

# PATENT SPECIFICATION

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## (54) THERMOSETTING RESIN INJECTION MOLDING MACHINE AND METHOD

(71) We, SUMITOMO BAKELITE COMPANY LIMITED, a corporation organised under the laws of Japan, of 2-2, Uchisaiwaicho-1-chome, Chiyoda-ku, Tokyo, Japan, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The present invention relates to injection molding machine incorporating therein an improved kneading screw and a method of injection molding a thermosetting resin utilizing the improved screw.

The property of the thermosetting resins, which must be distinguished from that of the thermoplastic resins, is that the thermosetting resins are first plasticized by the application of heat and then hardened by the further application of heat and that the once hardened thermosetting resins cannot be plasticized again. Therefore the molding of the thermosetting resins gives rise to various problems which are not encountered in the molding of thermoplastic resin. In a previously proposed thermosetting resin molding machine, a full flight screw with a low compression ratio is used in order to avoid curing of the molding compound while the compound is being conveyed within the heating cylinder or barrel. In this machine, therefore, the molding compound is not satisfactorily mixed and kneaded; the shot injected into the mold does not have a uniform temperature distribution so that it is difficult to mold articles with a uniform quality. When the temperature of the molding compound injected into the mold varies over a wide range, the curing time must be determined depending upon the lowest temperature. As a result, the injection molding cycle becomes longer and consequently the high productivity cannot be attained.

In order to overcome the above problems, it has been proposed to use a screw with a compression ratio higher than that of the screws used in the conventional injection molding machines, but within the heating cylinder greater shearing and compression forces are exerted on the molding compound so that it is adversely heated to high temperatures and consequently is not maintained in a thermally stable state. That is, mechanical shearing forces are imparted to the moulding compound by the screw flights so that curing occurs within the cylinder before the injection. Therefore such high compression ratio screws can be used only when a special molding compound is used under special molding conditions. In other words, such screws cannot be used with any kinds of thermosetting resins.

The present invention makes it possible to overcome the above and other problems encountered in the prior art thermosetting resin injection molding machines and methods.

The present invention provides an injection molding machine having an injection nozzle, a screw device enclosed coaxially within a heating cylinder, and a kneading barrier provided at the end of the screw device nearer to the injection nozzle, whereby shearing forces are mechanically imparted to resin passing over said kneading barrier, there being a clearance of 0.6 to 8.0 mm between the outer periphery of the barrier and the inner surface of the heating cylinder to provide an annular passage through which in use the resin passes.

The invention also provides a screw suitable for use in an injection molding machine in

which the screw is received coaxially in a heating cylinder the inner dimensions of which substantially correspond to the outer dimensions of the screw flights, the end of the screw which in use is nearer to the injection nozzle comprising a kneading barrier, the outer periphery of the barrier being radially offset from the outer periphery of the screw flights by 0.6 to 8.0 mm so as to provide, in use, a clearance of 0.6 to 8.0 mm between the outer periphery of the barrier and the inner surface of the cylinder, the clearance providing an annular passage through which in use the resin passes, and the ratio of the cross-sectional area taken at right angles to the flights of a spiral resin passage defined between adjacent screw flights to the cross-sectional area of a resin passage defined, in use, between the outer surface of the said barrier and the inner surface of the heating cylinder being 0.3 to 0.7

The invention further provides a method for injection molding thermosetting resins with the use of a screw in-line type injection molding machine wherein the screw is enclosed casually within a heating cylinder and a shearing and kneading barrier is provided at the end of the screw which is nearer to the injection nozzle, there being a clearance of 0.6 to 8.0 mm between the outer periphery of the barrier and the inner surface of the heating cylinder to provide an annular passage through which the resin passes.

In some embodiments of the molding machine of the invention, one end closer to the injection nozzle of a screw shaft, which may be of a known type, is enlarged in diameter to form a shearing and kneading barrier which comprises grooves, projections or a smooth surface, so that shearing forces are imparted to the molding compound. This makes possible uniform heating of the molding compound to a predetermined temperature and the satisfactory mixing and kneading of the molding compound before the injection step and positive prevention of backward flow of the molding compound during the injection step.

The injection molding method of the invention makes it possible considerably to reduce the curing time and to produce molded articles with uniform and stable quality.

A number of embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 is a schematic view of a prior art screw in-line type thermosetting resin injection molding machine; and

Figs. 2A, 2B to 6A, 6B are sections through preferred embodiments of an injection molding machine in accordance with the present invention, in which Figs. 2B, 3B, 4B, 5B and 6B are vertical cross-sectional views taken along the lines IIB - IIB, IIIB - IIIB, IVB - IVB, VB - VB and VIB - VIB of Figs. 2A, 3A, 4A, 5A and 6A respectively.

#### *Prior Art, Fig. 1*

Prior to the description of the preferred embodiments of the present invention, the prior art screw, in-line type injection molding machine of the thermosetting resins will be briefly described in order specifically to point out the drawbacks thereof, which the present invention may overcome as will be described in detail hereinafter. The injection molding machine shown in Fig. 1 has a full-flight type screw with a low compression ratio (in general between 0.9 and 1.3) consisting of a shaft 1 and a screw flight 2. The screw flight 2 is so designed and constructed that the generation of heat due to the shearing forces may be minimized in order to prevent the curing of the molding compound while the latter is forced through the cylinder toward the injection nozzle thereof and that the molding plastic may be suitably plasticized until it reaches the injection nozzle. However, such screw flight design has some drawbacks in that the molding plastic tends to flow backwards, in that sufficient mixing and kneading of the molding compound cannot be attained and in that when the molding compound is injected into the die, it tends to flow in the reverse or opposite direction along the screw flight. If the compression ratio is increased, as described above, in order to eliminate these drawbacks, the molding compound starts curing before it reaches the injection nozzle. As a result, the rotation of the screw is stopped and consequently the injection molding cannot be carried out.

#### *The Invention, Figs. 2A, 2B, 6A, 6B*

In Figs. 2A, 2B to 6A, 6B, there are shown a number of preferred embodiments of thermosetting injection molding machine in accordance with the present invention. The dimension and shape of the screw shaft, the design and arrangement of the screw flights and the compression ratio may be substantially similar to those of the conventional screws in the conventional injection molding machines.

Briefly stated, according to the present invention, the end portion of the screw on the side of injection nozzle is not provided with a flight, but is enlarged in diameter and is provided with a kneading barrier 4. An annular passage through which the molding compound can flow to the injection nozzle is defined between the inner wall surface of the cylinder 3 and the kneading barrier 4.

In the embodiment shown in Fig. 2A, 2B, the kneading barrier 4 comprises slanting elongate grooves 5 and 7 formed around the peripheral surface of the barrier 4 at an angle relative to the axis of the screw shaft 1. Therefore, the molding compound is forced to pass

through a groove 5, over the land 6, through a groove 7 and over the land 6 and so on.

In the embodiments shown in Figs. 3A, 3B and 6A, 6B a plurality of slanting grooves 8 are formed around the peripheral surface of the barrier 4 at an angle relative to the axis of the screw shaft 1. Therefore the molding compound is forced through these grooves 8.

5 In the embodiment shown in Fig. 4A, 4B, the molding compound is forced through the annular passage formed between the inner wall surface of the cylinder 3 and the peripheral surface 9 of the barrier 4. 5

10 In the embodiment shown in Figs. 5A, 5B, a plurality of pins 10 extend in zig-zag form from the peripheral surface of the centre portion of the barrier 4. The molding compound therefore is forced through the spaces between these pins. 10

15 In all of the embodiments described above, the molding compound transported by the screw 2 in the cylinder 3 is subjected to strong shearing forces when the molding compound is passing through the annular passage between the cylinder 3 and the barrier 4 so that the molding compound may be instantaneously heated immediately before it is injected into the molding dies. As a result, the molded article may be removed from the mold in a very short time because it is immediately cured in the mold. Therefore, the injection molding cycle may be considerably reduced. Furthermore since the resin is sufficiently mixed and kneaded before it is injected, a substantially constant degree of reaction is obtained upon curing the resin within the mold and there is substantially no variation in quality between the molded articles. 15

20 The above described barrier arrangements have previously been proposed for use in thermoplastic resin injection molding and extrusion machines, but they have not previously been proposed in the field of thermosetting resin injection molding. In the thermoplastic injection and extrusion machines, the spacing or clearance between the cylinder and the barrier is of the order of 0.1 to 0.5 mm, and if this clearance is increased in excess of this order, the satisfactory distribution, mixing and kneading of the thermoplastic compounds cannot be attained. If a thermoplastic injection molding machine with such a barrier is used for the injection molding of thermosetting resins, too much heat is generated by the shearing forces exerted on the resin so that the resin is prematurely cured and its flow is so reduced that it cannot pass through the barrier portion. 20

25 However, according to the present invention, the clearance  $t$  is selected to be of the order of from 0.6 to 8.0 mm which may be considered so much greater than the clearance of the prior art thermoplastic injection and extrusion machines that the desired effects of the barrier cannot be attained at all. It is this greater clearance that overcomes the problems of curing of the thermosets before injection. Thus, the barrier may be used in the thermosetting injection molding method and machine. Therefore, as compared with the prior art thermosetting injection molding machines and methods described with reference to Fig. 1, the injection temperature may be remarkably increased and may be uniformly distributed through the shot so that the setting time may be considerably reduced. Furthermore, the backward flow of the molding compound, which is encountered in the injection molding machine of the type shown in Fig. 1, when the compounds injected, may be positively prevented. Thus, the articles with stable and uniform quality may be molded. 25

30 Next, the barriers in accordance with the present invention will be described in more detail. The screw used in the present invention may be similar to the conventional screws having a flight pitch almost equal to the diameter of the screw flights. However, the length  $L$  of the barrier 4 is preferably 0.3 to 2 times the overall diameter of the screw device, and is more preferably approximately equal to the overall diameter of the screw device. The grooves of the barrier 4 may extend over part of the length of the barrier and may be alternately opened at one end thereof at the front and rear sides of the barrier 4 as shown in Fig. 2A. 30

35 Alternatively, the grooves may extend completely from the rear to the front end as shown in Fig. 3A. Furthermore, the axis of each groove may be parallel to the axis of the screw or may be inclined in the direction opposite to the direction of inclination of the screw flight as shown in Fig. 6A. The grooves may have any suitable cross sectional configurations (taken along, for instance, the line IIB - IIB of Fig. 2A) for example semi-circular, semi-elliptical, U-shaped, V-shaped sections including those in the form of a reverse-trapezium. The depth of the grooves is preferably between about 2 and 5 mm. The number of the grooves is not limited, but it is preferably between 8 and 12. The ratio  $V/S$  between the cross sectional area  $V$  taken at right angles to the flights of the space defined between the adjacent screw flights in the cylinder 3 (the two flights nearest to the barrier in Fig. 2A) and the cross sectional area  $S$  of the passage between the outer surface of the barrier and cylinder taken along the lines IIB IIB through VIB - VIB is preferably between 0.3 and 0.7 and more preferably between 0.4 and 0.6. In Figures 2B, 3B, 5B and 6B the area  $S$  includes not only the annulus of clearance  $t$ , but also the areas between the grooves or projections as the case may be; in other words, the area  $S$  is the whole of the unhatched area in Figures 2B to 6B between the hatched area designating the cylinder and the hatched area 4 designating the barrier. The number and 35

40 45 50 55 60 65

depth of the barrier grooves may be determined depending upon a selected V/S ratio.

According to the present invention, instead of grooves the barrier may comprise projections or pins having a height of for example about 2 to 5 mm may extending from the peripheral surface of the central portion of the barrier as shown in Fig. 5A. The number and height of the barrier projections may also be determined depending on a selected V/S ratio. The contour of the top of the projections may be round, elliptical, square, hexagonal or of any other shape. The dimensions and arrangement of the projections may be suitably selected by the skilled person.

The thermosetting injection molding machine incorporating the barrier in accordance with the present invention results in the great improvement of the thermosetting injection molding method. That is, the barrier may be considered as means for promoting the satisfactory mixing and kneading of the thermosetting compound, raising the temperature of the shot immediately before injection and preventing the backward flow during injection.

According to the present invention, the thermosetting compound is not cured before injection, but its temperature is advantageously raised at the barrier so that the curing time in the mold may be considerably reduced and consequently the molded articles may be removed from the mold in a very short time. Therefore the injection molding cycle may be considerably reduced so that a large number of articles may be molded within a very short time.

The following Examples illustrate the invention:-

#### Example 1

A thermosetting injection molding machine with the following ratings and dimensions was used:

Molding die clamping pressure: 80 tons  
Maximum injection quantity: 250 cm<sup>3</sup>  
Inner diameter of cylinder or barrel: 40 mm  
Compression ratio of screw portion: 1 : 1

For the sake of comparison, the prior art injection molding machine of the type shown in Fig. 1 was also used.

The barrier grooves were cut as shown in Fig. 2A, 2B, but their axes were parallel to the axis of the screw shaft. The barrier was as follows:

Clearance: 2 mm  
Cross section of groove: semi-circle of a diameter 6 mm  
Number of grooves: 10  
Length of barrier: approx. 40 mm  
V/S ratio: 1/2

The composition of the thermosetting injection molding compound used was as follows:

Phenol resin: 50% by weight  
Wooden powder: 40% by weight  
Hardener: 7% by weight  
Pigment Lubricant and Accelerator: 3% by weight

The molding conditions were as follows:

Temperature of cylinder: 90°C (front) to 50°C (at rear)  
Temperature of molding dies: 180°C  
Rotation of screw: 60 r.p.m.  
Mold cavities: 4  
Shot: 60 gr. (for 4 molds)  
Injection stroke: 50 mm

Under the above conditions, four plates 6 x 20 x 100 mm were molded. The comparison results are shown in Table below:

|                                                                                                      | Prior Art | Invention | Reduction |
|------------------------------------------------------------------------------------------------------|-----------|-----------|-----------|
| MBFT*                                                                                                | 30 sec.   | 24 sec.   | 20%       |
| Curing time at Barcol Hardness 40 (No. 935& measured just after removing the articles from the mold) | 50 sec.   | 30 sec.   | 40%       |
| Molding cycle                                                                                        | 60 sec.   | 40 sec.   | 33%       |
| Temperature of compound injected                                                                     | 115°C     | 125°C     | -         |

\*MBFT = minimum blister free time

**Example 2**

Following the procedure of Example 1, handles of frying pans were molded under the following conditions:

|   |                    |         |   |
|---|--------------------|---------|---|
| 5 | Maximum thickness: | 30 mm   | 5 |
|   | Shot:              | 150 gr. |   |
|   | Mold cavities:     | 2       |   |
|   | Injection Stroke:  | 130 mm  |   |

10 The molded handles were substantially rod-like articles whose maximum cross-section taken near one end was substantially square. "Maximum thickness" is the length of a side of this square, and the maximum time required to finish curing depends on the maximum thickness. 10

The comparison results are shown in Table below:

|    |                                  |                  |                  |                  |    |
|----|----------------------------------|------------------|------------------|------------------|----|
| 15 |                                  | <i>Prior Art</i> | <i>Invention</i> | <i>Reduction</i> | 15 |
|    | MBFT                             | 40 sec.          | 28 sec.          | 30%              |    |
|    | Molding cycle                    | 52 sec.          | 40 sec.          | 23%              |    |
| 20 | Temperature of compound injected | 113°C            | 124°C            | -                | 20 |

From the above Examples the remarkable effects and features of the present invention are apparent.

25 There will now be obvious to those skilled in the art many modifications and variations of the above described structure. These modifications and variations will not depart from the scope of the invention defined by the following claims. 25

**WHAT WE CLAIM IS:-**

1. An injection molding machine having an injection nozzle, a screw device enclosed coaxially within a heating cylinder, and a kneading barrier provided at the end of the screw device nearer to the injection nozzle, whereby shearing forces are mechanically imparted to resin passing over said kneading barrier, there being a clearance of 0.6 to 8.0 mm between the outer periphery of the barrier and the inner surface of the heating cylinder to provide an annular passage through which in use the resin passes. 30
2. A molding machine as claimed in claim 1, wherein the axial length of the barrier is approximately 0.3 to 2 times the overall diameter of the screw device. 35
3. A molding machine as claimed in claim 1 or claim 2, wherein the barrier comprises a plurality of projections which extend radially outwardly from the peripheral surface of a central portion of said barrier.
4. A molding machine as claimed in claim 1 or claim 2, wherein a plurality of grooves are formed in the peripheral surface of said barrier. 40
5. A molding machine as claimed in claim 4, wherein said grooves comprise a plurality of first grooves each of which extends from one side of the peripheral surface of said barrier and terminates before reaching the other side of the peripheral surface and a plurality of second grooves each of which extends from said the other side and terminates before reaching said one side, said first and second grooves being alternately arrayed. 45
6. A molding machine as claimed in claim 4, wherein the axes of said grooves are inclined at an angle to the longitudinal axis of said screw device.
7. A molding machine as claimed in claim 4, wherein the axes of said grooves are parallel to the longitudinal axis of said screw device.
- 50 8. A molding machine as claimed in any one of claims 4, 6 and 7 wherein the depth of said grooves is about 2 to 5 mm. 50
9. A molding machine as claimed in claim 5, wherein the axes of said grooves are inclined at an angle to the longitudinal axis of said screw device.
- 55 10. A molding machine as claimed in claim 5, wherein the axes of said grooves are parallel to the longitudinal axis of said screw device. 55
11. A molding machine as claimed in any one of claims 5, 9 and 10, wherein the depth of said grooves is about 2 to 5 mm.
- 60 12. A screw suitable for use in an injection molding machine in which the screw is received coaxially in a heating cylinder the inner dimensions of which substantially correspond to the outer dimensions of the screw flights, the end of the screw which in use is nearer to the injection nozzle comprising a kneading barrier, the outer periphery of the barrier being radially offset from the outer periphery of the screw flights by 0.6 to 8.0 mm so as to provide, in use, a clearance of 0.6 to 8.0 mm between the outer periphery of the barrier and the inner surface of the cylinder, the clearance providing an annular passage through which in use the resin passes, and the ratio of the cross-sectional area taken at right angles to, 65



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\*MBFT = minimum blister free time

**Example 2**

Following the procedure of Example 1, handles of frying pans were molded under the following conditions:

5 Maximum thickness: 30 mm 5  
Shot: 150 gr.  
Mold cavities: 2  
Injection Stroke: 130 mm

10 The molded handles were substantially rod-like articles whose maximum cross-section taken near one end was substantially square. "Maximum thickness" is the length of a side of this square, and the maximum time required to finish curing depends on the maximum thickness. 10

The comparison results are shown in Table below:

| 15                                  | Prior Art | Invention | Reduction | 15 |
|-------------------------------------|-----------|-----------|-----------|----|
| MBFT                                | 40 sec.   | 28 sec.   | 30%       |    |
| Molding cycle                       | 52 sec.   | 40 sec.   | 23%       |    |
| 20 Temperature of compound injected | 113°C     | 124°C     | -         | 20 |

From the above Examples the remarkable effects and features of the present invention are apparent.

25 There will now be obvious to those skilled in the art many modifications and variations of the above described structure. These modifications and variations will not depart from the scope of the invention defined by the following claims. 25

**WHAT WE CLAIM IS:-**

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2. A molding machine as claimed in claim 1, wherein the axial length of the barrier is approximately 0.3 to 2 times the overall diameter of the screw device. 35
3. A molding machine as claimed in claim 1 or claim 2, wherein the barrier comprises a plurality of projections which extend radially outwardly from the peripheral surface of a central portion of said barrier.
4. A molding machine as claimed in claim 1 or claim 2, wherein a plurality of grooves are formed in the peripheral surface of said barrier. 40
5. A molding machine as claimed in claim 4, wherein said grooves comprise a plurality of first grooves each of which extends from one side of the peripheral surface of said barrier and terminates before reaching the other side of the peripheral surface and a plurality of second grooves each of which extends from said the other side and terminates before reaching said one side, said first and second grooves being alternately arrayed. 45
6. A molding machine as claimed in claim 4, wherein the axes of said grooves are inclined at an angle to the longitudinal axis of said screw device.
7. A molding machine as claimed in claim 4, wherein the axes of said grooves are parallel to the longitudinal axis of said screw device.
8. A molding machine as claimed in any one of claims 4, 6 and 7 wherein the depth of said grooves is about 2 to 5 mm. 50
9. A molding machine as claimed in claim 5, wherein the axes of said grooves are inclined at an angle to the longitudinal axis of said screw device.
10. A molding machine as claimed in claim 5, wherein the axes of said grooves are parallel to the longitudinal axis of said screw device. 55
11. A molding machine as claimed in any one of claims 5, 9 and 10, wherein the depth of said grooves is about 2 to 5 mm.
12. A screw suitable for use in an injection molding machine in which the screw is received coaxially in a heating cylinder the inner dimensions of which substantially correspond to the outer dimensions of the screw flights, the end of the screw which in use is nearer to the injection nozzle comprising a kneading barrier, the outer periphery of the barrier being radially offset from the outer periphery of the screw flights by 0.6 to 8.0 mm so as to provide, in use, a clearance of 0.6 to 8.0 mm between the outer periphery of the barrier and the inner surface of the cylinder, the clearance providing an annular passage through which in use the resin passes, and the ratio of the cross-sectional area taken at right angles to 60 which in use the resin passes, and the ratio of the cross-sectional area taken at right angles to 65

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the flights of a spiral resin passage defined between adjacent screw flights to the cross-sectional area of a resin passage defined, in use, between the outer surface of the said barrier and the inner surface of the heating cylinder being 0.3 to 0.7.

13. A method for injection molding thermosetting resins with the use of a screw in-line type injection molding machine wherein the screw is enclosed casually within a heating cylinder and a shearing and kneading barrier is provided at the end of the screw which is nearer to the injection nozzle, there being a clearance of 0.6 to 8.0 mm between the outer periphery of the barrier and the inner surface of the heating cylinder to provide an annular passage through which the resin passes.

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