reduce production cost: 3 \$ per unit
 reduced variations in part weight: 2 +- grams
 Improve color consistency: 100 %

Uncertainty: 1 - Performance of the Screw Design

Key Variables: Formulation of confer materials, part weight, process window, Processing conditions, screw designs

Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Design of the Non-Return Valve	Process trials: 350 runs / samples Physical prototypes: 1 samples ... prototype revisions: 2 revisions	Improve production speed: 40 Units per hour (50 %) Improve color consistency: 95 % (0 %) reduced variations in part weight: 3 +- grams (66 %)	Formulation of confer materials part weight process window Processing conditions screw designs	0.00	0.00	0.00	2009
2 - Using Precipitated Calcium	Process trials: 12 runs / samples	Increase Regrind content: 10 % (33 %) Increase impact resistance: 300 % (4100 %) Improve production speed: 40 Units per hour (50 %) maintain or reduce production cost: 4 \$ per unit (66 %) reduced variations in part weight: 2 +- grams (100 %) Improve color consistency: 100 % (100 %)	Formulation of confer materials part weight process window Processing conditions screw designs	0.00	0.00	0.00	2010

1001 - Development of an UHMW-PE Abrasion Resistant:

Scientific or Technological Objectives:

M e a s u r e m e n t	C u r r e n t P e r f o r m a n c e	O b j e c t i v e
Flexural modulus (GPa)	3.5	5
Increase modulus of flexibility (%)	80	95
Maintains abrasion and impact resistance (%)	90	91
Increase production speeds (Feet per min)	25	32
minimize cost of production (\$ per foot)	5.25	3.25

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The objective is the development of a new product, which maintains abrasion and impact resistance while offering increased flexural modulus.

Additionally, to find a way to increase the flexural modulus without loss of abrasion resistance and impact resistance.

Technology or Knowledge Base Level:

Benchmarking methods & sources for citations:

- Internet searches: 8 sites / articles -- No sufficient info on cross-linked sheets found.
- Patent searches: 3 patents -- formulations for cross-linked sheet for different applications
- Similar prior in-house technologies: 1 products / processes -- In-house product needs higher flexural modulus, while maintaining abrasion & impact resistance.
- Queries to experts: 3 responses -- no new info on maintain the abrasion resistance and impact resistance achieved through cross-linking

A company launched a new cross-linked sheet to meet their customer's need for improved abrasion resistance. After launching the product the company received a customer feedback indicating a liking for the abrasion resistance and impact resistance of the new material but a higher flexural modulus was desired. The company decided that it was necessary to try to develop a product that would maintain the abrasion resistance and impact resistance achieved through cross-linking as well as meets this new primary requirement of an increased flexural modulus.

Field of Science/Technology:

Materials engineering & metallurgy (2.05.01)

Intended Results:

- Develop new processes
- Develop new materials, devices, or products

Work locations:

Commercial Facility

Scientific or Technological Advancement:

U n c e r t a i n t y # 1 : T o p r o v i d e a l e s s f l e x i b l e p r o d u c t

Increasing the cross-linking of a polyethylene resin increases both the abrasion resistance and the impact resistance. At the same time this increased cross-linking will reduce the flexural modulus of the polymer. The obvious way to provide the

Project Name: Development of an UHMW-PE Abrasion Resistant
Project Number: 1001

Start Date: 2010-09-01
Completion Date: 2010-12-20

customer with a less flexible product (by reducing the cross-linking) cannot be used since this will reduce abrasion resistance and impact resistance of the product. Hence a more creative solution must be found to meet these seemingly contradictory requirements.

The most significant underlying key variables are:
impact resistance, amount of cross-linking, formulation and variety of additives, additives loading levels, optimum pressure and temperature cycles

A c t i v i t y # 1 - 1 : P e r f o r m i n g E x p e r i m e n t s

Work performed in Fiscal Year 2010:

Methods of experimentation:

- Process trials: 35 runs / samples - 5 blends tested each on 7 different loading levels.

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

- The company carried out an extensive series of small scale laboratory experiments [HOW MANY?] to determine what effect a variety of additives have on the flexural modulus of the cross-linked product. Several additives were found that increased the flexural modulus of the product to the required levels.

- The flexural modulus, abrasion resistance and all of the other secondary properties including: tensile strength, izod impact strength, coefficient of thermal expansion and coefficient of friction were tested on several [HOW MANY?] blends of each of these additives at a variety [HOW MANY?] of loading levels. These experiments Provided an optimum blend.

- A production trial was carried out to determine what effect this formulation had on the processing of the product. Using standard processing parameters problems were encountered during both the mixing of the blend and compression moulding of the new material formulation. Laboratory experimentation [HOW MANY EXPERIMENTS?] in addition to several [HOW MANY?] production trials were carried out to determine how to obtain through mixing of the product and what the optimum pressure and temperature cycles are for the new formulation.

Results:

- Flexural modulus: 5 GPa (100% of objective)
- increase modulus of flexibility: 94 % (93% of objective)
- maintains abrasion and impact resistance : 91 % (100% of objective)
- Increase production speeds: 31 Feet per min (85% of objective)
- minimize cost of production: 3.01 \$ per foot (112% of objective)

Conclusion:

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD CONTAIN A CONCLUSION FOR THE CURRENT ACTIVITY. CAN WE PROVIDE ANY FURTHER TECHNICAL CONCLUSIONS AS TO WHY THESE "RESULTS" AND RELATED "INTEGRATED ISSUES" WERE NOT "READILY PREDICTABLE" TO YOU FROM A TECHNICAL STANDPOINT?]

ADDITIONAL CRA COMMENTS REGARDING ELIGIBILITY:

Through these trials & experimentation we developed the knowledge that allowed us to develop a product that met both the primary property requirements of improved abrasion resistance and higher flexural modulus as well as the secondary property requirements of maintained tensile strength, izod impact strength, coefficient of thermal expansion and coefficient of friction.

Key variables resolved: additives loading levels, amount of cross-linking, formulation and variety of additives, impact resistance, optimum pressure and temperature cycles

Project Name: Development of an UHMW-PE Abrasion Resistant
Project Number: 1001

Start Date: 2010-09-01
Completion Date: 2010-12-20

1001 - Development of an UHMW-PE Abrasion Resistant

Benchmarks: Internet searches: 8 sites / articles
 Patent searches: 3 patents
 Similar prior in-house technologies: 1 products /
 Queries to experts: 3 responses

Objectives: Flexural modulus: 5 GPa
 increase modulus of flexibility: 95 %
 maintains abrasion and impact resistance : 91 %
 Increase production speeds: 32 Feet per min
 minimize cost of production: 3.25 \$ per foot

Uncertainty: 1 - To provide a less flexible product

Key Variables: additives loading levels, amount of cross-linking,
 formulation and variety of additives, impact resistance,
 optimum pressure and temperature cycles

Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Performing Experiments	Process trials: 35 runs / samples	increase modulus of flexibility: 94 % (93 %) maintains abrasion and impact resistance : 91 % (100 %) Increase production speeds: 31 Feet per min (85 %) minimize cost of production: 3.01 \$ per foot (112 %) Flexural modulus: 5 GPa (100 %)	additives loading levels amount of cross-linking formulation and variety of additives impact resistance optimum pressure and temperature cycles	0.00	0.00	0.00	2010

1002 - Large Compression Moulded Parts:

Scientific or Technological Objectives:

M e a s u r e m e n t	C u r r e n t P e r f o r m a n c e	O b j e c t i v e
Cycle time (min/part)	60	2
Strength of part (kg)	35000	40000
Maintain size and weight tolerance (%)	90	99
minimize cost of production (\$ per units)	35	20
Increase production speed (Units per min)	75	80
Minimize cycle time (minutes)	65	2

[AUTHOR'S NOTE: THESE EXAMPLES HAVE BEEN ADAPTED FROM THE "PLASTICS MATERIALS, PROCESSING, EQUIPMENT & TOOL MAKING GUIDANCE DOCUMENT & CASE STUDIES" - APRIL, 2004. THIS DOCUMENTS ARE AVAILABLE FOR DOWNLOAD AT (www.cra.gc.ca/sred). THIS DOCUMENT WAS PREPARED BY A JOINT CANADA REVENUE AGENCY (CRA)-INDUSTRY SECTOR COMMITTEE.]

The objective is development of compression moulding tooling for thermoplastic material to produce ELCMP (Extra Large Compression Moulded Parts) for road grading plates to withstand up to 40,000 kg dynamic load.

- To fill larger moulds than anyone had ever used before. These moulds would be used to make parts that were twice as big as any that our company has ever made.
- To use thermoplastic materials in compression moulding. Most compression moulding is carried out with reinforced and thermoset materials. We were using thermoplastic materials so that the resultant parts could be recycled. As a result a completely different process was required.
- To develop a manufacturing process with a commercially acceptable cycle time. Our initial attempts to make these parts gave a process with a cycle time of more than one hour. In order to have an economically viable process, we had a target of 2 minutes cycle time per part.
- To design plastic parts that would withstand 40,000 kg dynamic load strengths to which they would be subjected during their use.
- To develop techniques to prevent uncontrolled shrinkage of these parts.
- To develop lifting and handling techniques that would allow the assembly of these very large parts at the construction site. The design required screwing two identical parts together; this required that the slots in the parts were aligned. The two parts then needed to be welded along the 4 sides to produce a watertight weld.

Technology or Knowledge Base Level:

Benchmarking methods & sources for citations:

- Internet searches: 17 sites / articles -- No info on preventing uncontrolled shrinkage of parts
- Patent searches: 6 patents -- existing plastic road gratings technology insufficient due to size
- Similar prior in-house technologies: 1 products / processes -- We have experience with moulds, but these were larger than any that had been manufactured before.
- Queries to experts: 1 responses -- IRDI did not provide us with either technical information or scientific papers

An American company had requested that we develop, design and build moulds that would produce plastic road gratings. These gratings were meant to replace the wooden planks used to construct temporary roads in construction sites.

The parts would have to be strong enough to withstand dynamic loads over 40,000 kg from construction machinery. Each plastic part would measure 84" wide by 156" long and weigh over 500 lbs, and would have to be made from plastics that could be recycled. Right at the outset, we realized that plastic parts of the required size and strength could not be moulded with current technology. The moulds for these parts were larger than any that had been manufactured before and as a result, the presses had to be redesigned around our new moulds. Our challenge was to design parts that would have the necessary properties, to build the moulds for these parts and to work with our client to develop a process that would enable our customer to manufacture these parts. This had to be done in a way that gave a finished product, materials and processes that met the cost constraints.

Field of Science/Technology:

Materials engineering & metallurgy (2.05.01)

Project Name: Large Compression Moulded Parts
Project Number: 1002

Start Date: 2010-10-02
Completion Date: 2010-12-31

Intended Results:

- Develop new processes
- Develop new materials, devices, or products

Work locations:

Commercial Facility

Scientific or Technological Advancement:

Uncertainty #1: Handling Thermoplastics for Compression Moulding

Compression moulding is usually carried out with filled and thermoset materials. These materials are available as either bulk moulding compound (BMC) or as sheet moulding compound (SMC). Since we wanted a system that was neither thermosetting nor filled, we had to develop a way to handle thermoplastics for compression moulding. Filling the mould with liquid plastic was not feasible since commercially available equipment could not provide an adequate shot size. We developed a technique whereby the mould was filled with granules, and then heated to melt the plastic; uneven filling resulted in voids in the parts that would in turn cause stress points and low strength. Thus, we would have to overcome the problem of uneven filling of these extremely large moulds.

Heating and cooling the mould in order to liquefy the plastic required that the mould be rapidly cycled through a wide range of temperatures. This was causing damage to the high grade of aluminum used in the mould. We then had to design and add special wear plates and determine if these could resolve this problem.

Shrinkage of the parts resulted in an unexpected locking of the part into the mould. A traditional compression mould contains a knockout box containing knock out pins and plates that move in unison. Since this could be incorporated into the moulding machine without a complete redesign and rebuild, we had to design and build a series of self-contained individual spring loaded mechanisms. The challenge was to design and locate these knockout pins so that they would move together and avoid cracking of the parts.

The part has a honeycomb pattern on its underside. Initial computer design of the honeycomb pattern showed us that this approach should give parts with the required strength. The initial parts had dynamic load strength of less than 20,000 Kg because of the interaction between the process and the material. The size of the hex pattern, its wall thickness and the depth of its ribs had to be optimized to withstand the extreme dynamic loads without cracking.

The design of the parts would have to be amenable to easy assembly at the construction site. We did not know how to control the shrinkage to ensure that the locking slots would coincide with each other. Lifting the large parts gave a number of problems and experimentation was required before we found a way to resolve this problem by introducing grooves onto the surface of the parts.

The most significant underlying key variables are:
temperature, shrinkage, wall thickness, formulation of thermoplastic plastics, type of mould material and mould method

Activity #1-1: Prototype Mould Design and Parts Testing

Work performed in Fiscal Year 2010:

Methods of experimentation:

- Process trials: 93 runs / samples - Total number of sample parts produced in the experimentation outlined below.
- Physical prototypes: 1 sample - A prototype mould was built to produce parts with the same thickness as the final product, but only one foot square.
- ... Prototype revisions: 9 revisions - Revisions required because testing showed that the product strength properties were significantly different from the predictions.

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

Literature, patent and Internet searches as well as discussions with IRDI did not provide us with either technical information or scientific papers that could assist us with the project planning.

Based on our technological experience and our cost calculations, we concluded that a blend of thermoplastic plastics should be used to meet the strength requirements in a part that could be recycled.

Project Name: Large Compression Moulded Parts
Project Number: 1002

Start Date: 2010-10-02
Completion Date: 2010-12-31

A prototype mould was built to produce parts with the same thickness as the final product, but only one foot square. The parts produced were subjected to mechanical testing which showed that the strength properties were significantly different from the predictions. The mould was systematically altered until it yielded parts that met the design criteria.

In order to deal with challenges of making the plastic parts economically feasible, we designed a process whereby large parts measuring 84" x 156" would be moulded. The pieces were designed to allow easy assembly at the construction site by screwing them together in an overlapping fashion. Each assembled unit weighed over 1000 lbs.

We had to develop a way to handle thermoplastics for compression moulding. We soon found that melted plastic could not be injected rapidly enough into a mould this large. We therefore developed a process wherein plastic granules would be laid into the mould, which was then be heated until the plastic liquefied and filled the entire cavity of the mould. The mould was then cooled.

In order to minimize the heating and cooling time we investigated the use of aluminum moulds. We determined that high grade aircraft aluminum provided the required tensile strength and thermal conductivity, while being commercially available with an acceptable delivery time for the width required.

At this point, the cycle time required to fill, heat, cool and eject the part was economically unfeasible-nearly one hour. We designed and built a system of 12 identical moulds in three carousels of stack presses four moulds high. As the first carousel was heated, the second would be cooling while the third was ejecting parts and being refilled with fresh resin. This process had to be developed using all twelve moulds, since the cooling rate of an isolated mould would be different, and we could not accurately assess shrinkage effects and warping.

The next problem to be overcome was locking of the part into the mould because of shrinkage. We therefore had to determine how parts this heavy could be removed from the moulds without damaging the moulds or cracking the part. We had to develop a series of spring-loaded knockout mechanisms that were built into each mould to avoid redesigning and rebuilding the presses. A moving machine platen would push the knockouts forward, thereby ejecting the part.

The scaled up parts did not shrink as predicted from the results of the prototype testing and experimentation. A large L-shaped design ran the length of two sides of the part and the resulting difference in cross sections caused the part to twist. The L-shape was integral part of the design that allowed us to mould the mats with a honeycombed interior and solid edges needed to withstand the stresses and provide a means of joining the two sub-assemblies together. The edges with the L-shaped design shrank over 1.5" more than the rest of the part. Once again, we had to redesign and test alternative processes that would give us a part that remained square and flat during shrinkage.

The two halves of each mould did not have the same thickness and cross section, since one half had to accommodate the ribbing required for the honeycomb. The base was machined into an aluminum plate 3.7" thick, but the lid was only 1.75" thick. As the two halves of the moulds were heated and cooled, they expanded and contracted at different rates. The thinner lids expanded more quickly, and this interfered with the closing of the halves. We therefore had to design and build a series of wear plates to eliminate damage to the aluminum of the mould. Our design used lids with hardened O-1 inserts built into the four outer edges, and bases with built in Ampco 21W inserts to mate with its O-1 partners. Ampco 21W was selected for its high lubricity properties.

Results:

- Cycle time: 2 min/part (100% of objective)
- Strength of part: 35000 kg (no improvement)
- maintain size and weight tolerance: 98 % (88% of objective)
- minimize cost of production: 22 \$ per units (86% of objective)
- Increase production speed: 78 Units per min (60% of objective)
- Minimize cycle time: 30 minutes (55% of objective)

Conclusion:

The project is not complete. The parts are currently undergoing extensive field testing. The latest reports shows that the parts are still cracking and therefore do not have the required strength. The moulds have been altered so many times during initial testing that new tooling will likely be required for the commercial moulds. There is still a reasonable likelihood that the entire project will have to be scrapped.

ADDITIONAL CRA COMMENTS REGARDING ELIGIBILITY:

This project meets the SR&ED criteria. Project descriptions can be presented in a number of ways. The above approach often works well for the kind of experimental development projects that occur in plastics and in other manufacturing sectors. After an introduction of the commercial and technical objectives of the project, the description identifies the technological advances that were needed for the project to be successful. The technological uncertainties that had to be resolved to make those advances are described next; this is achieved by comparing what was known at the beginning of project with what was known at the end

Project Name: Large Compression Moulded Parts
Project Number: 1002

Start Date: 2010-10-02
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of the project. The summary of the work then provides an overview of how this was achieved, illustrating a systematic approach to resolving the technological issues.

Key variables resolved: formulation of thermoplastic plastics, shrinkage, temperature, and type of mould material and mould method, wall thickness

1002 - Large Compression Moulded Parts

Benchmarks: Internet searches: 17 sites / articles
 Patent searches: 6 patents
 Similar prior in-house technologies: 1 products /
 Queries to experts: 1 responses

Objectives: Cycle time: 2 min/part
 Strength of part: 40000 kg
 maintain size and weight tolerance: 99 %
 minimize cost of production: 20 \$ per units
 Increase production speed: 80 Units per min
 Minimize cycle time: 2 minutes

Uncertainty: 1 - Handling Thermoplastics for Compression Moulding

Key Variables: formulation of thermoplastic plastics, shrinkage, temperature, type of mould material and mould method, wall thickness

Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
				0.00	0.00	0.00	2010
1 - Prototype Mould Design and Parts Testing	Process trials: 93 runs / samples Physical prototypes: 1 samples ... prototype revisions: 9 revisions	Strength of part: 35000 kg (0 %) maintain size and weight tolerance: 98 % (88 %) minimize cost of production: 22 \$ per units (86 %) Increase production speed: 78 Units per min (60 %) Minimize cycle time: 30 minutes (55 %) Cycle time: 2 min/part (100 %)	formulation of thermoplastic plastics shrinkage temperature type of mould material and mould method wall thickness				

1003 - The Bevel Gear:

Scientific or Technological Objectives:

M e a s u r e m e n t	C u r r e n t P e r f o r m a n c e	O b j e c t i v e
Dimensional accuracy (mm)	0.5	0.01
Maintain performance of metal gear (%)	0	100
minimize cost of production (\$ per unit)	35	20
Improve production speed (Units per hour)	15	25
Improve drive smoothness (%)	0	20
Maximize tool life (cycles)	10000	20000

[AUTHOR'S NOTE: THIS EXAMPLE HAS BEEN ADAPTED FROM THE "PLASTICS MATERIALS, PROCESSING, EQUIPMENT & TOOL MAKING GUIDANCE DOCUMENT & CASE STUDIES" - APRIL, 2004. THIS DOCUMENT IS AVAILABLE FOR DOWNLOAD AT (www.cra.gc.ca/sred). THIS DOCUMENT WAS PREPARED BY A JOINT CANADA REVENUE AGENCY (CRA)-INDUSTRY SECTOR COMMITTEE.]

[AUTHOR'S NOTE: IDEALLY THE TAXPAYER WOULD ATTEMPT TO QUANTIFY THE OBJECTIVES THEY ARE TRYING TO ACHIEVE. A QUANTIFIABLE OBJECTIVE HAS BEEN ADDED ABOVE, TO ILLUSTRATE.]

The objective is to develop a manufacturing process to produce small, plastic injection-moulded precision straight bevel gears to replace conventional machined metal Gleason gears. Additionally, to demonstrate this technology by moulding a paired set of two trial gears and verifying their dimensional accuracy and their meshing performance using a special test fixture.

The main technological advancement sought and achieved in this project was the development of a moulding process to produce small, precision straight bevel plastic gears. Being of glass-filled nylon, these alternative gears offer superior toughness, durability, low operating noise, and freedom from lubrication while still having a performance matching metal gears. Being injection moulded, they can also be produced rapidly in large volumes.

Parts shrink after they have been moulded. The normal manufacturing process for injection moulding requires that the shrinkage be estimated with the help of a mathematical model. The model requires the input of equations that describe the geometry of the part; in the case of the Gleason gear the shape is complex and the needed equations are not available.

A process must be developed to provide a part with the required tolerances without the use of these shrinkage predictions. This work resulted in an increase in the company's technology base, giving them the capability to mould complex geometric parts.

Technology or Knowledge Base Level:

Benchmarking methods & sources for citations:

- Internet searches: 12 sites / articles -- No new info on plastic bevel gears
- Patent searches: 3 patents -- current patents do not include plastic bevel gear
- Competitive products or processes: 1 products -- original metal straight bevel gear
- Similar prior in-house technologies: 1 product / processes -- The Company has experience producing moulded plastic parts, but the geometry here raises challenges.
- Potential components: 1 products -- modified tooth form is automatically produced on the Gleason machine and is difficult to reproduce

Our Company was incorporated in 1990. It is a recognized leader in designing and producing complex and innovative moulded plastic parts for several OEM industries.

The company was approached by a potential customer who wanted to purchase a mould that would produce a plastic bevel gear set that would match the performance of an original metal straight bevel gear set. The gear set included a 2-inch diameter, 16-tooth gear and a 1-3/8 inch diameter, 11-tooth pinion.

The customer offered us an opportunity to design and build the required mould. This potential customer was not contracting us to perform SR&ED. However, we had to perform SR&ED to satisfy the customer and win the business.

We decided to mould the gear set out of 6, 6 nylon with a 33% glass fill. For the project to be economically viable, we needed to create a single mould with two cavities, allowing the gear and the pinion to be produced at the same time. Producing gears out

Project Name: The Bevel Gear
Project Number: 1003

Start Date: 2010-02-25
Completion Date: 2010-06-15

of plastic provides considerable benefits in several areas such as drive smoothness, low noise in operation, durability, balanced tooth strengths for both pinion and driven gear, and freedom from interference in meshing.

Conventional bevel gears are machined with special machine tools. In the present example the specified tooth type is Gleason straight bevel, with a 20-degree pressure angle. This modified tooth form is automatically produced on the Gleason machine and is difficult to reproduce by other methods. The complex geometry of the Gleason gear cannot readily be described by simple equations.

Field of Science/Technology:

Materials engineering & metallurgy (2.05.01)

Intended Results:

- Develop new processes
- Develop new materials, devices, or products

Work locations:

Commercial Facility

Scientific or Technological Advancement:

U n c e r t a i n t y # 1 : G e a r T o o t h g e o m e t r y

The information provided to the company or available through technical reference sources was not enough to establish the data needed to cut the tooth forms in a mould through processes applicable to building a mould (as opposed to cutting teeth on a gear blank with a Gleason machine).

The most significant underlying key variables are:
gear geometry variables, Tooth profile, related dimensional data

A c t i v i t y # 1 - 1 : T e s t F i x t u r e D e s i g n a n d F a b r i c a t i o n

Work performed in Fiscal Year 2010:

Methods of experimentation:

- Analysis / simulation: 1 alternative - Computer modeling of tooth geometries and dimensions was performed. Simulated meshing of the gear pair was studied for engagement and disengagement action.
- Physical prototypes: 3 samples - Sets of experimental aluminum gears cut in order to generate information that could be used to correct the electronic 3-D data.

Experienced engineers and technicians studied the crude samples and incomplete data made available to us by the potential customer. They developed alternate scenarios and preliminary strategies on how the two gears could be produced via a moulding process.

Extensive literature searches and professional contacts were initiated to discover what means could be employed to precisely determine the gear geometry, tooth profiles, and related dimensional data, so as to establish baseline information for designing the mould for each gear.

Computer modeling of tooth geometries and dimensions was performed. Simulated meshing of the gear pair was studied for engagement and disengagement action.

In parallel, an instrumented test fixture was designed and fabricated for a physical evaluation of the actual meshing behavior of the supplied sample gear pair, and later of trial gears.

When a preliminary workable set of 3-D dimensional data appeared to have been finally evolved, a trial pair of aluminum gears was cut using this data on a CNC Wire-EDM set-up at a specialist shop. Meshing trials of the experimental aluminum gears were conducted on the test fixture. This generated information that could be used to correct the electronic 3-D data.

A second set of experimental aluminum gears was cut using the corrected data, and meshing trials were repeated on the test fixture. Another iteration of electronic 3-D data correction was performed. Final corrections were determined

Project Name: The Bevel Gear
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Start Date: 2010-02-25
Completion Date: 2010-06-15

using information based on actual tooth contact signatures obtained by using "machinists' blue" on gear tooth engagement areas.

The electronic data was adapted to CNC Wire-EDM cutting a set of electrodes for a Plunge-EDM process to make the mould cavities. This required extensive work with Solids and Surface programs for developing precision cutter paths to achieve the desired accuracy and finish.

Results:

- Dimensional accuracy: 0.01 mm (100% of objective)
- maintain performance of metal gear: 100 % (100% of objective)

Conclusion:

[AUTHOR'S NOTE; AN IDEAL DESCRIPTION WOULD CONTAIN A CONCLUSION FOR THE CURRENT ACTIVITY.]

Key variables resolved: gear geometry variables, related dimensional data, and Tooth profile

U n c e r t a i n t y # 2 : M a n u f a c t u r i n g p r o c e s s

In conventional bevel gear manufacturing, handbook references are available to specify the critical gear blank dimensions, cutter parameters, and the appropriate Gleason machine settings required to produce the required bevel gears. However, this approach was not applicable to mould manufacture. Hence the first problem in this example was to determine the absolute 3-D tooth geometry and related dimensional data for both pinion and gear in terms of spatial coordinates, which could then be used to generate data to CNC machine the (mould) surfaces.

For mould dimensioning, compensation would have to be provided for material shrinkage, draft angles (if applicable), etc. Completely unknown were the distortions that would arise through the moulding process and how to correct for them. Tight tolerances were specified for backlash, TIR runout, etc. on the finished gear set. All of these were inter-related to the integrity of the tooth form and the roundness and face perpendicularity of the gears after moulding. Large local mass variations in material existed in the tooth areas, and it could not be foreseen how much, and where, sinking and other moulding-related distortions would appear to cause still further difficulties in the performance of the meshed gear set.

Furthermore, glass-filled nylon is a highly abrasive moulding material that flows only with difficulty. It was clear that an even filling of the mould would be problematic to achieve in any event, let alone with all the complex part geometry features discussed above.

The most significant underlying key variables are:
material shrinkage, draft angles, distortions, tolerances, material formulation

A c t i v i t y # 2 - 1 : M o u l d D e s i g n a n d I n j e c t i o n M o u l d i n g T r i a l

Work performed in Fiscal Year 2009:

Methods of experimentation:

- Process trials: 36 runs / samples - 12 samples parts produced for each of the 3 mould revisions.
- Physical prototypes: 1 samples - Prototype injection mould.
- ... Prototype revisions: 3 revisions - Revisions required in order to deliver parts with the required precision.

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

In the mould design, a deliberate strategy was adopted to place the bulk of the critical areas of one gear as a core detail, and that for the other gear as a cavity detail. This would enable a comparative determination to be made on which approach was better for making the final, exact adjustments to achieve the minute details required.

A trial injection mould was made and experimental plastic gear samples were produced. Evaluation with the test fixture showed that corrections were required to local mould tooth geometry/dimensions to minimize backlash. [HOW MANY TESTS WERE DONE?]

After the injection moulding trial and a detailed gear sample evaluation, corrections were made to both core and cavity in the mould, and moulding trials were repeated. [HOW MANY TESTS WERE DONE?] With three iterations of this procedure, it was found that the process would deliver parts with the required precision, and sample gears were then shipped to the OEM customer for approval.

Results:

- Dimensional accuracy: 0.01 mm (100% of objective)
- maintain performance of metal gear: 100 % (100% of objective)
- minimize cost of production: 25 \$ per unit (66% of objective)

Project Name: The Bevel Gear
Project Number: 1003

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- Improve production speed: 26 Units per hour (110% of objective)
- Improve drive smoothness: 20 % (100% of objective)

Conclusion:

The potential customer granted approval after extensive inspection and tests, and the mould stands were accepted for regular part production in an offshore factory.

ADDITIONAL CRA COMMENTS REGARDING ELIGIBILITY:

This project is an example of a case in which the need for a technological advancement is identified at the outset. A significant amount of effort is required in preparation for "first try-out." This work meets the definition of SR&ED. The subsequent work is also eligible since it is required to achieve the technological advancement. Accordingly, all work in the actual claim was deemed eligible, other than a few initial business meetings between the claimant and potential customer when non-technical matters were discussed.

This case is a good example of why in many (if not most) situations the "first try-out" is a poor indicator of project eligibility.

Since the designing and building of the mould involved experimental development, the portion of the costs incurred for SR&ED would be allowed. The costs incurred for the experimental development, in this case, could include the costs of labour and materials.

The costs of any materials that were destroyed or rendered virtually valueless as a result of the SR&ED may be claimed as costs of materials consumed. The costs of materials that were incorporated into the mould as a result of the SR&ED may be claimed as costs of materials transformed. If the mould is sold, converted to commercial use, or used for demonstration purposes, the costs of the materials transformed would be subject to recapture.

Key variables resolved: distortions, draft angles, material formulation, material shrinkage, tolerances

Benchmarks: Internet searches: 12 sites / articles
 Patent searches: 3 patents
 Competitive products or processes: 1 products
 Similar prior in-house technologies: 1 products /
 Potential components: 1 products

Objectives: Dimensional accuracy: 0.01 mm
 maintain performance of metal gear: 100 %
 minimize cost of production: 20 \$ per unit
 Improve production speed: 25 Units per hour
 Improve drive smoothness: 20 %
 Maximize tool life: 20000 cycles

Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Test Fixture Design and Fabrication	Analysis / simulation: 1 alternatives Physical prototypes: 3 samples	Dimensional accuracy: 0.01 mm (100 %) maintain performance of metal gear: 100 % (100 %)	gear geometry variables related dimensional data Tooth profile	0.00	0.00	0.00	2010

Activity	Testing Methods	Results - % of Objective	Variables Concluded	Hours	Materials \$	Subcontractor \$	Fiscal Year
1 - Mould Design and Injection Moulding Trial	Process trials: 36 runs / samples Physical prototypes: 1 samples ... prototype revisions: 3 revisions	Dimensional accuracy: 0.01 mm (100 %) maintain performance of metal gear: 100 % (100 %) minimize cost of production: 25 \$ per unit (66 %) Improve production speed: 26 Units per hour (110 %) Improve drive smoothness: 20 % (100 %)	distortions draft angles material formulation material shrinkage tolerances	0.00	0.00	0.00	2009

1004 - Cast Figurines:

Scientific or Technological Objectives:

M e a s u r e m e n t	C u r r e n t P e r f o r m a n c e	O b j e c t i v e
Casting detail achieved (mm)	2	0.5
Increase production speed (Units per hour)	450	550
Minimize production costs (\$ per unit)	0.23	0.13
Minimize line maintenance (hours per week)	13	2

[AUTHOR'S NOTE: THIS EXAMPLE HAS BEEN ADAPTED FROM THE "PLASTICS MATERIALS, PROCESSING, EQUIPMENT & TOOL MAKING GUIDANCE DOCUMENT & CASE STUDIES" - APRIL, 2004. THIS DOCUMENT IS AVAILABLE FOR DOWNLOAD AT (www.cra.gc.ca/sred). THIS DOCUMENT WAS PREPARED BY A JOINT CANADA REVENUE AGENCY (CRA)-INDUSTRY SECTOR COMMITTEE.]

[AUTHOR'S NOTE: IDEALLY THE TAXPAYER WOULD ATTEMPT TO QUANTIFY THE OBJECTIVES THEY ARE TRYING TO ACHIEVE. A QUANTIFIABLE OBJECTIVE HAS BEEN ADDED ABOVE, TO ILLUSTRATE.]

The objective is to develop a manufacturing process that produces small, highly-detailed cast plastic figurines faithfully reproducing fine surface detail and geometrical features. Additionally, to demonstrate this technology by producing samples covering a range of figurines representing a range of action movements.

The main technological advancement sought and achieved in this project was to develop a casting methodology and technique to produce a range of highly detailed miniature cast plastic figurines with an unprecedented level of surface detail and delicate geometrical features. The technology also had to be compatible with a high rate of production.

Achieving this objective would open up a technical capability to reproduce levels of fine detail and geometry in cast figurines that was previously unobtainable in the industry.

Technology or Knowledge Base Level:

Benchmarking methods & sources for citations:

- Patent searches: 3 patents -- closest patents did not include highly realistic sports and military miniatures.
- Competitive products or processes: 1 product -- Handcrafting specimens is an alternative, but much more costly, approach.
- Similar prior in-house technologies: 1 products / processes -- The level of detail was far in advance of anything the company had attempted before.
- Queries to experts: 3 responses -- no new info on methodology to produce a highly detailed miniature cast plastic figurines

Our company was incorporated in 1985. It produces complex and innovative moulded plastic parts for several OEM industries. The business initially concentrated on the decorative figurines market sector and has achieved considerable success over the years in this specialized area. Over time, as consumer tastes have become more sophisticated, figurines have come to require an increasingly finer level of detail. Until recently, the manufacturing techniques established by the company had been able to sustain this increasing product refinement.

This example looks at the scenario created when a dealer in collectible figurines approached the company to develop a line of highly realistic sports and military miniatures. Extremely detailed features were to be reproduced, and the postures of the figurines were to accurately show examples of action movement (such as shooting a hockey puck, kicking a soccer ball, parrying a sword thrust, leading a bayonet charge or riding a horse into battle).

This requirement for extreme detail meant that the facial expressions, drape of the clothing, body stance, tensing of muscles, and all other visual cues had to be completely faithful to the action being represented. The new figures were 5cm tall and included details that were less than 1mm across; some of the more demanding details included a gun site on the end of a rifle, collar buttons and buckles and holes on a belt. The level of detail was far in advance of anything the company had attempted before.

Handcrafted specimens of the figurines were made available by the company.

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Sample handcrafted figurines are used as patterns for making the moulds. The moulds are cavities in a block of silicone rubber, and are created by pouring a liquid silicone compound over the patterns. The compound sets into a shape that conforms to the outer contours of the pattern. The pattern is removed and the hollow cavity then becomes the mould for producing a cast figurine. Liquid casting resin is then poured into the moulds to produce the figurine.

The company believed that the basic method would work for the new line of figurines as well. However, as discussed below, trials revealed that the standard techniques could not reproduce the level of detail that was demanded.

The company did eventually succeed in establishing a suitable process for making this new line of highly-detailed figurines, but only after a considerable effort in experimental development.

Field of Science/Technology:

Materials engineering & metallurgy (2.05.01)

Intended Results:

- Improve existing processes
- Improve existing materials, devices, or products

Work locations:

Commercial Facility

Scientific or Technological Advancement:

U n c e r t a i n t y # 1 : M a t e r i a l t o c o n f o r m

The technological uncertainty stems from the inability of the previous established company techniques to achieve the results that were needed in the as-cast figurines. In other words, standard practice was inadequate. Specifically, the technological problems were: the ability of the mould material (silicone compound) to faithfully conform to the surface detail and delicate geometry of the figurine. The choice of a parting surface for the mould that would allow the cast figurine to be extracted without damaging the delicate features.

The most significant underlying key variables are:
parting surface for the mould, Methods for material to conform to surface, process conditions

A c t i v i t y # 1 - 1 : P e r f o r m i n g t r y - o u t s

Work performed in Fiscal Year 2010:

Methods of experimentation:

- Process trials: 10 runs / samples - Sample figurines made from the prototype mould.
- Physical prototypes: 1 sample - A single cavity trial mould was made.

[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

Engineers and technicians studied the sample figurines and made a preliminary selection of an item for tryout to see whether the company's existing casting method would succeed. A single cavity trial mould was made. Trial castings were made. [HOW MANY?] Results were very far from acceptable. Facial and clothing details were not adequate and the extremities were not filled. Internal meetings were held, and it was realized that the problems revealed by the first tryout failures could not be solved with knowledge that existed in the company.

Results:

- Casting detail achieved: 2 mm (no improvement)

Conclusion:

[AUTHOR'S NOTE; AN IDEAL DESCRIPTION WOULD CONTAIN A CONCLUSION FOR THE CURRENT ACTIVITY.]

Key variables resolved: Methods for material to conform to surface, parting surface for the mould, process conditions

U n c e r t a i n t y # 2 : C h o o s i n g a c a s t i n g r e s i n

Choosing a casting resin related to its fluid flow properties, and then to the cure regime, outgassing, and as-cured mechanical properties.

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The most significant underlying key variables are:
casting resin, as-cured mechanical properties, material formulation

Activity # 2 - 1 : Discussions with casting resin suppliers

Work performed in Fiscal Year 2010:

Methods of experimentation:

- Analysis / simulation: 7 alternatives - Different materials considered. Main concern was degree of shrinkage.
[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

Discussions were held with casting resin suppliers and mould material suppliers to find better materials for filling the moulds. Special choices were made, particularly for low-shrinkage casting resins.

Conclusion:

[AUTHOR'S NOTE: AN IDEAL DESCRIPTION WOULD CONTAIN A CONCLUSION FOR THE CURRENT ACTIVITY.]

Key variables resolved: as-cured mechanical properties, casting resin, material formulation

Uncertainty # 3 : Resin to reach all the features

Uncertainties include:

- The ability of the liquid casting resin to actually reach all the extreme delicate features in the mould and properly fill the mould cavity, and any external arrangement to assist the mould-filling process.
- The gating and feeding arrangements for sustaining multiple-cavity moulds to suit volume production.
- The curing process - Would a room-temperature cure be adequate, or would a heating arrangement be required?
- The possible need for mould release agents to facilitate part release. Would these be compatible with the mould material and the casting material (in its initial liquid and cured stages)?

The most significant underlying key variables are:
ability of casting resin to reach all features, gating and feeding arrangements, curing temperature, mould release agents

Activity # 3 - 1 : Performing trials and obtaining results

Work performed in Fiscal Year 2010:

Methods of experimentation:

- Process trials: 68 runs / samples - Total number of sample figurines created in the below experimentation, before satisfactory castings were obtained.
[AUTHOR'S NOTE: THE DESCRIPTIONS BELOW WERE PROVIDED IN THE CRA'S EXAMPLE. THE DATA ABOVE (# TRIALS/ALTERNATIVES) IS PROVIDED TO ILLUSTRATE SOME OF THE ADDITIONAL DETAILS THAT WOULD IDEALLY BE INCLUDED.]

Several [HOW MANY?] trials were conducted with these low shrinkage casting resins, but the extremities of the moulds were still not filled.

Centrifugal assist was employed, using a motorized turntable to rotate the mould.

Difficulties were still encountered with mould filling, along with new problems caused by venting and outgassing.

A vacuum draw was added.

Eventually, after several iterations [HOW MANY?] to adjust the cooling conditions, satisfactory castings were obtained.

To define limits to the process, the method was extended to selected figurines in the dealer-requested range.

[AUTHOR'S NOTE: QUANTIFY HOW MANY EXPERIMENTS AND HOW MANY RUNS WERE CARRIED OUT. REMEMBER THAT THE TAX COURT'S CONTINUALLY REITERATE THE FACT THAT, "SYSTEMATIC INVESTIGATION MUST INVOLVE EXTREMELY ACCURATE MEASUREMENTS AND SUBSEQUENT ANALYSIS OF THOSE MEASUREMENTS." WE SHOULD THEREFORE ATTEMPT TO PROVIDE REVENUE CANADA WITH SUCH EVIDENCE WHENEVER POSSIBLE.]

Results:

- Casting detail achieved: 0.5 mm (100% of objective)

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- Increase production speed: 600 Units per hour (150% of objective)
- Minimize production costs: 0.15 \$ per unit (80% of objective)
- Minimize line maintenance: 3 hours per week (90% of objective)

Conclusion:

Through the extensive experimental development work described above, the company did achieve the capability to cast a completely new class of highly-detailed figurines, and it established a technology base that could be applied to other figurines with similar levels of fine surface detail and complex geometrical features.

ADDITIONAL CRA COMMENTS REGARDING ELIGIBILITY:

In most real-life examples, eligible work can be found before the first-tryout event. However, in this case, the SR&ED project actually did commence only after the first try-out, because that is when the company established that its existing technology base was inadequate to handle the complex new requirements and therefore began an experimental development process.

In this case the work described after the first try out was found to be eligible.

SR&ED is not required for every new figurine. It was required for the first example and then for any others that had special requirements such as finer details than any previously produced or for figurines with longer narrower parts.

Key variables resolved: ability of casting resin to reach all features, curing temperature, gating and feeding arrangements, mould release agents

1004 - Cast Figurines							
Benchmarks:		Patent searches: 3 patents Competitive products or processes: 1 products Similar prior in-house technologies: 1 products / Queries to experts: 3 responses	Objectives:		Casting detail achieved: 0.5 mm Increase production speed: 550 Units per hour Minimize production costs: 0.13 \$ per unit Minimize line maintenance: 2 hours per week		
Uncertainty:		1 - Material to conform		Key Variables:		Methods for material to conform to surface, parting surface for the mould, process conditions	
<u>Activity</u>	<u>Testing Methods</u>	<u>Results - % of Objective</u>	<u>Variables Concluded</u>	<u>Hours</u>	<u>Materials \$</u>	<u>Subcontractor \$</u>	<u>Fiscal Year</u>
1 - Performing try-outs	Process trials: 10 runs / samples Physical prototypes: 1 samples	Casting detail achieved: 2 mm (0 %)	Methods for material to conform to surface parting surface for the mould process conditions	0.00	0.00	0.00	2010
Uncertainty:		2 - Choosing a casting resin		Key Variables:		as-cured mechanical properties, casting resin, material formulation	
<u>Activity</u>	<u>Testing Methods</u>	<u>Results - % of Objective</u>	<u>Variables Concluded</u>	<u>Hours</u>	<u>Materials \$</u>	<u>Subcontractor \$</u>	<u>Fiscal Year</u>
1 - Discussions with casting resin suppliers	Analysis / simulation: 7 alternatives	(none)	as-cured mechanical properties casting resin material formulation	0.00	0.00	0.00	2010
Uncertainty:		3 - Resin to reach all the features		Key Variables:		ability of casting resin to reach all features, curing temperature, gating and feeding arrangements, mould release agents	
<u>Activity</u>	<u>Testing Methods</u>	<u>Results - % of Objective</u>	<u>Variables Concluded</u>	<u>Hours</u>	<u>Materials \$</u>	<u>Subcontractor \$</u>	<u>Fiscal Year</u>
1 - Performing trials and obtaining results	Process trials: 68 runs / samples	Casting detail achieved: 0.5 mm (100 %) Increase production speed: 600 Units per hour (150 %) Minimize production costs: 0.15 \$ per unit (80 %) Minimize line maintenance: 3 hours per week (90 %)	ability of casting resin to reach all features gating and feeding arrangements curing temperature mould release agents	0.00	0.00	0.00	2010