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BDX-613-1964 (Rev.)

POLYURETHANE FOAM, 0.05 g/cm³
DENSITY

By J. R. Fender

Published October 1978

Final Report

Prepared for the United States Department of Energy
Under Contract Number EY-76-C-04-0613.

**Kansas City
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Final Report
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BDX-613-1964 (Rev.), UNCLASSIFIED Final Report, Published
October 1978

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A process developed to meter and mix Rigifoam 6003-2 material on an automatic mixing machine gave a substantially improved yield over the batch-mixing process used in initial development work. It has been shown that this process meets the necessary requirements for a high production yield. Previous evaluation of the Bendix Rigifoam 6003-2 foam system is discussed, as well as continued dimensional studies, long-term aging of material, and machine metering and mixing.

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SUMMARY

This project was initiated to develop the capability to pour, machine, and gage polyurethane foam parts having a density of 0.05 g/cm^3 . All goals of the project were accomplished, using Bendix Rigifoam 6003-2 material.

Previous activity¹ focused on evaluation of the 6003-2 material. Specific areas of study included material formulation, chemical analysis, physical property determination, dimensional stability, and moisture content, as well as machining, gaging, and processing techniques.

Stabilization studies, continued from this past work, show relative stability of billets 330 mm in diameter by 330 mm high after about 225 days. Cutting the billet size to 273 mm in diameter by 159 mm high, and scooping out a center section to closely approximate the finished part volume, reduced this time to about 140 days. The scooped-out configuration became the production stabilization blank configuration.

Two potential methods of reducing the stabilization time were evaluated. The first was changing of the resin to isocyanate ratio of the foam. The results were random, and no trends were evident. The second method was use of oven postcure for expediting the stabilization time. It was decided from this work that heat-aging changes the initial shrinkage level but has little or no effect on the following dimensional change with time. Therefore, it was concluded that no stabilization advantage is gained through the heat-aging cycle studied.

Analysis of 6003 foam taken from an assembly which had been in storage for 13 years indicated no degradation of properties during this time. This information gives added confidence to stockpile lifetime integrity of the Rigifoam 6003-2 foam system.

The final activity concerned development of the process for metering and mixing the 6003-2 material, using an automatic foam machine. The first series of foam billets produced from this new machine gave a yield of 80 percent. Comparison of chemical and tensile test results shows no significant differences between batch-mixed and machine-mixed foam.

This development project has provided the material and labor to successfully develop the production capability to pour, machine, and gage 0.05 g/cm^3 polyurethane foam parts at an acceptable yield. It has also provided data to assist in design decisions concerning specification limits for ash content, chlorine content, and stabilization times.

Future development activity on low-density foam would be anticipated only if more restrictive requirements, such as the following, become part of the new product definition: special chemical, strength, or temperature limits; complex configurations; molded-to-size application; or a change in material callout.

DISCUSSION

SCOPE AND PURPOSE

The purpose of this project was to develop the production capability to pour, machine, and gage polyurethane foam parts having a density of 0.05 g/cm^3 .

PRIOR WORK

The major work previously performed on this development project, the evaluation of Bendix Rigifoam 6003-2 material system, was documented in a topical report with the following conclusions.¹

Determination of Rigifoam 6003 properties proved the material to be capable of meeting the needed chemical and physical properties. The physical testing resulted in the following information. (1) Density has a pronounced effect on physical properties, with 0.06 g/cm^3 strength being nearly double that of 0.04 g/cm^3 material. (2) Strengths obtained in the parallel-to-foam-rise direction are consistently higher than those obtained in the perpendicular-to-rise direction. (3) Tensile and compressive strengths show some loss as a result of increasing test temperature; but both values are adequate up to 54°C .

Dimensional stability measurements over a long period show a continuing shrinkage. This shrinkage was rapid at first, became less with time, and was small when compared with part dimensional tolerances.

Moisture causes the foam to grow, and the change is rapid and reversible. Moisture pickup is more rapid than is moisture loss.

Machining and gaging studies show that no special tools, fixtures, or procedures should be required for fabrication and inspection of foam parts having a density of 0.05 g/cm^3 .

ACTIVITY

Dimensional Stability

Previous studies have shown that polyurethane foam billets and molded-to-size parts continue to shrink over a period of time. The exact nature of this shrinkage is dependent upon many factors including material density, part configuration, and environment.

The first dimensional stability study required taking periodic measurements of the height and diameter of 330- by 330-mm billets, rough machined from the center of 0.05 g/cm³ 6003-2 cast billets which were 508 mm high by 457 mm in diameter. Two flats were cut on the diameter to allow repeatability of measurement. The billets were measured in the dry inspection area [less than 15-percent relative humidity (RH), corrected to 20°C] and stored in desiccated containers between measurements. Figure 1 shows the dimensional change for 300 days and indicates relative stability after 225 days.

A second study was started with billets 159 mm high by 273 mm in diameter, which included a scooped-out area in the center for the removal of as much material as possible to establish a stabilization blank from which both parts could be machined. Dimensional change and weight loss are plotted in Figure 2, which shows similar curves for these two factors and relative stability at about 140 days. Cutting of the billet to a shape closer to that of the finished part provided accelerated stabilization of the foam by reducing the time to attain relative stability from 225 to 140 days.

Two additional studies were started, to evaluate potential reduction of the stabilization time through material ratio changes and heat-aging. Foam billets were poured, using resin-to-isocyanate ratios ranging from stoichiometric to 20 percent excess isocyanate. Data from this study provided no discernible trend; thus, it was concluded that ratio changes within the range studied had little effect upon long-term stabilization of the foam.

To determine the effect of heat-aging, another series of stabilization blanks was divided into three groups. One group was conditioned for 24 hours at 94°C; one group for 24 hours at 120°C; and one group was maintained at room temperature as a control. The results of this study are plotted in Figure 3. The heat-aged samples do indicate more initial shrinkage; but after this initial difference all three curves show the same shrinkage-with-time movement. This similarity, along with the fact that the 94°C group shows more overall shrinkage than does the 120°C group, indicates that no stabilization advantage is gained through heat-aging.

Long-Term-Aging Characteristics

The effect of long-term storage of the 6003 system foam material was evaluated by analysis of material taken from a joint test assembly, which had been in stockpile for 13 years. This work was reported in October, 1978.² The conclusion from this study show that a comparison of data from testing thermal and mechanical characteristics of stockpiled material with data from currently

Figure 1. Dimensional Change With Time of Billets 330 mm in Diameter by 330 mm High

Figure 2. Changes With Time in Dimensions and Weight of Stabilization Billets

Figure 3. Effect of Postcure on Stabilization

manufactured foam of identical composition indicates that no degradation of properties has occurred in the JTA foam material. This information gives added confidence to stockpile lifetime integrity of the Rigifoam 6003-2 foam system.

Machine Metering and Mixing

The batch-mixing process used to produce the first parts yielded billets with a high incidence of voids caused by air entrapment during mixing and pouring operations. Attempts to reduce the mixing time to allow pouring at a more fluid consistency reduced the voids within the billet but gave rise to streaks or variable density blend-lines.

The best method to provide a well mixed fluid foam system is through metering and mixing the material on an automated foam machine. The machine used for this project was ordered specifically for producing the 6003-2 foam billets. The material ratio and shot size are determined by a single stroke of two pistons, which are driven by a common drive motor and are adjustable only by changing drive gears in the gear train.

It was anticipated that a number of variables would require study before a void-free and streak-free process could be developed. The first pours from the machine, however, were very good, and the first series of production billets had a yield exceeding 80 percent. Compared with the batch-mixed yield of less than 15 percent, the advantage of machine mixing the foam is evident.

Comparison of tensile and chemical test data from billets produced by batch- and machine-mixing processes shows no significant differences. Chemical results are given in Table 1 and tensile results in Table 2.

ACCOMPLISHMENTS

All goals of this project were successfully accomplished.

The 6003-2 material per Materials Standard 2170577 was characterized to assure that it would meet the design requirements of the 0.05 g/cm³ foam product.

Gaging and machining techniques were reviewed, and it was determined that no special processes would be required.

Table 1. Elemental Analysis of Rigifoam 6003-2

Major Constituents (Percent)	Lot					
	449	452	466 (Batch-Mixed)		466 (Machine-Mixed)	
			Billet		Billet	
			1220	1224	1234	1250
Carbon	59.58	59.97	59.48	59.28	59.52	59.49
Hydrogen	6.06	6.03	5.93	5.59	5.96	5.83
Nitrogen	9.62	10.21	9.56	9.72	9.75	9.63
Oxygen (By Difference)	24.74	23.79	25.03	25.41	24.77	25.05
Trace Elements	Parts Per Million					
Ash Content	73	82	71	74	124	85
Silicon	MC*	MC	MC	MC	MC	MC
Manganese	0.03	0.02	0.07	0.05	0.28	0.09
Magnesium	0.19	0.43	0.43	0.26	1.19	0.52
Tin	BD**	0.33	0.09	0.05	0.16	0.09
Chromium	0.06	0.04	0.12	0.13	0.60	0.18
Iron	1.20	0.41	1.22	1.42	6.90	2.58
Aluminum	0.61	0.30	0.20	0.12	0.63	0.39
Calcium	1.20	1.60	0.47	0.34	0.69	0.73
Copper	0.07	0.09	0.57	0.49	0.14	0.09
Zinc	0.17	0.15	0.19	0.08	1.00	0.31
Titanium	0.10	0.07	0.18	0.08	0.21	0.10
Lead	0.04	0.14	0.04	0.04	0.06	0.04
Nickel	0.07	0.05	0.13	0.11	0.46	0.11
*Major Component of Ash						
**Below Detection						

Table 2. Tensile Strength of Rigifoam 6003-2

Test Values	Tensile Strength (kPa)		
	Batch-Mixed Previously Reported	Lot 466	
		Batch-Mixed	Machine-Mixed
Minimum	418	435	414
Maximum	555	566	612
Average	480	502	488

NOTE: Tested Per Production Testing Procedure

A process was developed to meter and mix Rigifoam 6003-2 material on an automatic mixing machine. This process gives a substantially improved yield over the batch-mixing process used in initial development activity.

FUTURE WORK

Future development activity on low-density foam would be anticipated only if revised requirements, such as those following, become part of the new product definition: special chemical, physical, or temperature limits; complex configuration; molded-to-size application; or a change in material callout.

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²F. N. Larsen, *Characterization of Low Density Rigid Urethane Foam* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-1890 (Rev.), October, 1978 (Available From NTIS).

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PLASTICS: Polyurethane Foam

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