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INVESTIGATION OF NEW ENGINEERING THERMOPLASTICS

PDO 6984844, Final Report

C. L. Walter, Project Leader

Published August 1976

Prepared for the United States Energy Research and Development Administration Under Contract Number E(29-1)-613 USERDA

Bendix Kansas City Division

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Technical Communications
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Prepared by C. L. Walter, D/814, under PDO 6984844

Nine newly developed injection molding materials were characterized chemically and several of their physical properties were determined. These materials each have special characteristics which make them suitable for particular applications. Polyphenylene sulfide, methylpentene polymer, four proprietary thermoplastic polyester molding resins, plus both glass-filled polycarbonate and polyester injection moldable structural foam systems were evaluated.

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SUMMARY

Development effort was required to obtain knowledge for selecting thermoplastic materials for new high strength-to-weight applications. This need existed because manufacturers' published product data are often limited and in most cases fail to disclose the disadvantages of new molding resins. Nine recently developed commercially available injection molding resins were investigated for these applications.[1-4]

Glass-filled polyesters and polyphenylene sulfide materials have excellent solvent and chemical resistance along with low and predictable mold shrinkage factors. TPX, a methylpentene polymer, has a low density of 0.83 g/cm^3, but a high and variable mold shrinkage factor. Structural foams were easily processed on existing equipment and parts having a density of about 50 percent of the base material were obtained.

DISCUSSION

SCOPE AND PURPOSE

Development effort was required to obtain knowledge for selecting the thermoplastic materials for new high strength-to-weight applications. New and different molding resins periodically become available to the molding industry with the information regarding these materials being limited to the manufacturer's published literature and an occasional cursory investigation of their properties. In most cases the manufacturers fail to publish the disadvantages, or the polymer structure, of their new products.

For this endeavor four thermoplastic polyesters, a polyphenylene sulfide, a methylpentene polymer, two polycarbonate structural foams and one thermoplastic polyester structural foam were investigated. Physical and chemical properties in addition to the processability of each material were determined.

PRIOR WORK

Data were generated in PDO 6984565, High Temperature Thermoplastics, which was concluded in January 1971. Early development lots of the Celanese Chemical Company's thermoplastic polyester and the Phillips Petroleum Company's polyphenylene sulfide injection molding resin were studied. These data were compared to the production material used in this endeavor.

ACTIVITY

Evaluation of Thermoplastic Polyester Molding Resins

Four thermoplastic polyester molding resins, each from a different manufacturer, were evaluated. A chemical characterization study of the materials revealed many similarities among materials. The few differences were probably no greater than normal lot-to-lot variations. From the rheology study, it appears these polymers are quite stable and can be molded using extended cycle times. The materials investigated were Valox 420 from General Electric Company, Celanex 3300 from Celanese Chemical Corporation, Tenite 6H91 from Eastman Chemical Company and LNP WF-1006 from Liquid Nitrogen Processing Company.

A molding study amplified the findings of the chemical characterization study. The polymers were all molded and processed under the same sets of conditions. Fifteen experimental lines (different sets of conditions) were used to produce test specimens for a statistical analysis of the physical characteristics of each resin. Three molding variables--injection pressure, mold temperature and melt temperature--each had five levels of variance while the mold fill time had three levels. All other molding conditions were held constant.

The flow in thin sections was very good; however, shrink marks occurred in parts with abrupt thickness changes. The major drawback associated with the materials was the differential shrinkage for both thick-to-thin areas and for the parallel and perpendicular to flow directions. Warpage usually results from differential shrinkage.

It was found that the following conditions must be obtained to produce high quality parts: a tight-fitting mold with adequate venting, moderate melt temperature, fast mold filling and moderate-to-high injection pressure. Absolute numbers cannot be given because each part, mold design and property desired must be considered.

Evaluation of Polyphenylene Sulfide

Phillips Petroleum Company's R-4 polyphenylene sulfide (PPS) was evaluated. The chemical structure was verified, the polymer was characterized and several physical properties were determined. A chemical evaluation determined the glass transition temperature to be 118°C and that thermal decomposition begins at about 375°C.

Sixteen experimental lines (different sets of conditions) were used to produce test specimens for a statistical analysis of the physical characteristics of the molding resin. Three molding variables--injection pressure, mold temperature and melt temperature--each had five levels of variance while the mold fill time had three levels. All other molding conditions were held constant.

Polyphenylene sulfide can be molded successfully under a wide range of conditions. It has low shrink along with low differential shrink and warp characteristics, as well as a 260°C heat distortion temperature.

The results of this study indicate that PPS is a very strong, stable material having high temperature stability. It is solvent resistant and can be used in applications where aromatic and chlorinated solvents are present. A drawback that would possibly influence its selection would be the opaque dark brown color, which also precludes it from being readily pigmented.

Evaluation of TPX Molding Resin

A methylpentene polymer (TPX) was evaluated for possible low density applications because this material has a specific gravity of 0.83 g/cm^3. Rheological properties were evaluated and physical characteristics were determined. Thermal analyses data were used to determine that the softening point was 93.5°C and that decomposition begins at 290°C. The material was produced by ICI Limited in Herts, England, but the process has since been acquired by the Mitsui Corporation, Japan.

Nine experimental lines (different sets of conditions) were included in the molding study to statistically evaluate the processing variables. Two variables, melt temperature and mold temperature, each had five levels of variance. All other molding conditions were held constant.

TPX can be molded successfully under a wide range of conditions. The major features of the material include high transparency and low specific gravity (0.83 g/cm^3). Physical properties of the polymer are similar to those of high density polyethylene except that it will shatter upon impact. The heat distortion temperature of TPX is about 130°C, which is far greater than that of polyethylene and about 20°C higher than that of polypropylene. A major drawback is its high and differential mold shrinkage. Precision injection molded parts would be very difficult to produce.

Molding Characteristics of Thermoplastic Foams

Glass-filled polycarbonate and polyester injection moldable structural foam systems were evaluated. In addition to processability, certain chemical and physical properties of the base materials were determined.

The 6-percent glass-fiber filler content of foamable polycarbonate resins was the only property found to differ from medium molecular-weight molding resin. No significant difference was found between foamable and standard polyester molding resin.

Mold temperature, material density, injection speed and blowing agent percentage were evaluated. Other molding conditions were held constant using set points recommended by the manufacturer.

Analysis of the molding study data suggests that the average part density is directly proportional to the shot size and the mold shrinkage factor is inversely proportional to the mold temperature. In addition neither the blowing agent percentage nor the mold temperature have little effect upon the average part density.

When selected molded specimens were X-rayed to evaluate cell structure and density gradient, large voids were found in many of those having lower densities.

It was determined that the density of the base resin can be reduced by approximately 50 percent and that the foam systems investigated can be processed on existing production equipment.

ACCOMPLISHMENTS

The chemical, physical and processing characteristics of nine new commercially available engineering thermoplastics were evaluated[1-4]. The 30 percent glass-filled thermoplastic polyesters and 40 percent glass-filled polyphenylene sulfide were found to have excellent chemical and solvent resistance. Their mold shrinkage factors are low and very predictable.

The TPX resin was found to be very similar to high density polyethylene, except the resin has higher temperature resistance. Desirable properties of TPX are low density (0.83 g/cm^3) and optical clarity. Major drawbacks of the material are poor impact resistance and a high and variable mold shrinkage factor.

The structural foams made from both glass-filled polycarbonate and polyester resins were found to be easily processed on existing injection molding machines to produce satisfactory parts having a density of about 50 percent of that of the base material. However, molds with large gates and vents are needed for effective molding.

FUTURE WORK

No further work will be performed on this PDO. Additional activity has been initiated under PDO 6984954, Process Parameters for New Thermoplastics and PDO 6985030, Injection Molding Thermoplastic Foams.

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