A screw (20) for a thixotropic injection molding machine. The screw (20) has a main flight (40) and a barrier flight (42). The main flight (40) has a reduced pitch near the point at which the feed stock is introduced into the barrel (22) and a greater pitch near the injection end of the screw (20) where the barrier flight (42) is superimposed on the screw (20) with the main flight (40). The barrier flight (42) separates a solids channel (44') from a melt channel (46), begins in a middle section of the main flight (40) and extends towards the injection end of the screw (20). The barrier flight (42) has pitch which is equivalent to that of the main flight (40) where the two flights are superimposed.
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THIXOTROPIC MOLDING MACHINE AND SCREW THEREFOR

BACKGROUND OF THE INVENTION

1. Field of the Invention.

The present invention relates to molding machines, and, more particularly, to thixotropic injection molding machines and screws therefor.

2. Description of the Related Art.

A variety of injection molding machines and screws for injecting plastic feed stock material are known in the prior art. Screws designed for injecting molten plastic material, however, are not necessarily directly adaptable for use in a thixotropic injection molding machine for injecting thixotropic metal feed stocks because of the different processes required in a thixotropic injection molding machine and the different characteristics of plastic and metal feed stock materials. For example, the radically higher viscosity of molten plastic materials relative to molten metal materials and the relatively lower heat transfer rate of plastic materials are characteristics which can have an impact on molding applications.

In addition to plastic injection molding machines, injection molding machines which inject a metal material in a thixotropic state are also known in the prior art. For example, a thixotropic injection molding machine may utilize a feed stock comprising solid chips of a magnesium alloy originating from a conventional ignot or by regrinding runners, sprues and other scrap material produced during molding operations. The feed stock is fed into a heated barrel under a protective Argon gas atmosphere and augured forward by the rotation of the screw within the barrel. The thermal and mechanical processing of the feed stock material places it in a thixotropic, semi-solid state. An example of a thixotropic injection molding machine is disclosed in U.S. Patent No. 5,040,589, the disclosure of which is expressly incorporated herein by reference.

When conventional alloys are heated and thereby partially melted, dendritic structures develop on the solid particles within the material. When the solid outwardly branching dendritic structures attached to the solid particles interlock, the viscosity of
the material is increased and the quick and complete filling of the mold-cavity is inhibited. Applying shear forces to the semi-solid alloy can remove the outwardly branching dendritic structures leaving solid particles with a degenerate globular shape and thereby creating a thixotropic slurry. The thixotropic metal material has a relatively lower and more stable viscosity in comparison to the same metal material in a semi-solid state with dendritic structures attached to the solid particles at the same temperature.

The relatively fluid thixotropic metal molding material is accumulated in a chamber near the forward end of the screw and, when a sufficient amount of material is present, the material is injected into the mold.

**SUMMARY OF THE INVENTION**

The present invention provides an improved screw for a thixotropic injection molding machine and a thixotropic injection molding machine having such a screw. The improved screw has two helical flights and a mixer section.

The invention comprises, in one form thereof, a thixotropic molding machine with a screw having a main flight and a barrier flight. The main flight has a reduced pitch near the point at which the metallic feed stock is introduced into the barrel and a greater pitch near the injection end of the screw where a barrier flight is superimposed on the screw with the main flight. The barrier flight separates a solids channel from a melt channel, begins in a middle section of the main flight and extends towards the injection or forward end of the screw. The barrier flight has a pitch which is equivalent to that of the main flight where the two flights are superimposed. The barrier flight, which separates the melt channel and solids channel, is slightly lower than the main flight and permits the transfer of melted material and relatively smaller, suspended solid particles of feed stock material from the solids channel to the melt channel. As the solids and melt channels extend toward the forward end of the screw, the axial widths of the two channels remain constant but the depth of the solids channel progressively decreases while the depth of the melt channel progressively increases in the region where both channels are present. The volume of the solids channel, however, decreases more rapidly than the volume of the melt channel increases. The changing depths of the two channels forces semi-solid material from the solids channel.
to the melt channel while the relatively smaller increase in volume of the melt channel accelerates the semi-solid material within the melt channel relative to the screw surfaces defining the melt channel. The melt channel and solids channel terminate prior to the forward end of the screw and are followed by a mixer section comprised of a plurality of grooves oriented at both left hand and right hand pitches.

An advantage of the present invention is that the reduced pitch of the main flight near the point at which the feed stock is introduced into the barrel increases the residence time of the feed stock and thereby facilitates the transfer of thermal energy to the feed stock and flood feeding of the thixotropic injection molding machine.

Another advantage of the present invention is that forcing a semi-solid metallic material from a solids channel over a barrier flight to a melt channel imparts shear forces to the solid particles suspended in the melt material and facilitates the creation and maintenance of a thixotropic state in the semi-solid material by removing dendritic structures from the suspended solid particles.

Another advantage of the present invention is that the use of a constant width solids channel which decreases in depth towards the forward end of the screw provides a larger area of contact between the remaining, relatively larger, solid particles and the heated barrel and thereby promotes the transfer of thermal energy to the remaining solid particles.

Another advantage of the present invention is that the use of a main flight having a reduced pitch near the point at which feed stock is introduced and a constant width solids channel in combination with a barrier flight allows for thermal energy to be transferred to the metal feed stock material with greater control. The ability to control the transfer of heat is particularly advantageous when using a metal feed stock material such as magnesium which has a sharp melting point and a high heat transfer rate.

Another advantage of the present invention is that the use of a melt channel having a volume which increases at a rate slower than the rate at which the solids channel decreases in volume accelerates semi-solid metal material within the melt channel relative to the surfaces of the rotating screw. The relative acceleration and
increased velocity of semi-solid material generates shear forces within the material and promotes the creation and maintenance of a thixotropic state in the feed stock material.

Yet another advantage is that the shear forces imparted to the feed stock by the mixer section helps to maintain the semi-solid metal feed stock material in a thixotropic state.

Yet another advantage is that the mixer section at the end of the screw helps to reduce the aggregate size of the solid particles within the thixotropic metal material and produces a narrower particle size distribution for the solid particles by removing dendritic structures from the solid particles within the material, thereby resulting in a molded piece having improved mechanical properties.

BRIEF DESCRIPTION OF THE DRAWINGS

The above mentioned and other features and objects of this invention, and the manner of attaining them, will become more apparent and the invention itself will be better understood by reference to the following description of an embodiment of the invention taken in conjunction with the accompanying drawings, wherein:

Figure 1 is a schematic view of a thixotropic injection molding machine having a feed screw in accordance with the present invention.

Figure 2 is a view of the screw.

Figure 3 is an enlarged view of a portion of Figure 2 showing the main flight.

Figure 4 is an enlarged view of a portion of Figure 2 showing the mixer section of the screw.

Figure 5 is an enlarged view of a portion of Figure 4 showing a groove of the mixer section.

Figure 6 is an end view of the screw taken along line 6-6 of Figure 2.

Figure 7 is an end view of the screw taken along line 7-7 of Figure 2.

Figure 8 is an enlarged view of a portion of Figure 2 showing the barrier flight.

Corresponding reference characters indicate corresponding parts throughout the several views. Although the drawings represent an embodiment of the present invention, the drawings are not necessarily to scale and certain features may be exaggerated in order to better illustrate and explain the present invention. The exemplification set out herein illustrates an embodiment of the invention, in one form,
and is not intended to be exhaustive or limit the invention to the precise form disclosed in the following detailed description.

DESCRIPTION OF THE PRESENT INVENTION

Referring now to the drawings, and to Figure 1 in particular, a reciprocating thixotropic injection molding machine is schematically illustrated. A screw 20 is located within barrel 22 which includes high temperature ceramic band heaters 24. It is also possible, however, to use high frequency induction heating to provide the desired thermal energy. Screw 20 is rotated within barrel 22 by a rotary drive 26. Screw 20 may also be axially translated within barrel 22 by a conventional high speed shot system 28 to inject molding material into a mold 30. Mold 30 is formed by mold halves releasably clamped between platens 32 which are, in turn, clamped together with tie rods 34.

In operation, feed stock, such as solid magnesium alloy chips, is placed in feeding assembly 36. The feed stock may be manufactured from a conventional ingot or by regrinding runners, sprues and other scrap materials resulting from previous molding activities. An inert atmosphere 38, such as Argon, surrounds the feed stock where it enters barrel 22.

The rotation of screw 20 moves the feed stock forward within barrel 22. As can be seen in Figures 1 and 2, a main flight 40 extends along screw 20 from a point slightly rearward of feeding assembly 36 towards a point near the forward end of screw 20 (as used herein, the "forward" end of screw 20 is the end located nearest mold 30). Although rotation of main flight 40 prevents the rearward migration of the feed stock material, collar 41 provides a seal within barrel 22 between the threaded portion of the screw and the rearward unthreaded portion of screw 20 and provides an additional partition for preventing the rearward migration of feed stock material. A barrier flight 42 begins near the forward end of screw 20 between the beginning and ending points of main flight 40 and separates solids channel 44 into a solids subchannel 44' and a melt subchannel 46.

Main flight 40 is illustrated in greater detail in Figure 3 and includes stellite 48. The screw 20 which may be comprised of Thryrotherm 2885, Bohler W321 or other suitable material has, in the illustrated embodiment, outer radial surfaces of varying
diameters, with the maximum diameter (including stellite 48) being approximately 2.75", a total length of approximately 100", and is stress relieved to straighten the screw prior to applying stellite 48. Stellite 48 may comprise a .03" thick stellite full cap which is applied to the main flight after preheating the screw 20. After applying stellite 48, the screw 20 and stellite 48 are cooled slowly after stress relieving the combination of the screw 20 and stellite 48. The push-side surface 50 of main flight 40 forms a 90° angle with the centerline of screw 20 while the follower-side surface 52 of main flight 40 is generally arcuate and has a radius approximately equivalent to the depth of solids channel 44. The width of the main flight 40 in the illustrated embodiment is .31".

As can be seen in Figure 2, first section 54 of screw 20 includes only main flight 40 while second section 56, which is located forward of first section 54, includes both main flight 40 and barrier flight 42. In the illustrated embodiment the first section is approximately 40" in length while the second section is approximately 21" in length. In first section 54, main flight 40 has a relatively small pitch of 2.00". Typically screws have a square pitch, i.e., the pitch is equivalent to the diameter of the screw. By reducing the pitch of the main flight 40 in the first section 54, where the feed stock is introduced into the barrel, the retention time of the feed stock within barrel 22 along first section 54 of screw 20 is increased. The increased residence time of the feed stock material permits the material to be heated with band heaters 24 in a manner which is more efficient and controllable than a screw having a larger or square pitch.

The use of a reduced pitch in first section 54 also enables the feed stock material to be flood fed into barrel 22 with fewer difficulties than a screw having a larger pitch.

As the main flight 40 advances the feed material within barrel 22, the material is heated by band heaters 24. The advancement of the material by main flight 40 also imparts shear forces to the feed material. Magnesium has a relatively sharp melting point and high heat transfer rate, thus the transformation of magnesium alloy feed material from a solid state to a semi-solid or liquid state occurs abruptly. Whereas plastic feed stocks melt over a relatively broad temperature range, a magnesium alloy feed stock will melt over a temperature range which is considerably smaller. Precision
in transferring thermal energy to magnesium feed stock materials is required due to the combination of the sharper melting point and higher heat transfer rate of such magnesium feed stock materials relative to plastic materials. Although magnesium alloys are most commonly used as the feed stock material for injection molding machines, other metal feed stocks may also be utilized. To efficiently heat the metal feed stock material, the melt should be separated from the remaining solid material as the phase change occurs.

To separate the liquid material and smaller suspended solid particles from the remaining feed stock material, a barrier flight 42 is introduced and partitions a melt subchannel 46 from a solids subchannel 44' in the second section 56 of screw 20 as shown in detail in Figure 8. The solids subchannel 44' forms a continuation of solids channel 44 located in first section 54 of screw 20. In the initial portion 58 of the second section 56 of the illustrated embodiment, the pitch of the main flight 40 changes from 2.00" to 3.00" while the pitch of barrier flight 42 remains constant at 3.00" throughout its length. Barrier flight 42 has a width of .15" which is approximately ½ the width of main flight 40. Thus, by introducing barrier flight 42 with a width of .15" and melt channel 46 with a width of .85" as main flight 40 changes from a pitch of 2.00" to 3.00", the axial width of solids channel 44 and solids subchannel 44' remains constant at 2.00".

As schematically shown above screw 20 in Figure 2, the depth of solids channel 44 and solids subchannel 44' is the distance between line 40a, representing the outermost radial surface (or top) of main flight 40, and line 44a which represents the position of the screw surface defining the bottom of solids channel 44 and subchannel 44' in relation to the top of main flight 40 along the length of screw 20. Similarly, the depth of melt subchannel 46, relative to the top of the main flight 40, is represented by lines 40a and 46a above melt subchannel 46. Additionally, the relative heights, i.e., the distance the radially outermost surface of the two radially projecting flights are from the axis of the screw shaft, of barrier flight 42 and main flight 40 are illustrated by lines 42a and 40a above barrier flight 42.

In the illustrated embodiment, the depth of solids channel 44 remains constant at an approximate depth of .30" throughout first section 54 of screw 20. A solids
channel 44 which increases slightly in depth within first section 54, however, is also envisioned. Unlike plastic feed stock which typically provides some self-lubrication as the plastic material melts and is deformable, the metal feed stock materials typically utilized in thixotropic injection molding machines are relatively incompressible and non-deformable. Thus, the solid metal feed stock material is not as easily compressed into the channel defined by the screw and barrel as a solid plastic feed stock material. As the metal feed stock material is advanced within the screw the solid metal material may become packed together in an interlocked mass. This mass is subjected to thermal expansion as it is heated. The frictional engagement of the barrel and screw with the interlocked metal feed stock material can cause jamming of the screw. It is anticipated that slightly increasing the depth of solids channel 44 as it approaches the point where barrier flight 42 begins, rather than using a constant depth solids channel 44 in first section 54 of screw 20, will decrease the possibility of the metal feed stock material jamming the screw.

In the second section 56 of screw 20 the depth of the solids subchannel 44' gradually decreases to a minimum depth of .03" near the point where barrier flight 42 terminates. Although the depth of solids subchannel 44' varies, the width of solids channel 44 and subchannel 44' remain constant at approximately 2" throughout the entire length of the main flight 40 as discussed above. Thus, as the depth of solids subchannel 44' gradually decreases in second section 56 of screw 20 the crosssectional area and volume of solids subchannel 44' also decreases.

Simultaneously with the decrease in the depth of solids subchannel 44', the depth of melt subchannel 46 gradually increases from an initial depth of .03" to a maximum depth of .30" at the point where solids subchannel 44' is at its most shallow point. Since melt subchannel 46 maintains a constant axial width, the crosssectional area and volume of helical melt subchannel 46 increases as the depth of melt subchannel 46 increases in cooperation with the decrease in volume of helical solids subchannel 44'. The width of the melt subchannel 46, however, is only 0.85" compared to a width of 2.00" for solids subchannel 44'. Thus, the melt subchannel 46 does not have a volume increase which is as great as the volume decrease of the solids subchannel 44' and the material within melt subchannel 46 is accelerated forward
relative to motion of the rotating screw surfaces defining melt subchannel 46. The velocity gradient of the material within melt subchannel 46 is not constant and the material immediately adjacent barrier flight 42 has a lower velocity which may approximate the velocity of barrier flight 42. Typically, such relative acceleration of the feed stock material is avoided in plastic injection molding applications to prevent the overheating of the plastic material. In a thixotropic injection molding machine, however, the increased velocity of the material within melt subchannel 46 relative to the screw surfaces defining melt subchannel 46 imparts shear forces to the metal feed stock material within melt subchannel 46 and thereby promotes the attainment and maintenance of a thixotropic state in the metal feed stock material.

The melted feed stock present in solids subchannel 44', together with suspended solid particles which are small enough to pass over barrier flight 42, are forced from the solids subchannel 44' over barrier flight 42 into melt subchannel 46 as the feed stock material is advanced in second section 56 and as the volumes of solids subchannel 44' and melt subchannel 46 are altered. When the melted feed stock and suspended particles pass over barrier flight 42, shear forces are imparted to the melt and suspended particles. The suspended particles may have attached dendritic structures, i.e., a structure similar to that of a tree trunk and its extending branches, the shear forces, however, tend to remove the dendritic structures leaving the particles with a more rounded and globular shape and thereby place the melt and suspended particles in a thixotropic state.

At the point where barrier flight 42 ends at line 60, the entirety of the feed stock should be in a semi-solid state and the solids subchannel 44' and melt subchannel 46 revert to a single channel having a depth of approximately .15" at the end of second section 56 which corresponds to line 62.

A mixer section 66 begins near the forward end of screw 20 at line 64 in Figure 2. Mixer section 66 is shown in greater detail in Figures 4 and 5 which illustrate the lands 68 and grooves 70 forming mixer section 66. Grooves 70 are milled on a 2.75" axially extending length of screw 20 which has a diameter equivalent to the diameter of main flight 40. Thus, lands 68 extend radially outward to the same extent as the radially outermost surface of main flight 40. Both main flight 40 and lands 68 are
configured to have a diameter which corresponds to the inner diameter of barrel 22. The illustrated embodiment of mixer 66 includes six grooves 70 equally spaced and milled on a 2.75" right hand pitch which intersect ten grooves 70 equally spaced and milled on a 16.0" left hand pitch. Grooves 70, which have a depth of .30" and a width of .25", are milled to extend slightly beyond the axial limits of the radially projecting lands 68. Although the illustrated embodiment is disclosed with specificity, alternative dimensions and configurations of mixer section 66 are also possible.

Injection end terminus 72 is located near mixer section 66 and is shown in Figure 6. Opposite the forward, or injection end, terminus 72 is a rear, or feed end, terminus 74 shown in Figures 2 and 7. A split ring groove 76 is provided in screw 20 near rear terminus 74 to facilitate the rotation of screw 20 by rotary drive 26.

The thermal and mechanical processing of the feed stock material is accomplished by the rotation of screw 20 together with the thermal energy provided by band heaters 24. When the solid feed stock material enters barrel 22 slightly forward of collar 41, it is augured forward by the rotation of main flight 40. As the feed stock material is moved forward within barrel 22 along the first section 54 of screw 20 it is heated to a temperature near its liquidus and is partially melted when it reaches the point at which barrier flight 42 begins.

The melted feed stock material and solid particles of feed stock material suspended therein are forced from solids subchannel 44' to melt subchannel 46 by rotation of screw 20. The passage of the melted feed stock material and small particles suspended therein over barrier flight 42 imparts shear forces to the semisolid feed stock material and places the material in a thixotropic state. The remaining solid material continues to melt as band heaters 24 supply thermal energy to the barrel and its contents in second section 56 of screw 20. The feed stock material is forced from solids subchannel 44' to melt subchannel 46 as it advances and melts.

At the point where main flight 40 and barrier flight 42 terminate and solids subchannel 44' and melt subchannel 46 become a single channel following the second section 56 of screw 20, all of the feed stock material within barrel 22 will be in a thixotropic state. Resolidification, or crystallization of the feed stock material on the suspended particles, at this point can create undesirable dendritic structures on the
suspended particles within the feed stock material and impair the quality of the feed stock material.

Some screws used in plastic injection molding machine include features which perform a mixing function and can thereby provide greater uniformity of color or temperature in the molding material. Mixer section 66, however, is rotated within the barrel of a thixotropic injection molding machine and maintains the metal feed stock material in a thixotropic state, and thus, provides the metal feed stock material with the fluidity required for injecting the material into mold 30. This is accomplished by forcing the metal material through grooves 70 which impart shear forces to the semisolid feed stock material. The agitation and shear forces created by the mixer section also reduces the aggregate size of the individual solid particles within the feed stock material and provides a narrower size distribution of solid particles by removing dendritic structures which extend from the generally rounded or globular core of the suspended particles. The reduced dimensions and narrower size distribution of the relatively globular solid particles results in higher quality molded articles which have a reduced porosity and improved mechanical properties.

As the thixotropic feed stock material is advanced beyond forward terminus 72 of screw 20, it is accumulated in barrel 22. After a sufficient quantity material has been accumulated for a shot, high speed shot system 28 is activated and the shot of thixotropic material is injected into the cavity of mold 30. A one-way valve may be placed in barrel 22 near forward terminus 72 to facilitate the injection process.

While this invention has been described as having an exemplary design, the present invention may be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this invention pertains.
WHAT IS CLAIMED IS:

1. A thixotropic molding machine comprising:
   a barrel; and
   a screw rotatably disposed within said barrel, said screw comprising:
   an elongate shaft with an axis, an injection end and a feed end;
   a helical main flight radially projecting from said shaft and axially
   extending from a first point located between said injection end and said feed end to a
   second point located near said injection end, said main flight having a radially outer
   surface disposed at a first distance from said axis, said main flight adapted to advance a
   feed stock material within said barrel from said first point towards said second point
   upon rotation of said screw; and
   a helical barrier flight radially projecting from said shaft and axially
   extending from a third point located between said first point and said second point to a
   fourth point located near said second point, said barrier flight having a radially outer
   surface disposed at a second distance from said axis wherein said second distance is
   less than said first distance, said barrier flight partitioning a helically extending space
   defined by said main flight, said shaft and said barrel into a solids subchannel and a
   melt subchannel, said solids subchannel defining a continuation of a solids channel
   defined by said main flight between said first point and said third point, said solids
   subchannel having a cross-sectional area of decreasing magnitude as said solids
   subchannel extends from said fourth point towards said second point, said melt
   subchannel having a second cross-sectional area of increasing magnitude as said melt
   subchannel extends from said fourth point towards said second point whereby melted
   feed stock and solid particles suspended therein are forced from said solids subchannel
   over said barrier flight into said melt subchannel by rotation of said screw within said
   barrel thereby imparting shear forces to the melted feed stock and solid particles
   suspended therein.

2. The thixotropic molding machine of Claim 1 wherein said solids
   subchannel and said melt subchannel have first and second axial widths respectively
   and said first and second axial widths each have a substantially constant value between
   said third point and said second point.
3. The thixotropic molding machine of Claim 1 wherein said main flight has a first substantially constant pitch between said first point and said third point and a second substantially constant pitch between said third point and said second point, said first pitch being less than said second pitch.

4. The thixotropic molding machine of Claim 3 wherein said first pitch is less than a diameter of said radially outer surface of said main flight.

5. The thixotropic molding machine of Claim 3 wherein said solids subchannel has a first axial width substantially equivalent to an axial width defined by said main flight between said first point and said third point.

6. The thixotropic molding machine of Claim 1 wherein said screw further comprises a mixer section disposed between said second point and said injection end, said mixer section comprising a plurality of radially projecting lands separated by a plurality of grooves.

7. The thixotropic molding machine of Claim 1 wherein said magnitude of said solids subchannel cross-sectional area decreases more than said second cross-sectional area of said melt subchannel increases.

8. A thixotropic molding machine comprising:
   a barrel; and
   a screw rotatably disposed within said barrel, said screw comprising:
   an elongate shaft with an axis, an injection end and a feed end;
   a helical main flight radially projecting from said shaft and axially extending from a first point located between said injection end and said feed end to a second point located near said injection end, said main flight adapted to advance a feed stock material within said barrel from said first point towards said second point upon rotation of said screw; and
   a mixer section disposed on said shaft between said second point and said first end, said mixer section comprising a plurality of radially projecting lands separated by a plurality of grooves, whereby melted feed stock material and solid particles suspended therein are forced through said grooves by rotation of said screw thereby imparting shear forces to the melted feed stock material and solid particles suspended therein.
9. The thixotropic molding machine of Claim 8 wherein said main flight has an outer radial surface disposed a first distance from said axis and said plurality of lands each have a partially cylindrical outer radial surface disposed at a distance from said axis approximately equivalent to said first distance.

10. The thixotropic molding machine of Claim 8 wherein said plurality of grooves includes a first plurality of equally spaced left hand grooves which intersect a second plurality of equally spaced right hand grooves.

11. A method of preparing a thixotropic material for injection molding, said method comprising:

- providing a thixotropic injection molding machine comprising a barrel and a screw rotatably disposed within said barrel, said screw comprising an elongate shaft with an axis, said screw having an injection end, and a feed end;
- introducing solid feed stock material into said barrel between said injection end and said feed end of said screw;
- rotating said screw to advance the feed stock material within said barrel towards said injection end with a helical main flight radially projecting from said shaft; heating the feed stock material within said barrel whereby the feed stock material within said barrel is partially melted as it is advanced by said main flight;
- imparting shear forces to the partially melted feed stock material to thereby place the feed stock material in a thixotropic state by forcing the partially melted feed stock material from a solids subchannel over a barrier flight to a melt subchannel;
- accumulating a shot of thixotropic feed stock material within said barrel near said injection end; and
- injecting said shot of thixotropic feed stock material into a mold cavity.

12. The method of Claim 11 further comprising:

- imparting shear forces to the partially melted feed stock material after forcing the partially melted feed stock material over the barrier flight and before injecting the material by passing the material through a rotating mixer section of said
screw, said mixer section comprising a plurality of lands separated by a plurality of grooves.

13. The method of Claim 11 wherein said main flight for advancing the feed stock material prior to forcing the material over said barrier flight has a pitch which is less than a diameter of a radially outermost surface of said main flight.

14. The method of Claim 11 further comprising the step of imparting shear forces to the partially melted feed stock by accelerating partially melted feed stock disposed within said melt subchannel relative to screw surfaces defining said melt subchannel.

15. A method of preparing a thixotropic material for injection molding, said method comprising:

providing a thixotropic injection molding machine comprising a barrel and a screw rotatably disposed within said barrel, said screw comprising an elongate shaft with an axis, said screw having an injection end, and a feed end;

introducing solid feed stock material into said barrel between said injection end and said feed end of said screw;

rotating said screw to advance the feed stock material within said barrel towards said injection end with a helical main flight radially projecting from said shaft;

heating the feed stock material within said barrel whereby the feed stock material within said barrel is partially melted as it is advanced by said main flight;

imparting shear forces to the partially melted feed stock material by passing the partially melted material through a rotating mixer section of said screw, said mixer section comprising a plurality of lands separated by a plurality of grooves disposed on said screw near said injection end, whereby the feed stock material is maintained in a thixotropic state;

accumulating a shot of thixotropic feed stock material within said barrel near said injection end; and

injecting said shot of thixotropic feed stock material into a mold cavity.

16. The method of Claim 15 wherein said main flight has an outer radial surface disposed at a first distance from said axis and said plurality of lands each have
a partially cylindrical outer radial surface disposed at a distance from said axis approximately equivalent to said first distance.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :B01F 7/08; B22D 17/10; B29C 47/40, 47/62
US CL: Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S.: 164/113, 312, 900; 264/211.23; 366/81, 88, 89, 319, 323; 425/208, 587

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>US 5,040,589 A (BRADLEY ET AL) 20 AUG 1991, ABSTRACT AND FIG. 1</td>
<td>1-16</td>
</tr>
<tr>
<td>Y</td>
<td>US 4,405,239 A (CHUNG ET AL) 20 SEP 1983, COL 3, LINES 20-55, COL 4, LINES 53-60, COL 5, LINES 30-35 AND 53-59, COL 6, LINES 29-34.</td>
<td>5, 6-7, 11-14</td>
</tr>
<tr>
<td>Y</td>
<td>FR 2,496,002 A (COMIND SPA AZIENDA STARS) 18 JUNE 1982, ABSTRACT AND FIGS. 2-3</td>
<td>6, 8-10, 12, 15, 16</td>
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Further documents are listed in the continuation of Box C. See patent family annex.

Date of the actual completion of the international search: 26 MARCH 1998

Date of mailing of the international search report: 21 MAY 1998

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A. CLASSIFICATION OF SUBJECT MATTER:
US CL:
164/113, 312, 900; 264/211.23; 366/81, 88, 89, 319, 323; 425/208, 587