PROCESSING AND TESTING OF REACTION INJECTION MOLDING URETHANES

Ashe/Dunleavy, *editors*

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Foreword

The symposium on the Processing and Testing of Reaction Injection Molding Urethanes was presented at Detroit, Michigan, 23 June 1981. The symposium was sponsored by ASTM Committee D-11 on Rubber. W. A. Ashe, BASF Wyandotte Corporation, and R. A. Dunleavy, Union Carbide Corporation, presided as symposium cochairmen and editors of the publication.

Related ASTM Publications

Rubber, Natural and Synthetic—General Test Methods, Carbon Black, Annual ASTM Book of Standards, Part 37 (1982), 01-037082-20

Rubber Products, Industrial—Specifications and Related Test Methods; Gaskets; Tires, Annual ASTM Book of Standards, Part 38 (1982), 01-038082-20

Tire Reinforcement and Tire Performance, STP 694 (1980), 04-694000-37

Rubber and Related Products: New Methods for Testing and Analyzing, STP 553 (1974), 04-553000-20

A Note of Appreciation to Reviewers

This publication is made possible by the authors and, also, the unheralded efforts of the reviewers. This body of technical experts whose dedication, sacrifice of time and effort, and collective wisdom in reviewing the papers must be acknowledged. The quality level of ASTM publications is a direct function of their respected opinions. On behalf of ASTM we acknowledge with appreciation their contribution.

ASTM Committee on Publications

Editorial Staff

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Introduction

The purpose of this symposium is to provide an overview of the new and exciting process called reaction injection molding (RIM). In addition, we intend to acquaint you with some of the more sophisticated problems related to the testing of polyurethane microcellular materials made by this process.

RIM is a mechanical-chemical process of converting liquid chemicals into microcellular molded parts. Ease of processing is the key to RIM's success. Two reactive liquid chemicals are metered into a mixing chamber and injected into a mold. The molding cycle time is 2 to 4 min. Parts weighing 8.2 to 11.4 kg (18 to 25 lb) are common. The metering injection machine can be small and simple to operate, or large, 273 kg/min (600 lb/min) with many complicated controls. Since the molds only contain the liquid and do not restrain, they need not be expensive like the molds required for rubber or injection molded plastics.

The definition according to ASTM Standard Rubber—Microcellular Urethane (D 3489-76) is more specific: a rubber material made by the interaction of a polyol and an organic isocyanate, having cell diameters in the range of 0.0001 to 0.001 mm (0.0000043 to 0.000043 in.), with a minimum density of 160 kg/m^2 (10 lb/ft^3).

Polyesters, epoxy, nylon, and other polymers are processed by RIM technology. For convenience, the term RIM often refers to the product manufactured by the reaction injection molding process. Urethane shoe soles are microcellular and are not manufactured by the reaction injection process.

RIM processing has several advantages, including: (1) low energy to process, (2) ease of processing, (3) short cycle times, (4) ability to produce large parts, (5) processing complex and complicated shapes, and (6) adequate properties for intended applications.

RIM polyurethanes are the fastest growing segment of the urethane industry. It's growth rate depends upon the auto manufacturer's acceptance of exterior body parts. Expansion is expected also in nonautomotive markets, 20 to 25 percent annually for the next 5 years. This market includes agricultural, recreational, hospital, electronic, mining, and lawn and garden equipment.

The papers in this volume are designed to bring together a representative cross section of the technical advancements occurring at this time. Advancement in the theories and principles of impingement mixing along with description of pumping and metering equipments are discussed in the first part of the symposium.

As in most new fields, the test development lags behind the product developments and only then do specific problems related to the unique properties of the product emerge that require new or entirely different tests with many temperature and humidity restrictions. Several papers address some of the unique testing problems associated with polyurethanes manufactured by the RIM process.

New developments include the introduction of reinforcing fibers such as milled glass, and the addition of fillers and pigments to impart special properties that expand the engineering property range and impart special finishes to the surface. With each new advancement brings new problems, increase in viscosity with the addition of fillers, wet-out problems, flow problems, and the necessary changes in chemical formulations required to drive home the cure and reduce cycle times. The future problems will be a challenge to the ingenuity of both the engineer and chemist as reaction injection molding expands into fields now held by other manufacturing processes.

The test methods and specifications for RIM urethane materials are under the jurisdiction of ASTM Committee D-11, Subcommittee 24.

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Reaction Injection Molding Urethanes—Detroit and Beyond

REFERENCE: Lewis, G. D., **"Reaction Injection Molding Urethanes—Detroit and Beyond,"** *Processing and Testing of Reaction Injection Molding Urethanes, ASTM STP 788*, W. A. Ashe and R. A. Dunleavy, Eds., American Society for Testing and Materials, 1982, pp. 3–11.

ABSTRACT: Reaction injection molding (RIM) of microcellular urethane elastomers has in a few years become an accepted technology for the production of elastomeric fascias and bumper covers for a variety of automobiles. This technology is now being extended to additional applications, both in automotive and nonautomotive uses. This wide variety of new applications is discussed along with the factors which have caused RIMs rapid growth.

KEY WORDS: reaction injection molding, polyurethane, applications, urethanes

Although commercial production of reaction injection molded (RIM) urethane fascia began only seven years ago with the 1975 Chevrolet Monza, the technology is now a standard production process for automotive bumper systems. Currently about 35 percent of American automobiles utilize RIM fascia or bumper covers, and projections are that by the end of the current decade this share will increase to over 80 percent. The use of RIM urethane elastomers has grown at remarkable speed, and this growth will continue, not only for fascia, but also in a variety of other applications, both automotive and nonautomotive.

The demands for lighter weight and more damage resistant automobiles, which resulted both from legislation and from changing consumer preference, were major factors behind this rapid growth. The use of flexible urethane moldings on the front and rear of the car allowed lightweight constructions which would still pass the required 8 km/h (5 mph) impact testing. Also significant was the design freedom inherent in the new process.

Although the large potential volume for bumper systems was the driving

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force behind the rapid development of RIM technology, it did not take long for imaginative designers to find additional applications which could benefit from the process. Beginning in the 1977 model year, RIM was used for a variety of parts: fender flares, spoilers, air dams, sight shields, and decorative trim components (Fig. 1). At the same time interest was developing in using the process for production of nonautomotive parts. The development of high modulus polymers which greatly extended the range of material options has been a significant factor in this broadening of RIMs potential markets. These developments were then followed by the development of processing equipment and materials to produce reinforced RIM urethane composites, extending the capabilities of the process even further.

The rapid growth of RIM urethane elastomer usage and the confidence in projections for its continued success have been based on both the properties of the material and the processing advantages of the technology.

RIM has three characteristics which make it especially attractive for high-volume production of large parts: the low pressures required, the low temperatures involved, and the use of reactive liquid intermediates.

While impingment pressures of 682 to 1136 kg/m^2 (1500 to 2500 psi) are high when compared with pressures in the mechanical mix heads used in low-pressure urethane casting, they are low in comparison with pressures involved in other high-volume plastic fabrication processes. For example, injection molding machines generate barrel pressures of 3636 to 18 182 kg/m^2 (8000 to

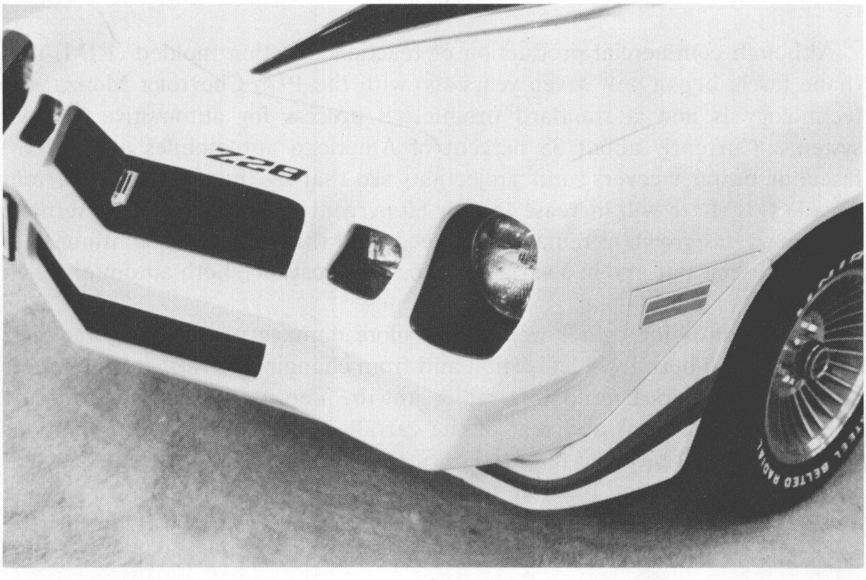

FIG. 1—*RIM urethane fascia and air dam on 1979 Chevrolet Camaro.*

40 000 psi), depending on the polymer being molded. These high pressures are necessary to force the highly viscous thermoplastic resin into the mold.

Pressure differences within the mold itself are even more dramatic. The low viscosity of the injected liquid and the relatively low-injection speeds make it possible to fill molds completely with pressures below 50 psi. For purposes of comparison, the rule of thumb for injection molding is to allow for pressures of 2273 kg/m^2 (5000 psi) in the mold, while polyester sheet molding compound requires pressures as high as 901.1 kg/m^2 (2000 psi). The data in Table 1 illustrate the effect that these pressures have on the clamping force requirements for parts of various sizes. The differences are particularly significant when comparing clamping force required for the larger parts.

Temperatures utilized in RIM processing are also low. The reactive liquid streams are maintained at temperatures ranging from 24 to 60°C (75 to 140°F), and the mold is kept at a temperature between 54.4 to 76.7°C (130 and 170°F). Since the urethane polymerization is highly exothermic, minimal heat input is required to maintain tooling temperature during production.

The use of liquid intermediates in RIM processing has benefits beyond the low-pressures and temperatures involved. A tremendous amount of design flexibility is possible with RIM. Since the mold is filled with low-viscosity liquid, very complex moldings can be produced. Ribs, mounting bosses, slots, and cut-out areas are all routinely incorporated into RIM parts (Fig. 2).

RIM parts are being molded with wall sections as thin as 0.254 cm (0.100 in.) and as thick as 3.8 cm (1.5 in.). Furthermore, moldings can incorporate variations in thickness within the same part. Incorporation of inserts either for mounting or reinforcement is also possible. Since the mold is filled before polymerization occurs, there are no molded-in stresses to cause part warping or stress cracking after demolding.

Although these processing advantages of RIM have been important factors in its rapid growth, the success of RIM also required the development of urethane elastomer systems which could be processed into parts meeting demanding physical property and performance specifications. Urethane elastomers have several characteristics which have made them suitable for a wide variety of applications.

Urethane chemistry can be used to produce a remarkably diverse range of

TABLE 1—*Clamping force, tons.*

Projected Area, $in.^2$	Injection Molding	SMC	RIM
400	1000	400	10
800	2000	800	20
1500	3750	1500	37.5
3000	7500	3000	75
6000	15000	6000	150

FIG. 2—*Ford Mustang fascias, a good demonstration of the complex shapes possible with RIM. Photo courtesy Ford Motor Company.*

materials. By varying the proportions and structure of the polyols, isocyanates, and chain extenders, polymers can be produced which range from soft, rubber-like materials to hard-rigid ones. Specific physical property objectives can be often achieved by careful selection of specific intermediates. Within relatively broad limits it is usually possible to design a chemical system which will produce a material meeting a set of specified physical property and processing constraints. In addition to varying the physical properties of the polymer system, the properties of the molding can be also varied by varying the density of the material or by incorporation of glass and mineral reinforcing fillers. These options have greatly extended the range of property options available to the user.

Unlike many plastics, urethanes are readily coated without the need for surface preparation other than mold release removal. Commercially available coatings which exhibit excellent adhesion and weatherability are readily available and have been used extensively on RIM parts.

RIM urethane elastomers are tough resilient materials with very good impact resistance over a broad temperature range. Automotive fascia must be able to withstand a 8 km/h (5 mph) impact over the entire temperature range of −29 to 71°C (−20 to 160°F). High modulus polymers also must often pass stringent impact testing.

One significant factor in the rapid growth of RIM urethane elastomers has been the ready availability of the chemical intermediates in large volume and at reasonable prices. While the consumption of these intermediates for RIM has grown dramatically in the recent past, RIM still represents a small portion of the market for urethane chemicals. Isocyanates and polyols used in RIM are produced in the same production units that also produce intermediates for other flexible and rigid urethane foams and elastomers. Consequently, there has been no delay in RIMs growth due to shortage of production capacity for intermediates.

The diversity of RIM applications is growing rapidly, and the development on nonautomotive applications is still at a relatively early stage. Consequently, it is difficult to fit these various applications into categories. There are, however, several attributes common to the majority of RIM parts: large size, complex configuration, high production rates, and impact resistance.

RIM is used most advantageously in producing large parts since it is here that the economic benefits of molding at low pressures become most significant. Other methods of fabricating large parts either require a much greater capital investment or have severe design limitations. Although there are a few RIM parts being produced which are as small as 0.45 kg (1 lb), the majority are much larger. Automotive fascia and bumper covers range from 2.3 to almost 9.1 kg (5 to almost 20 lb).

Nonautomotive parts are also large. The base of an evaporative cooler molded of high modulus RIM elastomer is a 7.7 kg (17 lb) part, measuring 101.6 cm^2 (40 in^2) (Fig. 3). Even larger are the panels used in an agricultural waste removal system (Fig. 4). These large moldings are 1.5 m (5 ft) long and over 0.61 m (2 ft) wide, and weigh over 9.1 kg (20 lb). With a projected area of over 488 m^2 (1600 in^2), these parts would require over 4000 tons (3636.4 t) of clamping force were they to be on an injection molding machine. Even larger parts are going to be significant in the coming years. Parts using over 23 kg (50 lb) of polyurethane are now in production, and parts with areas as large as 122 by 147 cm (48 by 58 in.) are scheduled for production this year.

In addition to being well suited for parts with large areas, RIM can be also advantageous for parts with thick-sections. Thermoplastic moldings are limited in wall thickness due to the greatly increased cycle times that thicker walls require. The thermosetting polyurethane, however, can be molded with a wall thickness of 2.54 cm (1 in.) or greater. One recently introduced part which takes advantage of this ability to mold thick-sections is a mounting block for hydraulic controls (Fig. 5). This molding, which at 0.91 kg (2 lb) is smaller than most RIM parts, is 2.54 cm (1 in.) thick and requires only 3 min in the mold.

Among all plastic technologies only injection molding allows as much design freedom as RIM. However, injection molding is usually not an economically viable alternative for the production of parts as large as most RIM moldings. Of processes that do lend themselves to large part production, thermoforming and spray up fiberglass reinforced plastics (FRP) are best suited for two dimensional parts of relatively uniform thickness. Ribbing, mounting bosses,

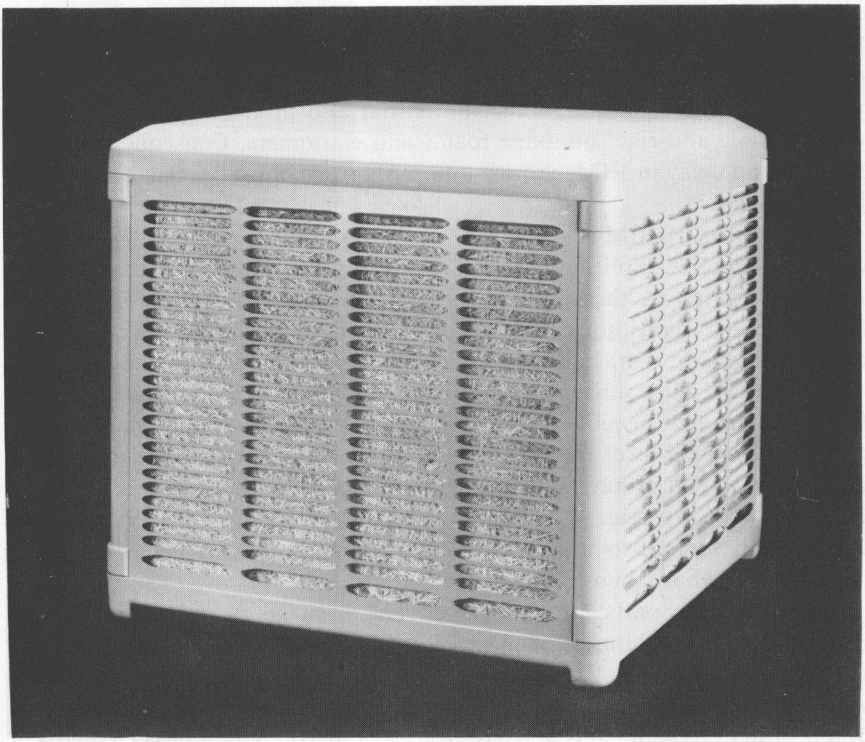

FIG. 3—*Evaporative cooler cabinet molded of high modulus elastomer. Photo courtesy Combined Technologies, Tempe, Ariz.*

slots, and cut-out areas all require secondary operations. Thermoplastic structural foam and sheet molding compound are more suited to production of complex shapes but still do not offer the design latitude of RIM.

The complex configurations that can be molded with the RIM process are well illustrated by several of the larger automotive-fascias currently being produced. Equally complex are the louvered-side panels for the evaporative cooler.

RIM is a process capable of large-volume output. Output from a single clamp operating on a 3 min total cycle will be over 40 000 parts per year for a single shift. Use of additional clamps, multicavity tooling, or additional shifts will result in even greater output. Most of the RIM parts currently being molded are produced in numbers that require this kind of high-volume production capacity. The majority of RIM parts are large, complex, and require a high-quality molded finish. Amortizing tooling for such parts over a small number of pieces is seldom economically justifiable.

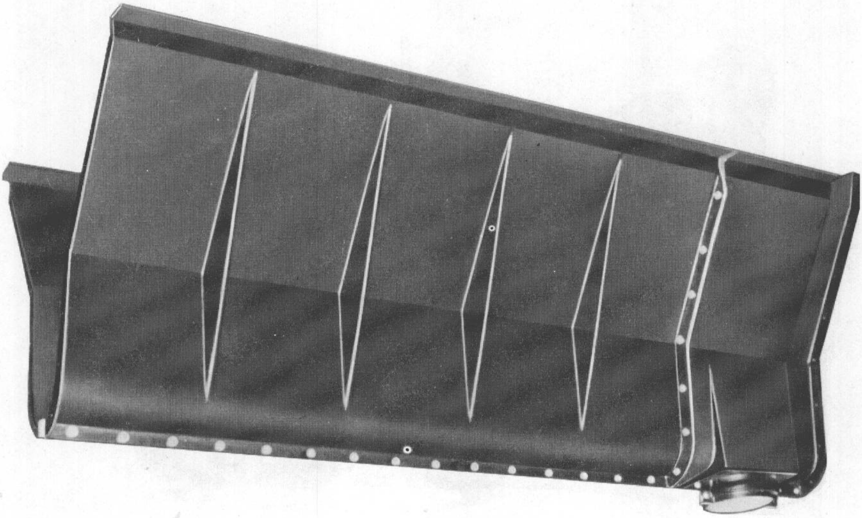

FIG. 4—*Panels for agricultural waste removal system. Photo courtesy Creataform, Ltd., Waterloo, Iowa.*

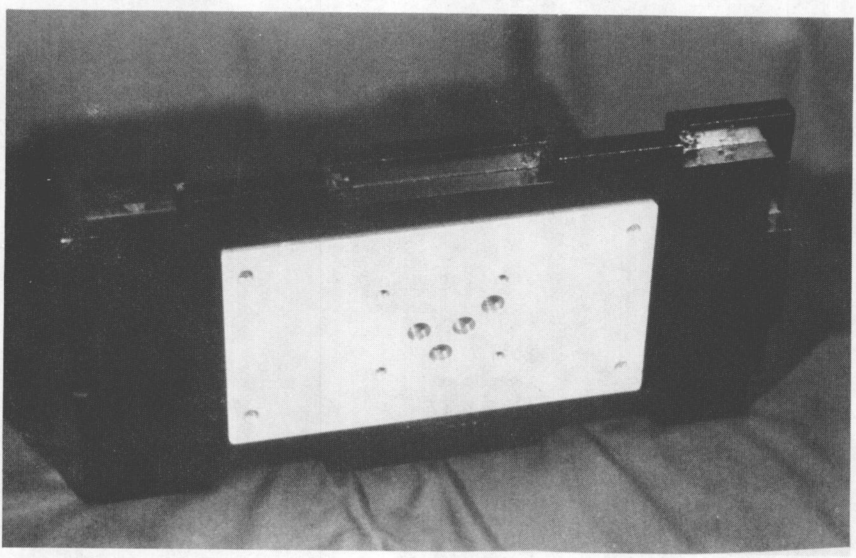

FIG. 5—*Mounting block for hydraulic valve. Photo courtesy Fallon Enterprises, Detroit, Mich.*