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Development of Automotive Exterior Parts by ASM Blow Molding

Akira Ohta*1
Hideki Andoh*1
Toshio Herai*2
Kosei Kushima*1
Satoshi Furuki*1

Abstract:

Area-selective multilayer (ASM) blow molding technology was developed as a new multilayer blow molding process in which the outermost layer of an automotive exterior part is composed of multiple reins. On the basis of this ASM blow molding technology, the concept of a multifunctional bumper having the fascia integral with the reinforcement or energy absorber was proposed, and was proved feasible by prototype molding. The multifunctional bumper first seemed very difficult to mold because its back side was designed to be hollowed to a great extent and to have projections as mounting brackets, but was found to be moldable by the new process. New polypropylene compounds with excellent blow moldability were developed for the fascia and reinforcement. The properties of the prototype bumper were evaluated by static bending test and other test methods.

1. Introduction

One of the objectives of founding the Polymer Processing Development Center (now incorporated in the Chemical Lab.) at Nippon Steel was the development of plastic molding technology to make large plastic structures as a steel substitute. To attain this objective, Nippon Steel developed a new area-selective multilayer (ASM) blow molding process for large structural parts and is pushing ahead with its commercial application. In this course of development, the authors noticed the possibility of realizing a totally new structure by applying the new technology to the automobile bumper system. To demonstrate this possibility, we built a model according to our own concept and evaluated the projected bumper system. The results obtained are presented in this paper.

2. Development of ASM Blow Molding Process

Blow molding is an old process employed to make hollow plastic containers like bottles. In the past 10 years or so, the process has drastically changed itself in response to the shifting of its application field away from containers[1]. One feature of the change is the diversification of molded shapes, and another is multilayer blow molding in which multiple resins are molded together into one piece. Conventional multilayer blow molding consists of forming a parison or concentric laminate of two or more resins, holding the parison with mold halves, and inflating it with air into a part of desired shape. The ASM blow molding process was developed as an improvement on the above blow molding process by the Polymer Processing Development Center aiming at higher value-added products[2]. It features molding the outer layer of a part from multiple resins. The process is outlined here.

Fig. 1 schematically shows the formation of a parison in

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*1 Technical Development Bureau

*2 Nippon Shokubai Co., Ltd.

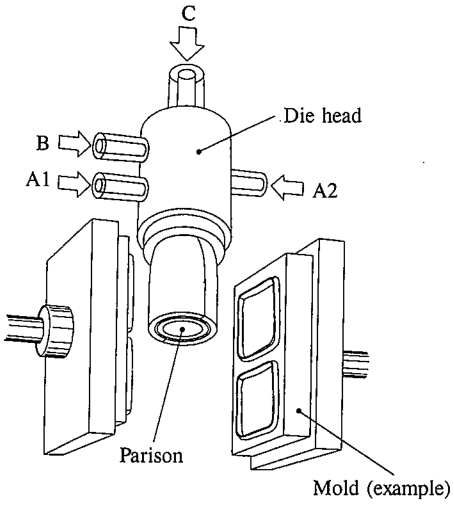

Fig. 1 Schematic diagram of parison for ASM blow molding

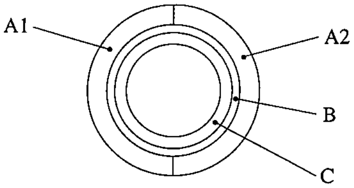

Fig. 2 Schematic diagram of cross section of four-resin, three-layer ASM parison

ASM blow molding. The parison is cross-sectionally composed as shown in **Fig. 2**, for example. By molding the parison with mold having cavities of desired shape, the front outer layer, rear outer layer, and inner layers of the hollow part can be produced from different resins. The front outer layer, rear outer layer, and inner layers of the hollow part can be provided with different functions and roles by selecting resins with properties required for the respective portions. For example, the portion A1 may be made of a resin to meet appearance and touch requirements, and the portion A2 may be made of another resin to meet mechanical strength requirements. The layer B is an adhesive resin and may be omitted. The layer C may be made of the same resin as the portion A2 or a recycled resin. In the bumper system described later, the front outer surface or portion A1 alone is made of a fascia resin.

3. Development of Multifunctional Bumper System

3.1 Conventional bumper system

Resins have replaced metals in automobile parts to reduce weight and cost as well as to provide a design freedom. Recently, however, this trend has run against a wall, and the revival of metals has become a topic[3]. About the future of plastic substitution, A. Kato[4] of Nissan Motor points out: "The optimum structural design of automobile parts is a critical point aside from plastic material development and molding technology." Then, what about the optinum design for the bumper system (including the fascia), one of the largest automotive parts open to plastic application?

The present bumper of passenger cars consists of a fascia, an energy absorbing unit, and a beam. The fascia is mainly injection molded from polypropylene (PP). The beam (or reinforcement) is made of steel, and studies are made for weight reduction by use of aluminum, stampable sheet, or a sheet molding compound (SMC). Some of these materials are already in actual use in bumper beams. Blow-molded beams are adopted on some passenger car models, and the possibility is pointed out of adding them the function of energy absorbing[5]. There has been no case of the fascia and beam being molded together into one piece, but there have been simple bumpers, essentially of one-piece construction, that are produced by blow molding[6].

The fascia is primarily governed by design, calls for very good surface quality, and demands fairly high skill of injection molding. Its necessary material properties are high fluidity, flexural modulus, and impact resistance. The beam must be regid and strong against collision. When it is made of a resin, it must be thick enough to withstand the collision impact. It is practically impossible to make a one-piece bumper by conventional injection molding technology. Lately, a one-piece bumper with many ribs arranged on the back side was commercially produced by gas-assisted injection molding[7]. This suggests one of the future courses of bumper system development.

Fig. 3 schematically shows the cross section of a commercially blow-molded beam (front)[5]. The flexural modulus of its material (high-density polyethylene: HDPE) is not high at about 12,000 kgf/cm^2 [5], but its section modulus is increased by making good use of a hollow structure that cannot be formed by injection molding or by compression molding an SMC or stampable sheet. High rigidity is achieved with relatively light weight in static bending as described later. There are several problems, however, when it comes to one-piece molding and functionality (including the fascia). The largest problem is the surface quality of the blow-molded bumper. Generally, blow molding uses relatively low-pressure air, which does not provide good surface transfer. Resins of low fluidity are used for smooth molding without such troubles as draw-down. This is also a factor responsible for hindering surface quality enhancement to the level offered by injection molding. When the beam function alone is the matter, the bumper is molded relatively straight. When the fascia is to be taken into account, the question is whether or not molding can meet the design requirement of the fascia. Further, some brackets are required to assemble the bumper, but this poses a pretty difficult problem in the one-piece design. When the beam is

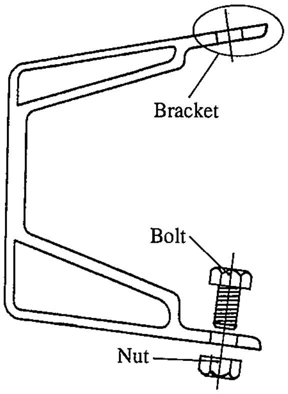

Fig. 3 Schematic diagram of cross section of commercial blow-molded bumper beam

molded separate from the other bumper parts, it can be provided with brackets in easy-to-mold positions as shown in **Fig. 3**, because it is not readily visible from outside. A one-piece bumper must be provided with brackets in invisible positions. Molding and designing techniques that can solve these problems are key to the future development of one-piece bumpers.

3.2 New concept of multifunctional bumper

There is the possibility of improving surface quality, the most serious problem of a one-piece bumper system, by applying the above-mentioned ASM blow molding process and using an appropriate resin for the fascia (at the sacrifice of blow moldability). A study was made of an integrated and multifunctional bumper made by molding together the fascia and the reinforcement or energy absorber into a single piece in a single operation while taking advantage of the hollow structure of the bumper as a hollow molded part. This is a totally new concept of bumper system.

Another new concept is introduced for assembly brackets. Blow molding molds the parison with the two mold halves. It is relatively easy to form projections like brackets by compressing some portions of the parison at the mold parting line in the mold clamping action (the brackets shown in **Fig. 3** were molded in this way). The brackets in the one-piece bumper under consideration by the authors must be completely formed on the back side and cannot be formed at the parting line. It is desirable to arrange the brackets as shown in the cross sections of **Figs. 4** and **5**. The brackets should be positioned near the midheight of the reinforcement and should not form the outermost surface of the car. It is also important that their end should fall within the dimension D. From a molding point of view, it is considerably difficult to make one side of a blow-molded part greatly concave and to form projections on the concave surface. This structure imposes various product design and molding technology constraints, but was taken up as a challenge for the authors to realize the new concept.

4. Molding of Prototype Multifunctional Bumper

4.1 Determination of shape

The shape of a multifunctional bumper model incorporating the two concepts described above was determined, a mold was made, and a prototype bumper was molded. The objectives of this prototype molding are as follows:

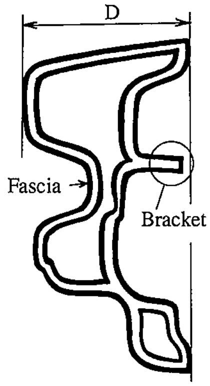

Fig. 4 Schematic diagram of cross section of prototype bumper (section III in Fig. 7)

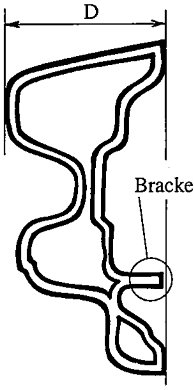

Fig. 5 Schematic diagram of cross section of prototype bumper (section II in Fig. 7)

(1) Establish ASM blow molding technology to create the overall shape of the bumper.
(2) Establish ASM blow molding technology for the brackets, in particular.
(3) Develop resins suitable for the main body (beam) and the fascia, respectively.
(4) Demonstrate the feasibility of the new concepts and accumlate data necessary in the next step of production bumper system development.

The shape of the prototype bumper is shown in **Figs. 6** to **8**. The bases and aims of the bumper design are described below.

(1) The design and dimensions of fascia are determined for small passenger cars (see **Fig. 6**).
(2) **Fig. 7** schematically shows the longitudinal section of the bumper. Four brackets are formed on the back side. The two end brackets are located as **Fig. 4** shows, and are used to secure the bumper to the car body. The two center brackets are located as **Fig. 5** shows, are provided in a row different from that of the end brackets, and are used to pre-vent the bumper from collapsing.
(3) The back side is longitudinally corrugated to support the

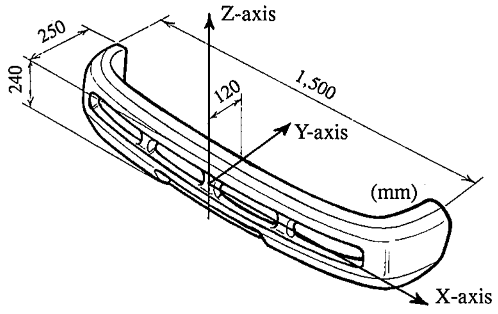

Fig. 6 Schematic diagram of prototype bumper

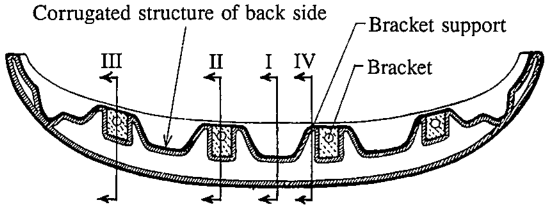

Fig. 7 Schematic diagram of longitudinal section of prototype bumper

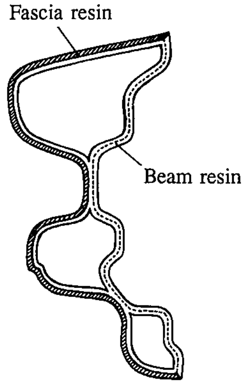

Fig. 8 Schematic diagram of cross section of prototype bumper (section I in Fig. 7)

brackets. The corrugated structure also helps to prevent the buckling of the X-Y plane of **Fig. 6**.

(4) **Fig. 8** schematically shows the center cross section (section I in **Fig. 7**) of the bumper. This design aims at providing as wide a space as possible behind the fascia while accomplish-ing the desired section modulus. The cross sections of **Figs. 4** and **5** are the sections III and II, respectively in **Fig. 7**.

(5) The prototype bumper is designed to secure some levels of strength and rigidity, but not to satisfy any particular standards. The design priority is given to the application of ASM blow molding and to the determination of whether or not the brackets can be molded together with the other parts of the bumper. The strength and rigidily of the prototype bumper are evaluated to provide data for the next-stage design.

(6) **Fig. 8** also shows the layer composition of the bumper. Two types of resins are used: fascia resin (A1 in **Fig. 2**) and beam resin (A2 and C in **Fig. 3**). The adhesive layer (B) is omitted.

4.2 Physical properties and moldability of resins

4.2.1 Molding ease

There are no established techniques yet for predicting the ease of blow molding. Blow molding introduces compressed air into a parison in the molten state and inflates it into the shape of the cavity machined on the mold. The portion of the parison in contact with the mold is presumed to be increased in deformation resistance on cooling and to be considerably high in the coefficient of friction. It therefore sticks fast to the mold surface without sliding against the latter[8]. As a result, the deformation of the parison gradually proceeds only in the area not in contact with the mold surface. If some portion steeply projects from the surrounding area, for example, it may be broken when its wall thickness falls below the fracture limit. The bumper in question contains plural such portions and therefore is considered rather difficult to mold. If the original shape cannot be changed, a thick-walled parison may be formed and molded into a thick bumper on the whole. This easy way out, however, runs counter to the purpose of reducing the bumper weight. Another possible solution is in material selection. Materials must be selected fully taking into account the strength and other properties required of the molded bumper. Discussed below are the results of a molding test conducted before prototype production.

4.2.2 Physical properties and moldability

Generally, high-molecular weight high-density polyethylene (HMW-HDPE) has good moldability, but is low in flexural modulus, and therefore must be high in wall thickness when used as material for structural members. Polypropylene (PP) compounds are high in flexural modulus but not as good in blow moldability as HMW-HDPE. Showa Denko Sholex 4551H and Nippon Steel Chemical S-Dash PX6525 were selected as typical HMW-HDPE and PP compounds, respectively, blended in various proportions, formed into parisons of different wall thicknesses, and molded into a single layer (not ASM). The minimum weight of the bumper that can be molded without breaking was adopted as criterion of moldability. Breaks occur near the bracket supports as normally expected from the bumper shape.

Fig. 9 shows the effects of the resin blend ratio on the minimum moldable product weight, yield point, and flexural modulus. The minimum moldable product weight or moldability largely depends on the blend ratio, and HMW-HDPE exhibits excellent moldability as expected. The moldability of the PP compound can be drastically improved by blending it with HMW-HDPE.

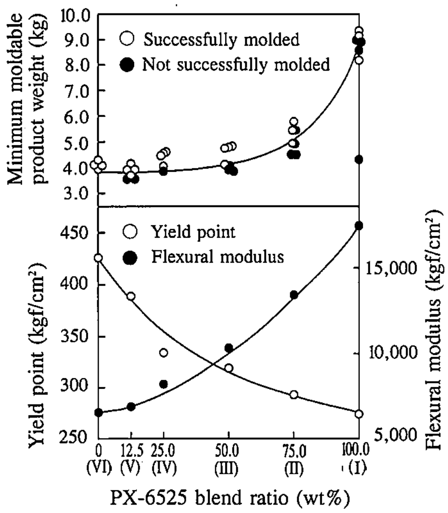

Fig. 9 Relationships of S-Dash PX6525/Sholex 4551H resin blend ratio to minimum moldable product weight, yield point, and flexural modulus

The suggests one direction of material development. With this resin system, moldability improves with rising yield point and declining flexural modulus, and, conversely, deteriorates with rising flexural modulus and declining yield point. The next step of the material selection process is search for resins with high flexural modulus and yield point (tensile strength) and excellent moldability within an appropriate cost range.

4.3. Wall thickness distribution

Blow-molded parts have a considerably wide range of wall thickness distribution because of the molding mechanism described above. This tendency is particularly remarkable in complex shapes with large surface irregularities. The one-piece bumper under consideration is a typical example. The molding conditions of single-layer parts molded from the above-mentioned resin blend are investigated for their effects on the wall thickness distribution.

4.3.1 Effects of die diameter

The die diameter is the diameter of the outlet through which the parison is extruded from the die head in **Fig. 1**. Generally, there is an optimum diameter to suit each molded part shape, size, and resin property, but must be empirically determined under the present circumstances. The wall thickness distributions measured at the section II of **Fig. 7** are shown in **Fig. 10** for the die diameters of 150 and 200 mm that are presumed to fit the shape of the bumper concerned. To avoid the effect of the product weight, the wall thickness values are all given as the normalized wall thickness that is the absolute wall thickness divided by the product weight. As expected, the wall thickness is small in the positions ⑪ to ⑬ near the bracket and in the convex apex positions ② and ④ on the fascia surface. The effect of the die diameter is not so large in the wall thickness range concerned, but relatively 150 mm is advantageous over 200 mm in the sense that the wall thickness distribution is a little smaller.

4.3.2 Effect of product weight

Fig. 11 shows the normalized wall thickness distribution on the cross section IV of **Fig. 7** for product weights of 3.0, 3.5, and 4.1 kg, respectively. The distribution does not appreciably vary with the product weight or average wall thickness as long as

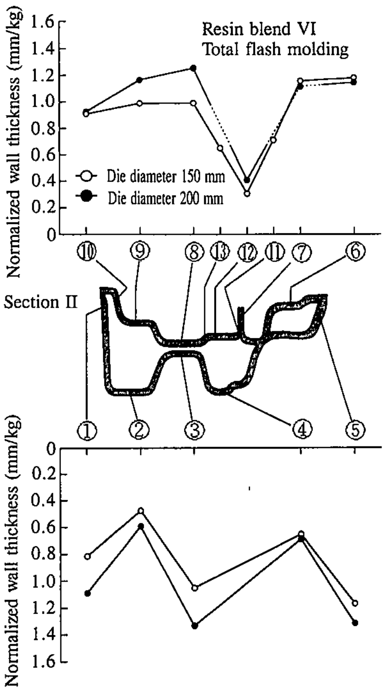

Fig. 10 Relationship between die diameter and wall thickness distribution

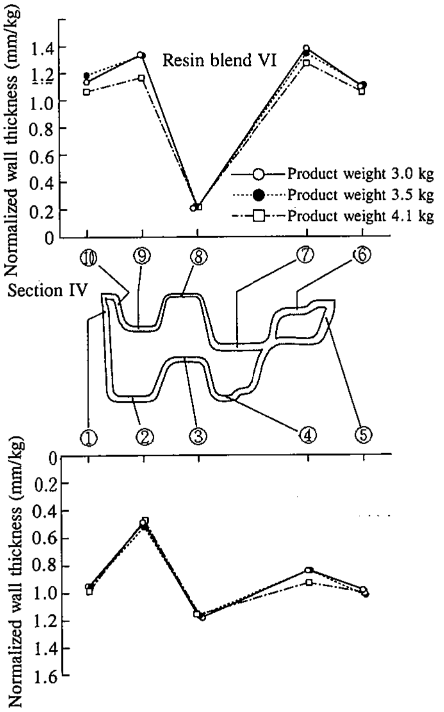

Fig. 11 Relationship between product weight and wall thickness distribution

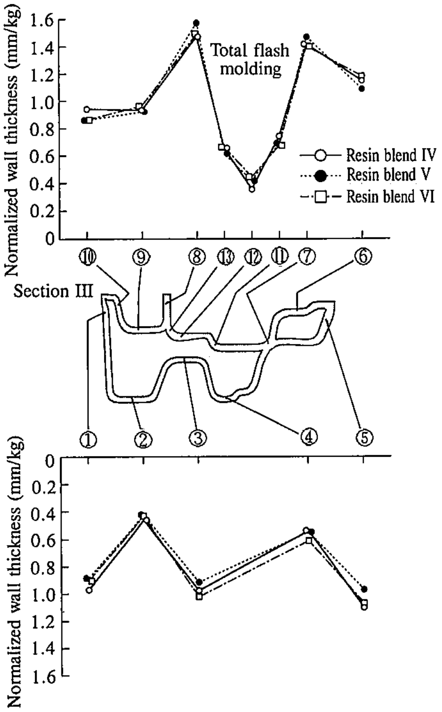

Fig. 12 Relationship between resin type and wall thickness distribution

the bumper is molded without rupturing at the thinnest portion. The absolute wall thickness of the thinnest portion decreases with decreasing product weight or average wall thickness. The molded part fails where its wall thickness reaches the minimum limit.

4.3.3 Effect of resin properties

Fig. 12 shows the wall thickness distribution on the section III in **Fig. 7** for bumpers molded from the resin blends IV to VI of **Fig. 9**. The difference of material to this extent has little or no effect on the normalized wall thickness distribution of the bumper.

4.4 Development of materials for multifunctional bumper

The realization of a multifunctional bumper requires the development of appropriate fascia and reinforcement resins (abbreviated F_0 and R_0, respectively). Both materials, of course, must have the properties required of the end product in addition to blow moldability. Recyclability must also be taken into account. There are two phases of recycling. One is the recycling of resins at the plant (returns), and the other is the recycling of used bumpers. The former concerns how to return to the resin supply system a large amount of flash produced with blow molding, particularly for the multifunctional bumper under development. This problem has a great impact on the economy of the bumper production system. In the present case, material design must be based on the condition that the flash from the bumper where the fascia and reinforcement resins are laminated should be recycled as the reinforcement resin. The latter consideration concerns the social routine of recovering and recycling used bumpers, which is not discussed in detail here. These two considerations are common in that the material design of the multifunctional bumper must be made to allow for bumper-to-bumper recycle.

The authors carried out material development according to the following concepts. The fascia and reinforcement resins should be both PP compounds. The other resins, fillers, and additives should be identical to the maximum possible extent for both the fascia and reinforcement resins. The properties of the resin blend are to be adjusted by changing the blend ratio. This facilitates the blending of fascia and reinforcement resins and eliminates the adhesive layer (B in **Fig. 2**) between the fascia and reinforcement resins.

The properties of the blend with flash and reject returns are studied next. Assume that the reprocessed resin obtained by crushing the flash and scrap where the fascia and reinforcement resins are present together is blended in the reinforcement at a certain ratio r (the reprocessed resin is not used for the fascia because the volume of the reinforcement is greater and because the fascia has surface quality and other more stringent requirements to meet). When the reprocessed resin is repeatedly blended in the reinforcement resin at the ratio r, the F_0/R_0 blend ratio is simply calculated to converge to a limiting value. The limiting blend ratio and resin blend are denoted by r_i and R_i, respectively. The ratio r_i becomes almost constant after about five blendings. This means that material design must be conducted so that the resin blend R_i can retain the properties required of the reinforcement, namely, blow moldability, flexural modulus and impact resistance.

The fascia may be made from a rigid resin for good surface quality or a flexible resin for high impact resistance. The flexible resin may be selected to compensate for the lack of impact resistance when a high-rigidity resin is used for the reinforcement. Various other studies must be conducted to cope with the future market trend, but for the present, a flexible resin was selected for the fascia of the prototype bumper, according to the above-mentioned recycle concept.

Table 1 Properties of fascia resin F_0 and reinforcement resin R_0

Resin	F_0 resin	R_0 resin
Grade	CPX-7002	CPX-7003
Melt flow rate (g/10 min): Temperature 230°C, load 2.16 kg	0.41	0.55
Izod impact value (kgf·cm/cm²): Specimen 1/8 in	65.2	36.5
Yield point (kgf/cm²): Tension rate 50 m/min	255	327
Flexural modulus (kgf/cm²)	17,311	19,160

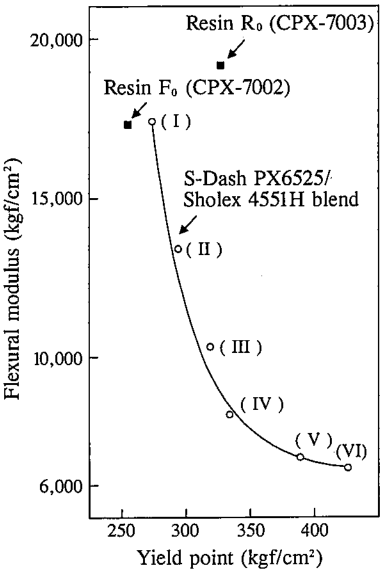

Fig. 13 Relationship between yield point and flexural modulus of new fascia resin F_0 and reinforcement resin R_0, and HDPE-PP blend of Fig. 9

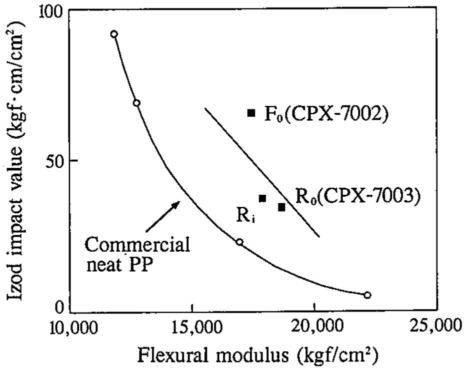

Fig. 14 Relationship between flexural modulus and Izod impact value of new fascia F_0, reinforcement resin R_0 and blend R_i, and commercial neat PP

Table 1 summarizes the properties of PP compounds developed according to the policy discussed above (CPX-7002 as the fascia resin and CPX-7003 as the reinforcement resin). The relationship between the yield point and flexural modulus of the new resins and the HDPE-PP blend is plotted in **Fig. 13**. The reinforcement resin CPX-7003 is significantly improved in flexural modulus as compared with the HDPE-PP blend of approximately the same yield point. **Fig. 14** shows the relationship between the flexural modulus and Izod impact value of the CPX-7002 and CPX-7003 as well as commercial neat PP resin. The CPX-7002 and CPX-7003 both exhibit high flexural modulus and impact strength. The CPX-7002 has particularly high Izod impact strength. In **Fig. 14**, R_i refers to a 1:1 blend of the CPX-7002 and CPX-7003. At this ratio R_i, the fascia accounts for one quarter of the bumper weight, the reprocessed resin accounts for three quarters of the weight of the reinforcement, and the resin blend is practically in a steady state. The resin blend is slightly lower in flexural modulus than the reinforcement resin CPX-7003, but has practically the same impact resistance as the reinforcement resin CPX-7003. The blow molding of prototype multifunctional bumpers from the resin blend is discussed in the next section.

5. Trial molding and Evaluation of Multifunctional Bumper

5.1 Trial molding with new resins

Prototype bumpers were ASM blow molded from the new fascia and reinforcement resins F_0 and R_0 described above. One of the prototype bumpers is shown in **Photo 1** to **3**. As can be seen from the cross section of **Photo 3**, the front side of the bumper is composed of both the fascia resin F_0 and the reinforcement resin R_0, and the back side is composed of the reinforcement resin R_0 alone. The standard wall thickness ratio of the fascia and reinforcement resins F_0 and R_0 in the front side was 1:1. This combination yields a minimum moldable product weight of 3.5 kg and is comparable in moldability to HMW-HDPE. The wall thickness of the concave portions of the fascia is about 1.8 mm.

5.2 Surface quality

Table 2 gives the center line average height of the fascia surface measured with a contact-type surface roughness tester according to JIS B 0601. The surface roughness measurements of a blow-molded bumper beam (B beam) and a one-piece gas-assisted injection-molded bumper (G bumper) are shown for the purpose of comparison. (It is the back surface of the G bumper that directly shows its surface roughness — the front surface is prepainted.) **Fig. 15** shows the surface profile curves of the molded parts. The B beam is installed inside the fascia, is invisible and does not present any special surface finish problem, but is taken here as a typical example of blow-molded part surface finish. The prototype bumper has better surface quality than the B beam, but still has room for improvement when compared with the G bumper that may be taken as today's surface finish standard of injection-molded parts. The prototype bumper development focused on molding the overall shape, the brackets in particular, but did not take any special measures to improve the surface quality. The fascia resin was selected for its impact resistance and recyclability. One of the future tasks is to improve the surface quality of ASM blow-molded bumpers to a level close to that of injection-molded bumpers through improvements in both material and molding technology.

5.3 Static bending test

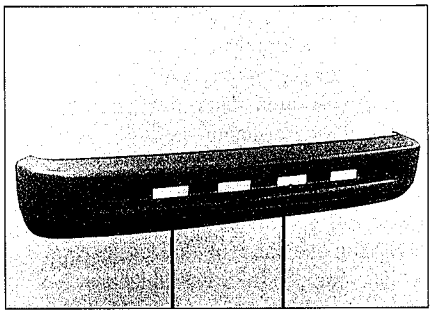

Photo 1 Front view of prototype bumper

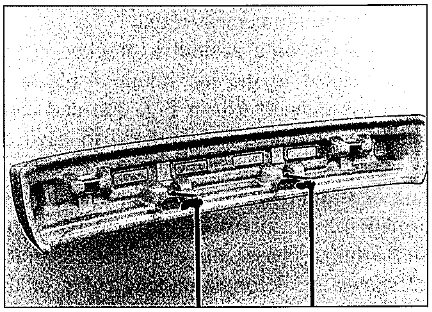

Photo 2 Rear view of prototype bumper

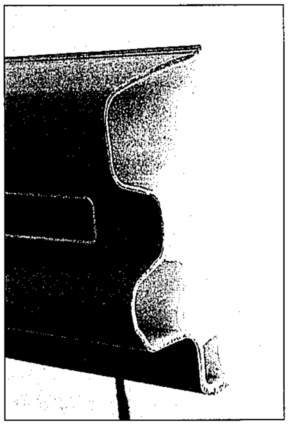

Photo 3 Cross-sectional view of prototype bumper (section I in Fig. 7)

Table 2 Surface roughness of prototype bumper, B beam, and G bumper

	Resin	Molding	Surface roughness(μm)	
			Measuring direction	Ra
Prototype bumper	CPX-7002	Blow	MD	0.52
			TD	0.72
B beam	HDPE	Blow	MD	1.28
			TD	0.80
G bumper	PP	Gas-assisted injection	Front surface*	0.16
			Back surface	0.28

* G bumper prepainted on front surface

The prototype bumpers were static bending tested to evaluate their overall rigidity and strength. As shown in **Fig. 16** and **Photo 4**, each prototype bumper was bolted and supported at the end brackets over the distance of 990 mm and loaded by a striker of the shape described in FMVSS Part 581 of the United States. The striker was positioned so that its center line should coincide with that of the bumper in the front view and should pass through the fixed brackets in the side view. The displacement rate of the striker was 20 mm/min, with a maximum displacement of 250 mm.

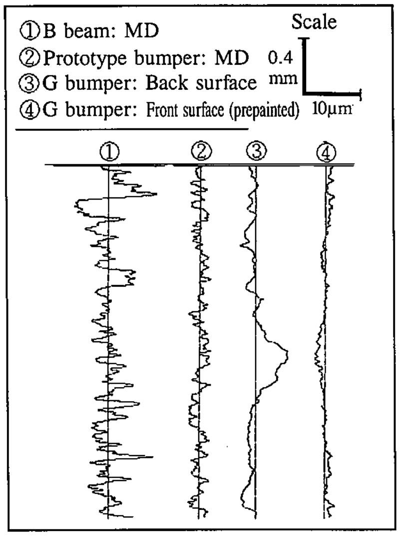

Fig. 15 Profile curves of molded part surface

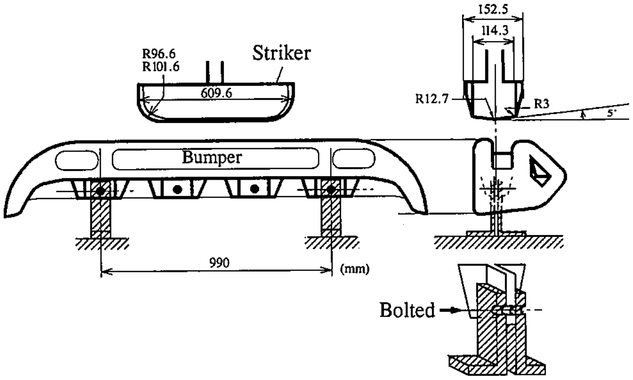

Fig. 16 Schematic diagram of static bending test

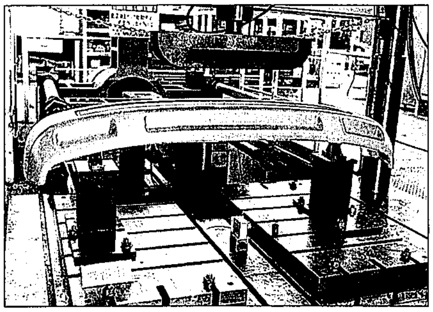

Photo 4 Bumper being static bending tested

Fig. 17 shows the displacement-load curves of four prototype bumpers of different product weights. The curves obviously change in the load level with the product weight, but are practically the same in profile. The load is saturated once when the striker displacement is 50 to 100 mm. This load is called the initial saturation load. The load then gradually increases with the

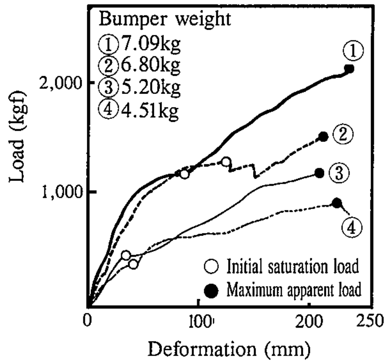

Fig. 17 Deformation-load curves of prototype bumpers

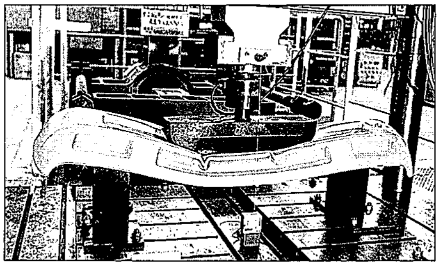

Photo 5 Deformation of bumper at striker displacement of 200 mm

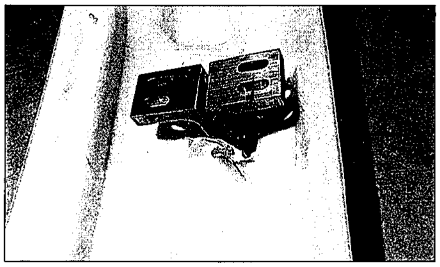

Photo 6 Deformation of bracket area at maximum striker displacement

displacement and is not saturated yet when the maximum displacement is reached. The load at the maximum displacement is called the maximum apparent load for convenience. **Photo 5** shows the deformation of a prototype bumper at the striker displacement of 200 mm. **Fig. 18** shows the effect of the product weight on the initial saturation load and the maximum apparent load. Both the initial saturation load and the maximum apparent load nearly linearly increase with increasing product weight or average wall thickness. This suggests a great contribution of the tensile component. It is confirmed that the prototype bumpers completely recover on unloading irrespective of the product weight, if their deformation is about 50 mm or less.

Fig. 19 shows the deformation-load curves of two prototype bumpers that have approximately the same product weight and are different in fascia layer composition and wall thickness. The prototype bumper with the larger fascia front wall thickness was molded by increasing the ratio of the fascia resin F_0 above the standard ratio. The bumper front wall thickness has an extremely large effect on the initial saturation load. This difference is estimated to be greater than experimentally observed taking into account the fact that the flexural modulus of the fascia resin is lower than that of the reinforcement resin.

Photo 6 shows the area around a bracket in a prototype bumper when deformed to the maximum displacement of the striker. This area is thinnest (⑧ in **Fig. 11**) and damaged, but not broken yet. The bracket is considered to have appreciable strength on the whole.

5.4 Discussion of static bending behavior

The deformation-load curves of the prototype bumpers are slow to rise in the initial phase, and their initial saturation load is low. **Fig. 20** shows the deformation-load curve of the B beam similarly measured for the purpose of comparison. The deformation-load curve of the B beam steeply rises in the early phase, reaching 1,400 kg with a smaller deformation than observed with the prototype bumpers, but after that slumps in the rate of load increase. The B beam weighs 2.34 kg net, but marks 6.14 kg when combined with an injection-molded fascia. The different static bending behavior of the B beam compared with the prototype bumpers may be attributed to differences in the cross-sectional structure and the deformation mode. As shown in the cross section of **Fig. 8**, three parallel mountain ranges longitudinally run on the plate that constitutes the back surface of the prototype bumper, and their tops form the front surface of the prototype bumper. In the initial stage of deformation, the back plate deforms little, but the front mountain ranges collapse and reach the initial saturation load. This is the reason why the bumper front wall thickness has a large effect on the initial saturation load. After this stage, the collapsed front and back plate start to deflect together, and the load gradually increases. As shown in its cross section in **Fig. 3**, the B beam generally deflects in the initial stage of loading without partially collapsing. For this reason, the deformation-load curve of the B beam rises at a steep slope and reaches the peak load with a small deformation.

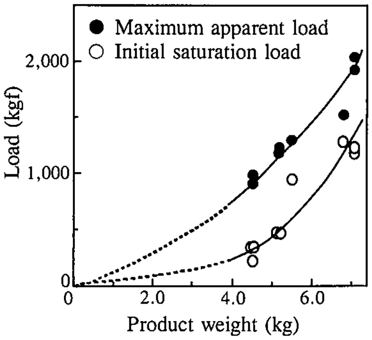

Fig. 18 Relationship of product weight to initial saturation load and maximum apparent load

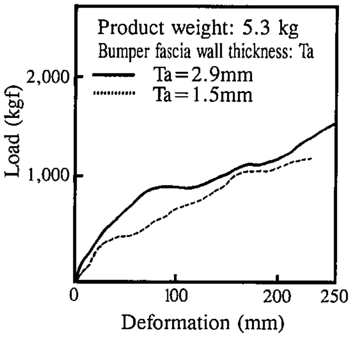

Fig. 19 Deformation-load curves of prototype bumpers

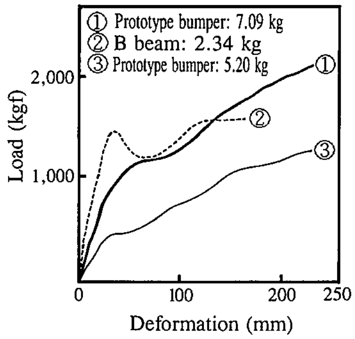

Fig. 20 Deformation-load curves of prototype bumpers and B beam

As discussed above, the cross-sectional shape of a bumper has an extremely large effect on its static bending behavior. When determining the final shape of the bumper, detailed studies must be made so that the desired strength and rigidity can be obtained. A bumper structure of high rigidity can be realized by properly designing the fascia. When such a bumper structure is difficult to mold, energy absorption may be taken as a principal design criterion. A new bracket molding technique has been proposed and proved feasible. It is a fact that these brackets constrain material selection and back surface shape. If the bumper is attachable to the car body without using such brackets, the design freedom of the back side shape will increase, and the reinforcement resin may be reinforced with glass fiber, irrespective of blow moldability, thereby enhancing the strength and rigidity of the bumper.

6. Conclusions

(1) Area-selective multilayer (ASM) blow molding was deveoped as an improved multilayer blow molding process to form the outer layer of molded parts from multiple resins.
(2) Based on the ASM blow molding technology, the concept of a multifunctional bumper having a fascia integral with a reinforcement or energy absorber was proposed and demonstrated to be feasible through trial manufacture.
(3) With its large hollow back side that have projections for mounting to the car body, the multifunctional bumper was proved to be moldable by the ASM blow molding process.
(4) New polypropylene compounds with excellent blow moldability were developed for the fascia and reinforcement of the multifunctional bumper.
(5) The properties of the prototype bumpers were evaluated by static bending test and other test methods.

The prototype bumper development has been carried out, not to meet any particular specifications but to demonstrate the feasibility of the proposed concepts. The multifunctional bumper has been evaluated only for limited items, and is not expected soon to be used on any passenger cars. There are many problems yet to be solved in the way to its commercial production. This bumper concept will be developed further by incorporating the study results reported here as well as suggestions to be received from those people concerned.

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