Technical Information Record **WRC–1859**

The Development of CARILON® Thermoplastic Polymers for Automotive Body Panels

E. R. George, J. H. Coker, Jr., P. S. Byrd, R. L. Danforth, J. M. Machado

Project No. 62182
CARILON® Engineering Thermoplastic Polymer Applications

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Based on work through August 1989

CONFIDENTIAL

Shell Development Company
A DIVISION OF SHELL OIL COMPANY

Westhollow Research Center
Houston, Texas

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ABSTRACT

The feasibility of using CARILON® EP polymers for automotive body panels was demonstrated at the end of 1987. Neat CARILON® EP polymers were modified via blending and reinforcement to achieve a good property set suitable for automotive body panels. Ford Econoline Van and Ford Taurus fenders were molded at lower clamp tonnage and faster cycle times than our key competitor Noryl GTX. Low temperature impact resistance and dimensional stability were identified as the key areas requiring improvements. Based upon this initial success we established an ongoing program with Ford Motor Company to develop CARILON® Thermoplastic Polymer compounds for automotive body panels. This record list in chronological order progress reports of the Ford body panel program from February 1988 to August 1989.

Technical Information Record WRC 1859

THE DEVELOPMENT OF CARILON® THERMOPLASTIC POLYMERS FOR AUTOMOTIVE BODY PANELS

by

E. R. George, J. H. Coker, Jr., P. S. Byrd,
R. L. Danforth, J. M. Machado

SUMMARY

Ford Taurus fenders were molded successfully in 1987 and tested for a range of physical properties. On-line paintability represents a value added feature of CARILON® Thermoplastic Polymers. Appendix I reports the analysis of these fenders for dimensional stability after simulated paint oven conditions. While the fenders did not meet requirements for dimensional change it was mutually agreed then on-line paintability was feasible with CARILON® Thermoplastic Polymer compounds.

Appendix II was a forward plan presented to Ford in September, 1988. The objective was to continue an ongoing program with Ford Plastics Product division to develop Shell's engineering polyketone for a fleet test on the Ford Taurus, either for the 1990 model year or one of the model years thereafter. Concurrently, we would explore other potential body panel applications. "Fit and Finish" combined with acceptable low temperature impact resistance were the key areas for development. Our progress in compound development and an Action Plan were presented with the goal of producing a viable fender compound by the end of 3Q 1989.

Appendix III summarizes a meeting with Ford's Materials and Paint Engineering Department responsible for screening new materials, writing specifications, and approving plastic products. This activity is separate from the Ford Plastic Products division where parts are developed. We obtained Ford's new requirements for plastics and plastic parts which went into effect January 1989. The new standards require ISO testing versus ASTM. We had ISO family test molds built for WRC at Eclipse Mold, Inc. in order to develop appropriate specifications for CARILON® Thermoplastic Polymer molding compounds.

An automotive development mold was designed and built in order to compare competitive materials for large body panels. Appendix IV summarizes an early discussion with Ford as to what features we should incorporate into the mold. The development of such a tool was clearly identified as a potentially important part of a fender development program.

Appendix V summarizes our most important meeting with Ford to date. Ford committed resources for the evaluation of CARILON® Thermoplastic Polymer as a candidate material for body panel applications. The Hoechst Celanese/Shell cooperation was explained and an update on

technical progress made in the 1Q 1989 was presented. Al Murray of Ford stressed that dimensional stability, warp free parts after molding, and after bake, was the key issue at Ford for plastic body panels and he believed that higher filler loading is a key in a semi-crystalline thermoplastic. At the end of the technical discussion, Paul Guy (Executive Engineer) said that Ford should do a complete evaluation of this material by the end of the 3Q 1989.

Appendix VI and VII report a series of molding trials conducted June 30, 1989 to August 3, 1989 at Premix/EMS in Portland, Indiana utilizing our automotive development tool. Experimental design programs established the key variables for molding large panels. Molding area diagrams were established for P1000 and confirmed the superior moldability of CARILON® Thermoplastic Polymers versus Noryl GTX.

Paul Burke and Ken Woodrich from Ford attended a molding demonstration at Premix/EMS on August 3, 1989. The purpose of the meeting was to show Ford personnel our plaque mold, which they helped design, and show them how CARILON® Thermoplastic Polymer molded. They were impressed with the mold and the amount of thought that had gone into its development. The Ford personnel recommended a gating change that would resemble the flow path of materials in the fender tool, to devise a method for measuring melt temperature in the cavity, and to incorporate pressure transducers along the flow length.

FORWARD PLAN

- The gating change recommended by Ford was completed and will be demonstrated the week of August 28, 1989.

- Two second generation filled CARILON® Thermoplastic Polymers were prepared at Hoechst Celanese and are available for a molding trial.

- Results from our Experimental design will be presented to Ford in September 1989. Other aspects of the automotive tool will be presented as well.

- The final goal is to mold body panels the last week of September 1989 or thereafter and preform actual part testing to determine the direction of the program.

REFERENCES

1. E. R. George and J. H. Coker, Jr., TPR 12-88, WRC.

Appendix I

SD-32 (REV. 5-78)

Shell Development Company
Interoffice Memorandum

FEBRUARY 23, 1988

FROM: E. R. GEORGE AND P. S. BYRD

TO: D. S. BRATH

SUBJECT: FEBRUARY 18 MEETING WITH FORD PLASTICS PRODUCTS DIVISION

PRESENT FROM FORD: DONALD S. MCLEAN
PATRICK A. YEZBICK
ALLAN D. MURRAY

SUMMARY:

Ford Taurus fenders molded 4Q 1987 from a glass filled CARILON EP polymer compound were tested for dimensional stability after simulated paint oven conditions. Three fenders each were heated for 22 minutes at 360°F and 415°F which simulate topcoat and ELPO paint conditions, respectively. The fenders survived these severe paint conditions and dimensional changes are reported here. While the fenders did not meet current requirements for dimensional change, it was mutually agreed that the proper combination of fibrous and particulate fillers would lead to acceptable dimensional stability. Note that Noryl GTX cannot survive 415°F temperatures and has only marginal performance at 360°F.

These initial measurements for the first generation CARILON EP polymer compound provide a benchmark for future development and Ford PPD invited us to develop second generation compounds which could be molded in their steel tools. Secondly, Ford PPD informed us of the availability of a 3500 ton Kraus Maffei injection molder at Delta Tooling in Detroit, MI. The molder has a smaller barrel than used in earlier trials thus reducing residence time an ideal situation for CARILON polymer processing.

Ford PPD indicated that a substantial cost savings would be realized if the conductive primer necessary for plastic exterior automotive parts could be eliminated. This would require a surface resistivity of 10^{-6} ohm -cm. CARILON polymers are chemically polar and would be more likely to achieve surface conductivity than other polymers. We will explore the possibility of surface conductivity at WRC with W. P. Gergen and D. R. Stewart. It was estimated that $30 per automobile could be saved by the elimination of plastic primer.

RESULTS AND DISCUSSION:

The Ford Taurus fender dimensions were measured at four points labeled A,B,C, and D in Figure 1. The percent dimensional change is reported in Table I for the hot dimensions (measured immediately upon removal from oven) and cold dimensions (measured after part cooled for 22 minutes). The fender expands upon heating and is characteristic of the material's coefficient of linear thermal expansion. ($5x10^{-5}$ in/in/^{o}F). The parts expand as much as 15mm along the C dimension which would require special fixtures with slots where the fender is attached to the frame. The addition of fillers such as mica are expected to significantly reduce this expansion to acceptable levels.

Upon cooling, the fender shrinks to dimensions smaller than the original values. This is characteristic of semicrystalline materials which anneal and become more dense. The negative values are indicative of this annealing effect. Again, this range of shrinkage may be reduced by the addition of the appropriate filler combination.

FIGURE 1
DIMENSIONS A,B,C, AND D MEASURED BEFORE AND AFTER PAINT BAKE SIMULATION

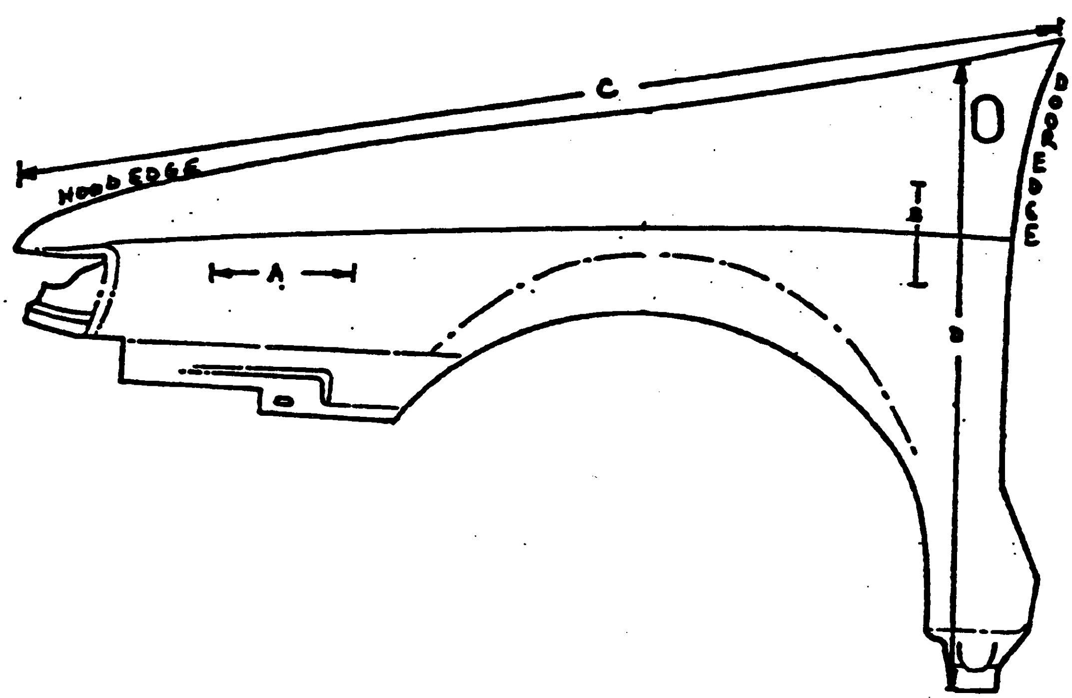

TABLE I
INITIAL DIMENSIONS AND PERCENT DIMENSIONAL CHANGE
UPON PAINT BAKE SIMULATION

TOPCOAT CONDITIONS (360°F 22 MINUTES)

DIMENSION	ORIGINAL VALUE (MM)	PERCENT CHANGE HOT	COOL
A	150.02	0.6	-0.4
B	150.02	-	-0.2
C	1241.55	1.4	-0.4
D	887.48	1.5	-0.4

ELPO CONDITIONS (415°F 22 MINUTES)

DIMENSION	ORIGINAL VALUE (MM)	PERCENT CHANGE HOT	COOL
A	150.05	1.2	-1.4
B	150.05	1.6	-0.03
C	1241.55	1.3	-0.6
D	887.48	-	-0.06

ACTION:

Blends of CARILON EP polymers containing various combinations of mineral fillers, fiberglass, impact modifiers, and melt processing aids will be prepared and characterized 2Q 1988. The two most optimum formulations will be prepared for a fender molding trial with Buick 2Q 1988. The recent discovery of efficient impact modifiers for CARILON EP polymers can enable us to reduce CLTE and shrinkage without significant loss of impact resistance. Ford PPD indicated that this would represent a significant development.

Depending upon the outcome of these experiments and the Buick molding trial, future work with Ford will be coordinated. The development of a surface conducting compound will be explored and preliminary results reported 3Q 1988.

Eric R. George

E. R. George

P. S. Byrd

ERG/sas

cc: S. W. Gilks (Shell UK)
W. P. Gergen
R. G. Hayter
W. P. Rothwell
J. H. Coker, Jr.
R. L. Danforth
Chron File

Appendix II

THE DEVELOPMENT OF CARILON™ THERMOPLASTIC POLYMER COMPOUNDS FOR FORD TAURUS FENDERS

ERIC R. GEORGE, R. L. DANFORTH, AND P. S. BYRD

THE DEVELOPMENT OF CARILON™ THERMOPLASTIC POLYMER COMPOUNDS FOR FORD TAURUS FENDERS

ERIC R. GEORGE, R. L. DANFORTH, AND P. S. BYRD

I. OBJECTIVE

To establish an ongoing program with Ford Plastics Product Division to develop Shell's engineering polyketone for a fleet test on the Ford Taurus, either for the 1990 model year or one of the model years thereafter. Concurrently, we would look for other potential fender and body panel applications. The fender will be on-line paintable and exhibit the same mold shrinkage as Noryl GTX.

II. BACKGROUND

Based upon earlier molding trials in which we molded Ford Econoline and Taurus fenders, engineering polyketones are viable for use as vertical automotive body panels. The key properties requiring improvement were low temperature impact resistance and dimensional stability. Dimensional stability encompasses a range of requirements including heat sag, coefficient of thermal expansion, and warpage requirements. The successful compound for fenders is expected to be impact modified and reinforced.

Table I lists the requirements for vertical body panels. The conditions of high temperature resistance during on-line painting combined with low temperature impact resistance requires engineering performance over a wide temperature range. Processing aids and fiberglass reinforcement were employed to produce our first automotive compounds for vertical body panels. Table II compares these first generation compounds to Noryl GTX and Bexloy C from General Electric and DuPont, respectively. These engineering polyketone compounds were molded, painted, and aged in Florida. Paint performance is exceptional and Table III lists the paint tests passed by both compounds. The painted fenders have lost no gloss, color, or appearance after 6 months Florida aging.

Subsequently, we developed two second generation compounds for improved impact resistance and dimensional stability, respectively. A complete property set for both compounds is listed in Table IV. Impact modified polyketones will often yield lower impact values in falling dart tests or Rheometrics impact. However, the mode of failure is altered. Impact modified systems fail in a ductile-like manner, even at low temperatures, in that a hole is punched in the sample versus the sample shattering. This represents a more localized failure more suited for repairs and safer should collision occur.

The reinforced system is expected to prevent warpage or any other problem associated with anisotropy. The system sacrifices impact resistance but optimization via impact modifiers and enhanced reinforcement could lead to viable systems. Preliminary results indicate that certain minerals significantly improve the temperature resistance and UL continuous use temperature of engineering polyketones.

III. ACTION PLAN (OUTLINED IN TABLE V)

The first step is to meet with Ford and establish mutual requirements. Our progress since the Taurus molding trial includes impact modification and mica reinforced systems. Once the key criteria are established we can proceed with formulation work, process optimization, and ultimately the production of quality fenders. Our goal is to produce such a fender by 3Q 1989.

Impact resistance is a key area of concern. The mode of failure is most critical. Obviously one would desire a true ductile failure but this is not likely in ETP's. The optimum formulation is expected to be a mineral reinforced system which fails upon impact at low temperature via a localized rupture versus shattering of the samples. Rheometrics impact and Gardner impact can only be compared when mode of failure is similar. We need a firm understanding with Ford concerning impact resistance and mode of failure.

We have identified four molding tools available at Ford for our use; a 24" x 18" plaque mold, a structural crossmember, Mustang hood scoop, and a Kerksite Taurus tool. The plaque mold could be used to measure physical properties and aspects of dimensional stability outlined in Table I. The hood scoop can be used for evaluation of Class A paint performance without using large injection molders and large amounts of compound. Taurus fenders would be molded in the Kerksite tool or a steel tool at a later date. The Taurus fenders will only be molded if significant progress is made toward meeting Ford-Shell mutual requirements.

TABLE I
KEY PROPERTY REQUIREMENTS FOR AUTOMOTIVE VERTICAL BODY PANELS

PROPERTIES	COMMENTS
I. Mechanical Properties Flexural Modulus Flexural Strength Tensile Strength Elongation to Break	I. The physical properties determine part design such as thickness and ribbing. The fender must have structural integrity as perceived by the general public. Stiffness and strength are critical.
II. Impact Resistance Notched Izod Rheometrics Gardner	II. A big advantage of plastic is the resistance to dings and dents at small impacts. Impact resistance versus temperature and mode of failure are important variables.
III. Dimensional Stability CLTE Heat Sag Mold Shrinkage Warpage	III. For fenders the CLTE is particularly important during the paint step. Large expansion, particularly if the material is anisotropic leads to warpage. Mold shrinkage must be measured before and after painting to have real world significance.
IV. Paint Performance Florida Aging Adhesion Class A Surface	IV. The painted part is ultimately what goes into service. The painted fender must maintain adhesion and Class A surface throughout the lifetime of the fender.

TABLE II
ENGINEERING POLYKETONE VS OTHER INJECTION MOLDED ENGINEERING THERMOPLASTICS

PROPERTIES	BUICK FENDER PPO/NYLON GTX 910	FIERO QTR PANEL A NYLON BEXLOY C	ENGINEERING POLYKETONE	
			NEAT	GLASS
Tensile Strength, psi	6,800	6,200	7,500	8,000
Flexural Mod, R.T., psi	250,000	250,000	245,000	361,000
Flexural Mod, 150^{o}F, psi	160,000	150,000	-	-
Izod Impact R.T. (ft.lb./in.)	4.5	13.0	4.5	4.4
Izod Impact -20^{o}F, (ft.lb./in.)	2.5	5.5	1.6	1.6
HDT, @ 264 psi, ^{o}F	290	275	230	250
Heat Sag, 1 hr (250^{o}F)	0.1	0.04	0.03	0.04
(325^{o}F)	0.2	2.0	0.09	0.09
(375^{o}F)	0.5	-	0.5	0.5
CLTE x10^{-5} in./in./^{o}F	5.0	5.0	7.0	5.0
Humidity, % Growth	0.45	1.2	0.3	0.3
Specific Gravity	1.1	1.1	1.2	1.25
Elongation at Break, %	-	-	104	96

TABLE III
PAINT CONDITIONS AND TEST RESULTS
PART PAINTING SCHEDULE

PART PREPARATION
SEVEN STAGE POWER WASH

	BAKE TEMPERATURE/TIME
Priming System Conductive	
PPG MCP 9500	350^{o}F/30 min
SO BP 9245	350^{o}F/30 min
AKZO 11 BME 42027	280^{o}F/30 min
E-COAT/ELPO	385^{o}F/22 min
E-COAT/Simulated	400^{o}F/60 min
Primer/Surfacer	
PPG DPX 1715	280^{o}F/30 min
Top Coat Systems	
PPG UBC/URC	270^{o}F/30 min
PPG HUBC/URC	270^{o}F/30 min
PPG DHT	260^{o}F/35 min
PPG DCT/DCT	260^{o}F/35 min

Paint Performance Testing
GM 4350-M, Class AO

Adhesion (GM 9071-P)	Pass
Water Immersion (GM 4466P)	Pass
Humidity (GM 4465P)	Pass
Cure Xylene (8 Rubs)	Pass
Thermal Shock (Ford FLTM-B1-7-5)	Pass

Flordia Exposure in Progress

TABLE IV
PROPERTIES OF CARILON™ THERMOPLASTIC EP POLYMER
COMPOUNDS B AND C

PROPERTY	COMPOUND B	COMPOUND C
Flexural Modulus (psi)	264,000	400,000
Tensile Strength (psi):		
Yield	7,500	8,200
Break	9,200	7,500
Elongation (%):		
Yield	22	17
Break	200	69
Notched Izod Impact (ft.lb./in.):		
R.T.	5.0 - 13.0	1.8
-20°F	1,6 - 3.0	0.9
Gardner Impact (in.lb.):		
R.T.	145	40
-20°F	91	12
Rheometrics Impact:		
R.T.	430 lbs.326 mils	320 lbs.265 mils
-20°F	340 lbs.182 mils	320 lbs.139 mils
Mold Shrinkage (%)	2.6	2.1
CLTE (in./in./°F)x10^{-5}:		
Machine Direction	7.7	5.8
Transverse Direction	6.5	6.8
HDT (°F @ 264 psi)	200	240

TABLE V
ACTION PLAN FOR FENDER PROGRAM

EVENT	ECD
1. Meet with Ford PPD and establish key requirements. Report on our progress to date such as Florida aging and New Formulations since the Ford Taurus Molding trial.	September 1988
2. Prepare and mold three grades of material in plaque mold and the Mustang hood scoop. Evaluate properties outlined in Table I. Optimize process conditions.	November 1988
3. Compound and mold at WRC (Paragon) new grades including impact modified, improved mica systems, improved fiberglass systems, and impact modified reinforced systems.	1Q 1989
4. Repeat Step 2 for improved grades resulting from Step 3.	2Q 1989
5. Mold, paint, and complete testing (excluding aging) of Ford Taurus fender. Make decision on program.	3Q 1989

Appendix III

TYPED 10/3/88

MEMORANDUM OF DISCUSSION

Date: September 23, 1988

Participants: FORD MOTOR CO.
Marilyn Perchard, Supervisor
Glen A. Molnar, Senior Engineer
Pat Yezbek, Senior Engineer

SHELL
P. S. Byrd, SCC-CHPO
E. R. George, SDC-WRC
Joe Epel, Consultant

Subject: ESTABLISHING REQUIREMENTS AND SPECIFICATIONS FOR FENDER PROGRAM

SUMMARY:

The purpose of the visit was to establish a fender program with Ford Motor Co. The Materials and Paint Engineering Department supervised by Marilyn Perchard is responsible for screening new materials, for writing specifications and approving plastic products. This activity is separate from Ford PPD where parts are developed. We learned that Ford has established a set of world requirements for plastics and plastic parts to go into effect January 1989. Ford agreed to send us a copy of these requirements and to send a copy of the specification sheet for Noryl GTX. We discussed in detail the key properties a plastic part must have to be viable as an exterior body panel. The meeting was successful and the next step is to complete the test protocol as laid out in the world requirements.

TEST PROCEDURES:

A key test pointed out by Marilyn Perchard was the temperature at which a plastic will retain 85 percent of its properties after 1000 hours of aging at that temperature. Secondly, Ford would like test data for up to 25 lots of material in order to feed reliable data into CAD programs. The other tests are all familiar to us and we have a good knowledge base for engineering polyketones. These include:

- HDT at 66 psi
- Dart Impact at -20^{o}F and -40^{o}F
- Notched Izod Impact
- Water Absorption
- CLTE
- Environmental Stress Cracking (1% strain)

The world specifications include the type of gates and molds, etc. to be used for injection molded test specimens. Details of the world test requirements will be distributed when we receive them.

ACTION:

Upon receiving the world specifications we will work with three basic polyketone compounds utilizing several batches for an evaluation of viability and lot to lot variability. The initial phase of the program will take approximately three months. The Ford Fender program will follow the same action plan as outlined earlier (Table I) but we will not use the plaque mold at Ford since it does not meet requirements for a fender development program. We need to have our own plaque mold built and ready for use by 1Q 1989. To this end we have had discussions with Joe Epel and Frank Pink (of ENTECH, a highly recommended mold designer) on what features should be incorporated in a test mold. Frank Pink will have preliminary drawing of a mold ready for review by SDC personnel and Ford personnel during October. It is estimated that such a mold could be ready by early 1989.

CONCLUSION:

The first step of the Ford fender program is complete (see attachment). Upon establishing a specification sheet for viable CARILON™ Thermoplastic Polymer fender compounds, Taurus fenders will be molded and once again tested via Ford world requirements. Assuming success in these initial phases we hope to be on a fleet vehicle by the end of 1990.

Eric R. George

Eric R. George

ERG/saj

Distribution:

K. V. Henton - KSLA-PRP
A. A. Broekhuis - KSLA-PRP/3
D. Medema - KSLA-CP
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S. W. Gilks - SICC-CBDAL/1
D. S. Brath
W. A. Zama
P. M. Paolucci
P. S. Byrd
Chron File

TABLE I
ACTION PLAN FOR FENDER PROGRAM

EVENT	ECD
1. Meet with Ford PPD and establish key requirements. Report on our progress to date such as Florida aging and New Formulations since the Ford Taurus Molding trial.	September 1988
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5. Mold, paint, and complete testing (excluding aging) of Ford Taurus fender. Make decision on program.	3Q 1989

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Appendix IV

MEMORANDUM OF DISCUSSION

DATE: December 7, 1988

COMPANY: Ford Motor Company
Plastic Products Engineering
24300 Glendale Avenue
Detroit, Michigan 48239

FORD PERSONNEL: Jim Gourd, Tool Engineer

SHELL PERSONNEL: P. S. Byrd
Dr. J. N. Epel, Consultant

The purpose of the visit with Ford was to discuss with them our version of a plaque mold which we are in the final stages of designing. We explained to Mr. Gourd our concept for the part and showed him the drawings of the tool as we envisioned it, and asked him to make comments, changes, or whatever else might be necessary in order to improve the performance of the tool and make it more versatile.

As a result of our visit, the following were decided:

- All agreed that the first tool should be a flat plaque 30 in. long and 7 in. wide with a variable gating arrangement.

- Considerations for cavity inserts will be incorporated in the mold, which will allow for a rib or leg on one side of the molded part, and a radius corner rather than a square corner. This radius would allow for a fillet-type of arrangement and would allow us to study the effect of external ribs.

- Mr. Gourd strongly urged that we provide in the tooling by having the appropriate amount of metal in the die base for inmold coating. This process is something that Ford is looking at for injection molded parts for the future. It is only necessary to plan for it at this time.

- Mr. Gourd's final consideration is that we consider a system called gas assisted injection (GAIN). This process is a nitrogen injection through the sprew which allows you to mold in ribs, bosses, etc., without sink marks. The process is apparently patented by Detroit Plastic Molding and discussion with DPM would be necessary.

J. N. Epel will take the recommendations made by Ford to the mold maker, have these features incorporated in the mold, and have the mold sources requote based on these most recent changes.

J. N. Epel has been given the go-ahead to have the tooling source order the long lead time items for construction of this mold. The target is to have this mold available and ready for use by the end of the first quarter 1989.

Paul S. Byrd
December 12, 1988

PSB/ckd

cc: D. S. Brath, Westhollow Research Center
R. L. Danforth, Westhollow Research Center
~~C. R. George~~, Westhollow Research Center
S. W. Gilks CBDAL/1, SICC London
F. W. Braat CBDA/11, SICM The Hague

Appendix V

MEMORANDUM OF DISCUSSION

FORD MOTOR COMPANY
PLASTIC PRODUCTS DIVISION
24300 GLENDALE AVENUE
DETROIT, MI 48239

MARCH 31, 1989

FORD PERSONNEL:	PAUL F. GUY, EXECUTIVE ENGINEER ALLEN MURRAY, MGR. BODY PANELS PAUL KILLGOAR, ENGINEER EDWARD SYKES, ENGINEER PAUL FUNG CHEUNG, ENGINEER AMOS GOLODOY, ENGINEER PAUL BURKE, ENGINEER ALLEN R. WOODLUFF, ENGINEER
HOECHST CELANESE:	STEVEN P. LEYRER, MGR. POLYKETONE DEVELOPMENT JIM ESCH, FORD ACCOUNT REP.
SHELL PERSONNEL:	PAUL S. BYRD ERIC R. GEORGE DR. J. N. EPEL (CONSULTANT)

The purpose of our meeting with Ford was three-fold - (1) to ask Ford to to commit resources for the evaluation of CARILON™ thermoplastic polymer as a candidate material for body panel applications, (2) to explain the Hoechst Celanese/Shell cooperation, and (3) to update Ford on the technical progress made over the past quarter. Attached is a copy of the agenda.

The writer briefly explained why the Hoechst Celanese/Shell cooperation was being considered, and Steve Leyrer detailed how the cooperation would work with the goal of forming a joint venture. Paul Guy questioned if the joint venture were to be formed, would it be autonomous or would the parents to the joint venture exercise control over the venture? The makeup of the joint venture and the operating vision of it was explained in great depth, as well as the raw material-supplied security. Mr. Guy seemed pleased with the explanation; however, you could see that based on Ford's experience, this was a difficult concept.

Eric George gave a technical update following the program that was established during the late September 1988 meeting with Ford. In the attachment of the technical presentation, a copy of the program is given. The dialogue on the technical issues was mainly between Al Murray and Eric George with Mr. Murray indicating that dimensional stability, warp-free parts after molding, and after paint-bake, was the key issue at Ford for plastic body panels and he (Murray) believed that higher filler loading is a key in a polymer-like CARILON. Recognizing that high filler loading would mean greater brittleness of the molded part (lower impact), Mr. Murray was ready to accept that and would work with us to determine what impact level was unacceptable. Attached is the presentation that Eric George gave Ford along with his technical MOD of the meeting.

Since Dr. Joe Epel has been instrumental in the design and construction of our multigated Class A 30-inch x 7 inch plaque mold, he discussed the idea behind the mold as well as the features incorporated in the mold. The Ford personnel, primarily Al Murray, Ed Sykes, and Paul Burke, could see the benefit such a mold would have on evaluating many materials for body panels. They expressed their desire to observe the mold being used as well as evaluate materials in it.

At the end of the technical discussion, Paul Guy said that we, Ford, should do a complete evaluation of this material by the end of the third quarter. The statement was made without our asking for Ford's involvement. It was agreed unanimously on both sides that we would cooperate jointly in such an evaluation.

The issue of dimensional stability, high filler loading versus low temperature impact, was again discussed with Al Murray in a smaller group. He again stated his position that Ford did not know how much impact was needed in a vertical body panel and would work with Shell/Hoechst Celanese to make this determination.

Ed Sykes volunteered that the General Electric NORYL was not making it in Ford's body panel program due to dimensional changes and warpage after paint-bake. He went on to state that they must be in a position by the end of the third quarter to pick a polymer material for the 1993 Tauraus Program or the part will remain in steel. Mr. Sykes went on to state that: <u>We could mold in the Tauraus now</u>.

Al Murray briefly discussed part economics and said that we should be careful not to get blind-sided by the finished part economics of polyurea-RIM.

Paul Boyd ckd

PSB/ckd

Attachments

FW89110002 - 0002.0.0

cc - <u>Hoechst Celanese</u>
Steven P. Leyrer, Summit, New Jersey
Jim Esche, Automotive Development Center, Auburn Hills, MI
Tom Butwin, Automotive Development Center, Auburn Hills, MI

<u>Shell</u>
W. A. Zama
P. M. Paolucci
J. H. Braden
E. R. George, Shell Development Company
D. S. Brath, Shell Development Company
S. W. Gilks, CBDAL/1, SICC London
F. W. Bratt, CBDA/11, SICM, The Hague
T. A. Broekhuis, KSLA, Amsterdam

PROPOSED AGENDA FOR THE FORD HC/SHELL MEETING

MARCH 31,1989

O EXPLANATION OF THE HC/SHELL COOPERATION

O TECHNICAL UPDATE SINCE THE LAST MEETING WITH FORD

- NEAT POLYMER PERFORMANCE BASED ON LARGE PLANT RUNS
- EFFECT OF FILLERS ON PERFORMANCE
    - o MOLD SHRINKAGE
    - o ISOTROPIC BEHAVIOR
    - o LOW TEMPERATURE IMPACT AND FAILURE MODE
- FLORIDA AGING
    - o ONE YEAR PAINT PERFORMANCE
- UPDATE ON PLAQUE MOLD

O HOW FORD CAN HELP HC/SHELL DETERMINE IF CARILON TM THERMOPLASTIC POLYMERS, ENGINEERING POLYKETONE IS A BODY PANEL CANDIDATE

THE DEVELOPMENT OF CARILON™ THERMOPLASTIC POLYMERS FOR COMMERCIAL APPLICATIONS

EXTERIOR AUTOMOTIVE APPLICATIONS

I. ACTION PLAN

II. PROPERTIES OF IMPROVED CARILON™ BASE POLYMER

III. BODY PANEL REQUIREMENTS

IV. FLORIDA AGING ONE YEAR PAINT PERFORMANCE

V. EFFECT OF FILLERS ON PERFORMANCE

ERIC R. GEORGE

SHELL DEVELOPMENT COMPANY

MARCH 31, 1989

ACTION PLAN FOR BODY PANEL PROGRAM

EVENT	ECD
1. Meet with Ford PPD and establish key requirements. Report on our progress to date such as Florida aging and New Formulations since the Ford Taurus Molding Trial.	September 1988
2. Establish contact with Ford Materials and Paint Engineering.	October 1988
3. Prepare, mold, and evaluate additional grades of material.	December 1988
4. Compound and mold improved filled grades	March 1989
5. Repeat step 3 for improved grades resulting from step 4.	2Q 1989
6. Mold, paint, and complete testing of the material in a Ford Body Panel application.	3Q 1989

PROPERTIES OF IMPROVED BASE RESIN

PROPERTY	UNITS	VALUE
Gardner Impact		
R.T.	in.lb.	>320
$-30^{o}C$	in.lb.	>320
Notched Izod Impact		
R.T.	ft.lb./in.	6.4
$-30^{o}C$	ft.lb./in.	1.3
Tensile Properties		
Yield strength	psi	8400
Elongation at yield	%	15
Break strength	psi	9500
Elongation at break	%	300
RHEOMETRICS IMPACT 5 MPH @ $-30^{o}C$		
Force at yield	lb.	1400
Deflection at yield	in.	0.549
Energy at yield	in.lb.	330
Deflection at break	in.	0.576
Energy at break	in.lb.	370

KEY PROPERTY REQUIREMENTS FOR AUTOMOTIVE VERTICAL BODY PANELS

I. MECHANICAL PROPERTIES

- Flexural Modulus
- Flexural Strength
- Tensile Strength
- Elongation to Break

II. IMPACT RESISTANCE AT -30°C

- Notched Izod
- Rheometrics
- Gardner

III. DIMENSIONAL STABILITY

- CLTE
- Heat Sag
- Mold Shrinkage
- Warpage

IV. PAINT PERFORMANCE

- On-line Paintability
- Adhesion
- Florida Aging
- Class A Surface

FORD ECONOLINE VAN FENDER
PAINT PERFORMANCE TESTING
(ESB-M2P80)-A

LAB TESTS PERFORMED PER SPEC	LIGHT BLUE*	PAINT BLACK**	WHITE***	SMOKE METALLIC****	1 YEAR FLORIDA EXPOSURE
ADHESION FLTM-B1-106-1	PASS	PASS	PASS	PASS	PASS
FILM THICKNESS, Mil BASE CLEAR FLTM-B1-17-1	1.2 1.90	TOP 1.8	TOP 2.2	1.0 1.75	
WATER IMMERSION FLTM-B1-4-1	PASS	PASS	PASS	PASS	PASS
CURE	PASS	PASS	PASS	PASS	PASS
THERMAL SHOCK FLTM-B1-7-5	PASS	PASS	PASS	PASS	PASS

*PPG BASE COAT DCT 1002, CLEAR COAT DCT 1002
**PPG TOP COAT DHT 1724
***PPG TOP COAT DHT 5920
****PPG BASE COAT DCT 6350, CLEAR COAT DCT 1002

CARILON™ THERMOPLASTIC POLYMER COMPOUND VERSUS NORYL GTX

PROPERTY	NEAT	CARILON™ + 10% TALC	NORYL GTX
Flex Modulus (PSI)	275,000	340,000	290,000
Heat Sag (in)			
375°F 30 min	0.1	0.1	0.4
400°F 30 min	0.2	0.2	
HDT @ 66 PSI			
°C	200	201	184
Gardner Impact			
R. T. (in.lb.)	>320	>320	
-30°C (in.lb.)	>320	80	
Mold Shrinkage	2.7	2.4	1.5

CONCLUSIONS AND FUTURE PLANS

- CARILON™ thermoplastic polymers exhibit an outstanding property balance suitable for automotive body panels.

- The use of fillers improves dimensional stability with some sacrifice of impact resistance.

- The optimization of filler content, tool design, and molding conditions should lead to a viable automotive body panel.

- The molding, painting, and testing of a real part in 3Q 1989 would determine on-line paintability and actual performance.

TYPED 4/6/89

MEMORANDUM OF DISCUSSION

Ford Motor Company
Plastics Product Division
24300 Glendale Avenue
Detroit, MI 48239

Ford Personnel:

Paul F. Guy
Al Murray
Paul Killgoar, Jr.
Mo-Fung Cheung
Amos Golovoy
Paul Burke
Edward Sykes
Alan R. Woodluff

Hoechst Celanese Personnel:

Steve Leyrer
Jim Esch

Shell Personnel:

Paul S. Byrd
Eric R. George (Reporter)
Dr. J. N. Epel (Consultant)

SUMMARY:

A meeting was held at Ford Plastics Product Division on March 31, 1989 to discuss the development of CARILON™ thermoplastic polymers for automotive body panels. An action plan was agreed upon by Shell and Ford to mold Ford Taurus fenders 3Q 1989. The fenders will be painted and tested to determine on-line paintability and actual part performance. A copy of the presentation is provided as an Appendix.

A progress report and action plan was presented for recent improvements in CARILON™ base resins and mineral filled compounds. The key property improvements were low temperature impact resistance and melt processability. The Ford personnel acknowledged that CARILON™ was a viable engineering thermoplastic with a property set suitable for automotive body panels. Their key concern was dimensional stability i.e. warp free parts which can be reproduced within dimensional tolerances. Ford recommended higher filler levels to reduce mold shrinkage and thermal expansion, and recognized that impact resistance would suffer but that impact values are negotiable.

A key attribute of CARILON™ thermoplastic polymer compounds is that a reactor polymer is used versus polymer blends such as Noryl GTX. This reduces the probability of part to part variation characteristic of complicated morphologies in polymer blends. Ford acknowledged that hot mold temperatures may be necessary for our engineering polyketone but fast cycles and low clamp tonnage requirements make CARILON™ thermoplastic polymer compounds attractive injection molding materials.

Ford expressed considerable interest in a 30"x7" plaque mold we have designed and built for evaluating compounds in body panel applications. The tool is equipped with multiple inserts to investigate the effects of runner and gate design on part performance. Other features of the tool include.

- an L flange to evaluate read-thru
- variable thickness (75-150 mils)
- oil heating for hot mold conditions
- advanced insulation
- class A surface

This tool will provide a convenient means to evaluate candidate compounds (including competitive materials) for body panels without having to use large amounts of material. Ford personnel will attend molding trials employing this tool.

We also presented results on paint performance for the Ford Econoline Van fenders molded in 4Q 1987. The painted fenders pass all paint specifications even after one year Florida exposure.

<u>CONCLUSION</u>:

An action plan was agreed upon with Ford Motor Company to mold Taurus fenders from improved CARILON™ thermoplastic polymer compounds by 3Q 1989, however a window of opportunity to mold the fender exists now and we should strongly investigate the possibility of taking advantage of this opportunity. The parts will be painted and tested to determine on-line paintability and actual part performance.

Ford confirmed that CARILON™ thermoplastic polymer compounds exhibit a property set suitable for automotive body panels provided that the issue of dimensional stability is resolved.

Eric R. George

ERG/saj

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S. P. Leyrer, Hoechst Celanese
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Appendix VI

SD-32 (REV. 5-78)

Shell Development Company
Interoffice Memorandum

JULY 26, 1989

FROM: E. R. GEORGE AND J. M. MACHADO

TO: D. S. BRATH

SUBJECT: PROGRESS REPORT ON AUTOMOTIVE DEVELOPMENT PROGRAM

EXECUTIVE SUMMARY

A series of molding trials were conducted June 30, 1989 to July 21, 1989 at Premix/EMS in Portland, IN. utilizing our automotive development tool and CARILON® thermoplastic polymer compounds including P1000. Seven molding variables were evaluated via a Plackett Berman experimental design program and established mold temperature, injection speed, and part thickness as the key variables for molding body panels. The use of two 3" fan gates, higher melt temperature, and longer hold time clearly reduced warpage so the decision was made to treat these parameters as constants. A full factored experimental design was conducted for the three key variables at a high and low setting resulting in eight experiments. Parts from each experiment will be evaluated for physical properties in order to establish optimum conditions for part performance. The three parameter, full factorial experimental design was completed for P1000, a 20 wt. percent talc compound, and four impact modified compounds each containing 10 wt. percent of impact modifier.

Molding area diagrams were established for P1000 at 150°F and 270°F mold temperature using two 3" fan gates at a thickness of 100 mils and 2 tons/in^2 clamp tonnage. A molding area diagram plots melt temperature versus injection pressure and establishes the molding window to fill a part without flashing or degradation. The scrap from these experiments was reground and will be used for future studies of recyclability.

A demonstration of the automotive development tool for Ford Motor Co. using P1000 and the talc compound will take place August 3, 1989 at Premix/EMS.

AUTOMOTIVE DEVELOPMENT TOOL

This tool was designed in order to evaluate the variables which may affect part performance in body panel applications. The part is a 30" x 7" plaque mold with multiple gating options. The mold features Class A surface, oil heat capability, a lifter to evaluate read-thru, and the ability to vary part thickness between 100 and 150 mils while in the press. The tool was used in a 500 ton Cincinnati Milacron injection molding machine and experimental design was employed to optimize molding conditions. The responses to these experiments will include mold shrinkage, impact resistance and anistropy.

The eight experiments employed for each compound is shown below:

Experiment	Mold Temperature (°F)	Injection Speed (in/sec)	Thickness (mils)
1	150	1	150
2	150	3	150
3	150	1	100
4	150	3	100
5	270	1	150
6	270	3	150
7	270	1	100
8	270	3	100

The melt temperature, hold time, and hold pressure were held constant at 535°F, 20 seconds, and 500 psi, respectively.

MOLDING AREA DIAGRAM

The molding of P1000 was investigated at three different melt temperatures 484°F, 520°F, and 537°F, versus injection pressure across the entire pressure range (0-2000 psi) of the machine. This was performed at mold temperatures of 150°F and 270°F. Note that 270°F heat would require oil heating and 150°F would require only water heated molds. The higher mold temperature clearly reduces the injection pressure to fill the part. Higher melt temperature (537°F) are required for longer flow lengths. The maximum flow length/thickness ratio for P1000 is ~250/1. For filled grades and higher viscosity resins the ratio is reduced to ~200/1.

MOLD SHRINKAGE

The mold shrinkage for P1000 in a 150°F mold at 100 mils and 150 mils was 19/1000 in. and 23/1000 in., respectively. The lower shrinkage at 100 mils can be attributed to orientation effects. The 100 mil part is more typical of body panel thicknesses.

TALC-FILLED GRADE

The objective of using a talc filler is to obtain "fit and finish" to meet automotive body panel requirements after painting. Impact resistance is sacrificed and filled materials are more difficult to mold versus neat materials.

We compounded 20 wt. percent of Micropflex 1200 talc and 1 wt. percent Nucrel 535 into P1000 on a 30 mm corotating twin screw extruder (WP). We molded successfully under a range of conditions including the 8 design experiments. Cycle time could be reduced to 38.5 seconds in our automotive tool.

Filled polymers may crystallize faster and at higher temperature than the neat polymer because of heat transfer and nucleation effects. Higher melt and mold temperature are necessary to mold a large plaque with a good surface finish. The part must be filled prior to onset of crystallization. Eighteen experiments were performed for the talc filled P1000. Reduction in cycle time and mold temperatures >200°F produced the best parts with minimal warpage and best surface appearance. The talc filled grade required only 200 psi additional injection pressure versus neat P1000. Its moldability was excellent. Some warpage was noted in the parts as they cooled to room temperature. The 20 percent mineral filler reduces mold shrinkage at 100 mils to 17/1000 in. comparable to Noryl GTX.

P1000 VERSUS NORYL GTX

We molded Noryl GTX under the recommended molding conditions. It molded well in our automotive development tool using two 3 inch fan gates.

We have watched closely the development and commercial production of Noryl GTX in the Mitsubishi Eclipse spoiler system at Premix/EMS. The mold was modified from a multi-gate design to a single full fan gate. Cycle times had to be increased to 2 minutes because of warpage problems. Noryl GTX has significant problems with read-thru at bosses and ribs. GTX 910 is believed to contain a small amount of fiberglass which requires an additional sanding and priming step.

IMPACT MODIFIED GRADES

CARILON® thermoplastic polymer 89/007 was blended at ten weight percent with Pebax 2533, Hytrel 4056, Cadon 127, and Nylon/KRATON® rubber combination. The results are incomplete but Pebax exhibited the best moldability, surface appearance and was equal or slightly better than Hytrel 4056 in impact resistance. Cadon and Nylon cause excessive melt degradation for practical molding trials. Pebax 2533 will be used to impact modify our talc filled grade in an effort to meet the requirements of on-line paintable body panels.

ACTION ITEMS

- Prepare two 1000 lb batches of 20 percent talc filled P1000 (one impact modified) for a subsequent molding trial of the Ford Taurus fender. One-thousand lbs of P1000 will also be required.

- Prepare and schedule molding demonstration for Ford on August 3, 1989 at Premix/EMS. Talc-filled P1000 and neat P1000 will be demonstrated.

- test plaques of P1000, talc filled, and impact modified grade for physical properties, particularly low temperature impact resistance, to determine optimum molding conditions for best part performance.

- paint P1000 and talc filled plaques with PPG and AKZO on-line paintable primers.

- test painted plaques for paint quality and physical properties.

- make surface tension measurement on plaques of P1000 and 20 percent talc filled P1000 prepared by various power washes.

Eric R. George

Eric R. George

J. M. Machado

J. M. Machado

ERG/saj

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P. S. Byrd

Appendix VII

MEMORANDUM OF DISCUSSION
AUGUST 3, 1989

PREMIX/E.M.S.

JOHN LOMBARDO, PLANT MANAGER
RAY BORGER, ENGINEER
MATT LEFFLER, ENGINEER

FORD MOTOR COMPANY

KEN WOODRICH, ENGINEER
PAUL BURKE, TOOLING ENGINEER

HOECHST CELANESE

TOM BUTWIN, AUTOMOTIVE DEVELOPMENT MANAGER

SHELL DEVELOPMENT

E. R. GEORGE
J. COKER

SHELL CHEMICAL COMPANY

P. S. BYRD

CONSULTANT

DR. J. N. EPEL

The purpose of the meeting at Premix/E.M.S. was to show Ford personnel our plaque mold, which they helped design, and show them how CARILON® Polymer molded. The Ford people were asked for any suggestions they had on how to make the mold more valuable as an evaluation tool for materials as well as an evaluation tool for molding fenders and other body panels.

The Ford personnel were impressed with the mold and the amount of amount of thought that had gone into its development. They made the following suggestions:

- Pressure transducers in the cavity would help understand cavity pressures.
- Make a gating change in the mold which would resemble the flow path of materials in a fender tool.
- Devise a method for measuring the temperature of the polymer melt in the cavity.
- Ford committed to spend 2-3 days evaluating the plaque tool with new gate design at Premix. They also said they would check on molding time at their facility in a 650 ton machine if we desired.

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A discussion was held about when the Taurus fender mold would be available for molding a CARILON Polymer system or systems which we found to be the best in the test plaque mold. Reference our Ford meeting June 14, 1989, and the MOD of that meeting. Mr. Burke stated that they would be molding to General Electric GTX in the fender tool late the week of August 14-16. The purpose of this molding would be (1) to evaluate the changes made to the mold based on mold flow evaluation and previous runs, and (2) to produce parts for testing by Ford's Body Assembly Division. Mr. Woodrich went on to state that Ford's management is now in a frenzy to get plastic fenders into production. They are one year behind schedule and must concentrate on GTX.

When asked if we could follow the GTX run the week of August 14 with CARILON Polymer, both Mr. Burke and Woodrich said there was no chance due to scheduling of press time at Delta Tool and the unknown problems that could occur and require tool revisions. Pushed for a time for evaluation, both indicated it would be late September before they could guarantee the tool and press time availability.

At this point, we redefined our program and the need for evaluation of CARILON Polymer in the fender by the end of the third quarter. We went on to state that this is an important piece of input for our management in order to help them make the determination whether or not to commit funds to build a polymer plant. Mr. Woodrich appreciated our position and asked us to understand that they too had made a commitment to their management and future platform programs were awaiting their results. He went on to state that Al Murray, Manager of Body Panel Development, fully supports the evaluation of CARILON Polymer in this application. As a result of this conversation, Mr. Burke and Mr. Woodrich held out some hope for a molding trial in very late August or early September.

P. S. Byrd

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