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STRUCTURAL FOAMS FROM THERMOPLASTICS 1/

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STRUCTURAL FOAMS FROM THERMOPLASTICS

NEW PROCESS FOR THE ECONOMIC PRODUCTION OF FURNITURE AND OTHER THICK-WALLED GOODS BY INJECTION MOULDING OF THERMOPLASTICS WITH FOAMING AGENTS

CONTENTS

I. INTRODUCTION

For the improvement of the living conditions of peoples and in connection with the construction of new and better housing, there is an increasing need of furniture and household establishment which have to be supplied adequately and at acceptable prices.

As raw material for such goods one always thought first of wood. All over the world this material is getting scarce. In places where it is easily accessible, too much of it has already been felled; and where there still is plenty of wood available, costs for its exploitation and transportation are increasing. So are the costs for its elaboration, everywhere. In addition, everybody should keep in mind that the existing stock of woods and forests should be conserved for the maintenance of stability of climate as well as stock of water, and finally for the production of natural oxygene as it is needed for human existence all over the world. Thus these stocks of forests or woods should rather be increased than reduced.

For an increasing production of goods of every-day use, synthetic plastics as they are coming out of constantly increasing industrial production, are appearing to be the most adequate type of material. For smaller goods they are already used all over the world, but their use for the production of bigger items has up to now been handicapped by too high production costs.

The chemical industry has now developed to supply plastic materials containing foaming agents, from which goods can be produced which are solid at the outside, but porous at the inside - what is called structural foam - and which therefore are of lower weight than they would be if they were completely solid.

In a corresponding way, the engineering industry has worked to solve this problem and has developed the necessary equipment by which goods can be produced from this new variety of material in such a way that makes it very interesting from the economic point of view.

In the following, the basic technical features of the process and the recent developments of the adequate equipment for the use of thermoplastic structural foam are being explained.

II. PROCESS TECHNOLOGY

In Europe, three process techniques are used currently and with preference:

1.) Normal plastics granules or powder are mixed with foaming agents in powder form (for example azodicarbonamide) and an adhesion promoter. This processing technique has the advantage that the amount of foaming agent can be suited to the particular material and moulding used; on the other hand it is a disadvantage that it requires great effort to achieve an uniform cell structure with dry-mixed batches. Other factors are the expenditure of time and labour when mixing.

2.) In a more recent processing technique, which avoids the necessity for the processor to produce dry blends, granules or powders with a foaming agent incorporated into the mass are used as the starting material. Such materials supplied ready-to-use by the raw material manufacturer, in addition to the foaming agent and colour pigments, contain substances which ensure that the cell structure is homogeneous (so-called cell correctors). The colour of such compositions (preferably in brown shades) is more uniform than for dry blends. At the present time, compositions of this kind based on polystyrene, ABS plastics, polyethylene and polypropylene are of importance.

3.) A processing technique which has been introduced in the United States and is now also finding acceptance in Europe, uses so-called foaming master batches for the processing of polyethylene, ABS plastics and polypropylene; about 4 to 10% of the master batches are mixed dry into normal granules.

Thermoplastic foam injection mouldings in cross-section show the character of a structural foam, namely a fairly uniform cellular core and a compact edge zone. The thickness of the edge zone and the density profile over the cross-section can be varied within certain limits by varying the processing conditions and, to a slight extent, by varying the amount of foaming agent. The density currently achieved in practice is between 0, 55 and 0, 8 g/cm3. The structural foam mouldings have the following characteristics:

1.) For a given weight, they are 3 to 5 times more rigid than comparable solid articles; thus moulding material can be saved for a given stiffness.

2.) They are largely free of orientations and interior stress and, therefore, do not distort. The shrinkage is uniform, so that the resistance against breakage is significantly increased.

3.) Thick-walled mouldings can be produced, with the density, measured over the cross-section, varying in the range of about 50 to 100% of the initial weight of the material.

4.) A considerable range of wall thicknesses can be produced; the range between 6, 5 and 15 mm is of particular industrial interest.

5.) Foamed mouldings do not show any sink marks, because the edge zone is pressed against the wall of the mould by the expanding cellular core.

6.) Their surface is roughly comparable with that of planed timber. Structural foam mouldings have a wood-like character, without, however, imitating wood.

7.) With this new material it is possible to produce new shapes which either could not be produced of wood or would be too expensive.

The main characteristic differences of this procedure as compared with normal injection moulding (without foaming agents) are:

1.) During the entire cycle time, a back pressure higher than the pressure of the evolved foaming gas must be applied in order to prevent premature expansion of the foaming agent which is dissolved in the melt.

2.) The mould cavity is only partly filled during the injection process - the remaining filling of the mould being effected by the expansion pressure of the foaming agent. Therefore, follow-up pressure is not necessary.

3.) The required closing pressure is significantly reduced.

4.) In order to achieve low densities, the highest possible injection speed must be used.

Since the melt which is under pressure in the injection cylinder expands immediately the pressure is released, the mould cavity must be filled before the foaming gas begins to expand; thus the injection mould has to be filled with extreme speed. The fastest possible injection speed produces the lowest possible density of the moulding. Furthermore, it was found that as the injection speed increases, the uniformity and fineness of the cell structure of the core are improved. The thickness of the solid edge zone can also be influenced by the injection speed; it decreases as the injection speed increases. The minimum possible weight of a moulding is achieved by using the available machine at maximum injection speed.

In the case of long flow paths the position in which the mould is gated plays an important role.

The lowest specific gravity of the moulding is achieved in the area of the sprue and the highest specific gravity at the end of the flow path. This can be explained by the melt increasingly cooling along the flow path, its capacity to foam thereby diminishing, and the foaming agent furthermore escaping at the flow front in the case of long flow paths, so that the material densifies at the end of the flow path.

In order to reduce the flow paths, the manifold hot runner gating was employed.

One of the important factors in processing thermoplastics containing foaming agents is a knowledge of the foaming pressures which arise, and hence of the required locking force.

The check of resulting pressures inside the mould when processing thermoplastics with and without foaming agents has proven that the difference factor lies in the range of about 1.5 to 6; the locking force is thus reduced by as much as a factor of 6. In the case of thick-walled mouldings and short flow paths, the locking force is even reduced by a factor of 10. The reason for only requiring a low locking force when foaming thermoplastics is that the mould cavity - in contrast to normal injection moulding - is only partly filled under the action of the injection pressure, depending on the degree of foaming of the melt. The remaining filling of the mould takes place under the foaming pressure of the foaming gas dissolved in the melt.

III. THERMOPLASTIC FOAM INJECTION MOULDING MACHINE.

Economical use of the thermoplastic foam injection moulding process demands, among other things, that the machine should be able to inject the plastic melt into the mould cavity at high injection speed. In order to manufacture large mouldings, the injection unit must have a high shot volume. The injection unit should be capable of injecting at different hights, by means of a vertical adjustment of the injection head. The closing unit must have large mould fixing platens, so that mouldings of large sizes can be manufactured to utilize the fact that the forces tending to open the mould are only slight. The large mould fixing platens should be fully suitable both for a single large mould and for the use of several smaller moulds by means of an appropriate adaptable runner system.

Finally, the machine must be capable to process all foamable thermoplastics available in granule or powder form. These requirements are fulfilled by the new special injection moulding machines of the TSG range KRAUSS-MAFFEI are supplying.

Characteristic features of the newly developed injection unit are the screw pre-plasticizer, the plastics accumulator and injector piston, the gas pressure unit and the hight adjustment of the injector head.

The melting process is controlled by the adjustable backpressure of the plasticised mass against the feed pressure of the screw, with a particular view to thorough mixing of spearately introduced foaming agents or of dry colour blends.

During the accumulation process, the injection piston of the gas pressure unit is forcibly displaced in the axial direction into the rear starting position by means of a newly developed hydraulic pressure difference control system. When metering is completed, the movement of the piston is stopped hydraulically.

In order to achieve an explosion like injection, the hydraulic valve is opened shortly after the nozzle closure is released, so that the compressed gas comes into full effect and shoots the pre-plasticised mass through the hydraulically controlled valve of the nozzle closure into the mould. The nozzle contact force and the injection speed can be infinitely varied for adjustment and setting purposes.

The vertical adjustment of the nozzle height is required by the processing technique. If, for example, the centre of gravity of the projected injection area lies along the central axis of the closing unit, the mould should not be gated centrally but somewhat above the centre in order to achieve uniform density of the moulding.

As the pressures tending to open the mould during injection and subsequent foaming are only slight, it is possible for the closing unit to be made in relatively light construction, though it is used for the manufacture of mouldings of large volume and large surface area.

Large mould mounting platens for receiving even very large moulds, whilst utilizing a novel runner system.

The high shot volume and the large mould fixing platens of the KRAUSS-MAFFEI Injection Moulding Machine are ideally suited to mounting and filling several mutually independent moulds simultaneously

Balancing of unsymmetrically acting mould opening forces is provided by means of two closing force cylinders acting in parallel as well as the novel mechanical locking.

Sequential separation of the hydraulic functions of movements and development of power. Very short closing and opening times can thereby be realised.

In designing the machine, particular importance was given to simplify its operation, and the following functions therefore received special attention; all control signals, such as for example the stroke restriction, the ejector movement, or the movements of the cores, are set in the control cabinet by means of simple push buttons. The accessibility of the mould fixing areas at the front and rear of the machine is ensured by guard doors on both sides pneumatically operated by means of push buttons.

The infinitely variable mould closing force is of particular importance when prototype moulds of extremely light construction are used. In order to protect moulds, the closing and opening movements can be controlled in either a fast or a slow setting, and either mechanical or hydraulic ejectors can be used.

If the required quantity of items to be produced rises at a later date, the single-station machine can be extended into a multi-station installation - if this is provided from the beginning. For this purpose, the closing units and injection units can last and easily be uncoupled, and a number of closing units combined with the injection unit.

The KRAUSS-MAFFEI extension system reduces the investment risk, because the installation can subsequently be adapted to the particular production requirements.

IV. MOULD TECHNOLOGY

In a complete production equipment, the mould is just as much an integral part as the machine itself. For this reason, we have summarized the essential effects of mould technology.

Moulds for thermoplastic foam moulding parts are not necessarily be made of steel as in the case of standard injection moulding. As a result of the low expanding pressures, it is also possible to use moulds of crockery or epoxide resin filled with metal powder for the pre-production series.

The selection of the mould material and mould construction technique essentially depends on the production quantity as well as on the required surface precision and surface configuration of the part to be produced. In contrast to standard injection moulding, the sealing edges can be less tight. The mould cavity is filled merely by the expanding pressure of the blowing agent.

In order to achieve maximum foaming action, the moulds must be provided with adequate vent channels. The air to be expelled and the excessive blowing gas must escape. In practice, vent channels of approximately 0.08 mm in diameter have proved to be successful. If the vents are too large, too much blowing gas escapes and the foam collapses.

For identical or similar mould designs, it is possible to use master moulds with a steel frame and replaceable inserts, e.g. made of aluminium or brass casting. This convertibility reduces mould costs considerably. Steel frames or steel supports are used for moulds of aluminium casting in order to protect them against damage.

The cast aluminium inserts allow low mould prices.

If the moulded article is to be produced in larger quantities at a later time, the aluminium inserts can be replaced by steel inserts. In the case of aluminium inserts, the cooling coils are an integral part of the casting.

Sprues and runners should have large cross-sections in order to allow rapid filling of the mould, whereby the flow resistance can be reduced.

Poor thermal conductivity of the plastic material and the cellular structure of the finished part of thermoplastic foam casting influences cooling time. Very intensive cooling of the mould should enable quick dissipation of heat. It is also possible to use conventional ejector designs. In order to avoid that the relatively thin skin of structural foam parts be damaged during the ejection process, it is recommended to use ejectors with the largest possible surface.

Since the characteristic surface of finished parts of thermoplastic foam casting is somewhat rough, careful polishing of the shaping mould surfaces is usually not necessary. In many cases, it will be sufficient to grind the milled surface.

The special characteristics of structural foam plastic materials allow to remove non-conic parts from the mould without having to use slides. Both removal from the core and from the cavity have been achieved without shaping the part with a slight bevel.

This is particularly interesting for furniture parts, such as shelf elements, which have to be put together without leaving any joints or inclinations.

The simultaneous operation of several independent moulds mounted together on the platens of the machine is done by the newly developed combined runner system which consists of a manifold runner, one or more injection nozzles and appropriate connecting pipes, and is built up on the unit structure principle.

The injection nozzles are hydraulically opened and closed; they can be controlled as desired, mutually independently. This results in the following technical advantages in the process; when injecting successively into several moulds, the maximum injection speed becomes fully effective for each mould. In this way the lowest achievable density is obtained. By using a number of injection units, the flow paths can be reduced, which also makes for a lower density.

V. CONCLUSIONS

The thermoplastic foaming technology allows the designer to design mouldings made from thermoplastics, which have a varying cross-section and which can be used as load-bearing structural elements to absorb major static and dynamic loads. A foamed cellular article can be about four times as stiff as its compact counterpart of the same weight.

This also provides the designer, for example in the furniture, vehicle or packaging industries, with a materials system which, through utilisation of its interesting properties, permits a generous forming.

Know-how has been developed by KRAUSS-MAFFEI and their customers for the injection moulding of foamed thermoplastic articles by the processing technique described, employing low priced mould constructions, which permits new product developments and new ideas to be put into practice.

Compared with conventional injection moulding of thermoplastics, the foam moulding process, within its limits of application, offers the advantage of much lower capital investment needed for machines and moulds. As also the weights and subsequently the costs of needed raw material are lower - always comparing mouldings of equal outside dimensions - this process allows to produce bigger items from plastic material at much lower costs than before.

Thus it opens the way for large scale economic production on a wide new field of application of thermoplastic materials.

Some examples of Structural Foam Moulded Items:

- Chairs
- Children's desks
- Cupboard parts
- Drawers
- Complete small cupboards
- Housings for radio and TV
- Transport containers
- Pallets
- Saddle-trees
- Roof cases for cars
- Water tanks
- Profiled bottom boards for technical appliances.

KRAUSS-MAFFEI AG. at Munich (Federal Republic of Germany), with her affiliated company ECKERT & ZIEGLER GMBH., are leading manufacturers of injection moulding machines and moulds, standard and special, for the processing of all kinds of thermoplastics, thermosets and elastomers. This equipment covers a range of injection weights from 30 grams to 16 kilograms, and locking forces from 25 to 3000 metric tons.

With the background of decades of experience with the large scale p roduction and constant improvement of such equipment and its delivery to all parts of the world, the new injection moulding procedure and equipment for the processing of structural foam is one result of many years of research and tests carried out in the plastics processing laboration of the KRAUSS-MAFFEI factory.

The staff, the knowledge and the facilities of this laboratory are placed at the disposal of partners interested in a cooperation for the solution of injection moulding problems and the supply of the most suitable equipment.

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SUMMARY

STRUCTURAL FOAMS FROM THERMOPLASTICS 1/

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I. INTRODUCTION

Increasing need of furniture and household establishment in connection with the construction of new and better housing. As wood is getting scarce and more expensive and existing stocks of forests and woods have to be protected, synthetic plastics appear to be the most adequate type of material. New developments of plastics with foaming agents and corresponding machinery allow its economic application for the large scale production of such items.

II. PROCESS TECHNOLOGY

Plastics material for structural foam are offered in different forms of which the addition of a foaming agent incorporated into the material which is fed into the machine is the most usual.

Thermoplastic foam injection moulding have a fairly uniform cellular core and a compact edge zone. Its density currently achieved in practice is between 0.55 and 0.8 g/cm^3. They are largely free of orientations and interior stress. Distortation and sink marks are excluded. The surface has a wood-like character

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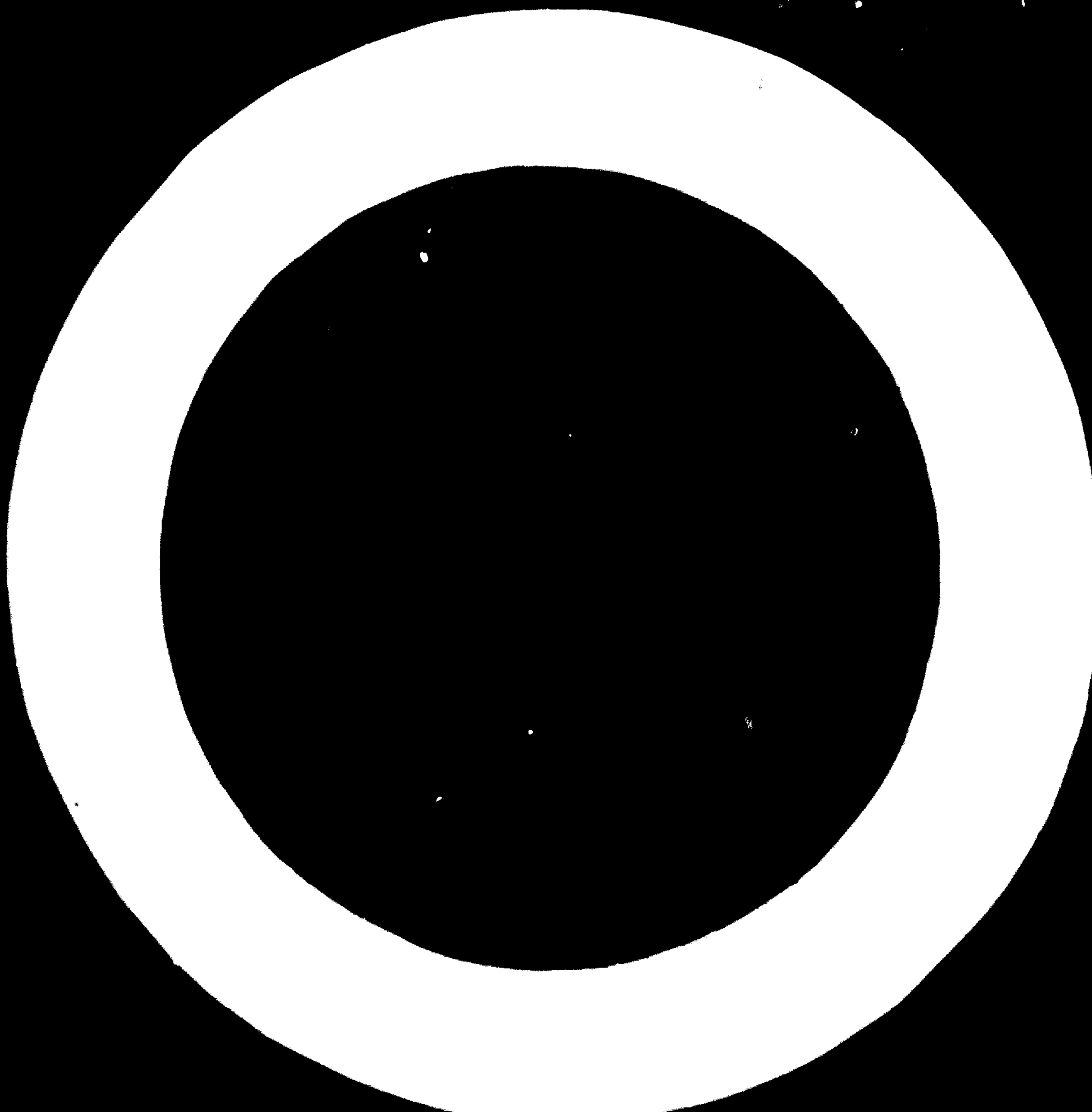

and wall thicknesses between 6.5 and 15 mm are mostly usual. Mouldings can be made in new shapes which wood would not allow or be too expensive. The main features of the injection moulding procedures of this material are a high backpressure in the cylinder and a high injection speed, against low pressure inside the mould and low locking force. A special gating system facilitates lowest possible density and fast cycling.

III. THERMOPLASTIC FOAM INJECTION MOULDING MACHINE

Special characteristics above those mentioned under II are a high shot volume and large mould fixing platens. A screw pre-plasticiser is used. A maximum injection speed is achieved by a pneumatic accumulator. The hight of the injection nozzle is adjustable in order to facilitate the achievement of uniform density of the moulding. The locking system is provided with 2 closing force cylinders in order to compensate unsymetrically acting mould open forces. Independent hydraulic functions allow very short cycling. Operation is simple.

It is possible to combine several mould locking units with one injection unit for maximum return of investment.

IV. MOULD TECHNOLOGY

For small production series and mainly for the production of prototypes and samples, moulds can be made of cheaper material than steel.

Details about general requests, such as vent channels, cross-sections of runners, cooling, surface and shaping are presented. A manifold runner system allows to place several moulds on the machine and inject the material at high speed into one mould after the other.

V. CONCLUSION

Structural foam mouldings offer high stability and the possibility of new styling. Compared with solid mouldings of equal dimensions, the production of structural foam mouldings requires much lower capital investment for machines and moulds, less material and therefore lower production costs. A wide new field of application of thermoplastic materials is opened.

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