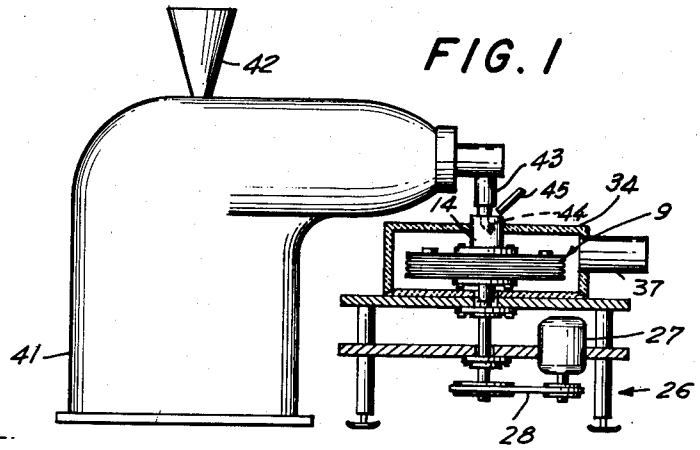
Jan. 5, 1965 C. D. SPENCER 3,164,654

PROCESS FOR CASTING THERMOPLASTIC MATERIALS

Filed April 18, 1960 3 Sheets-Sheet 1

FIG. 1



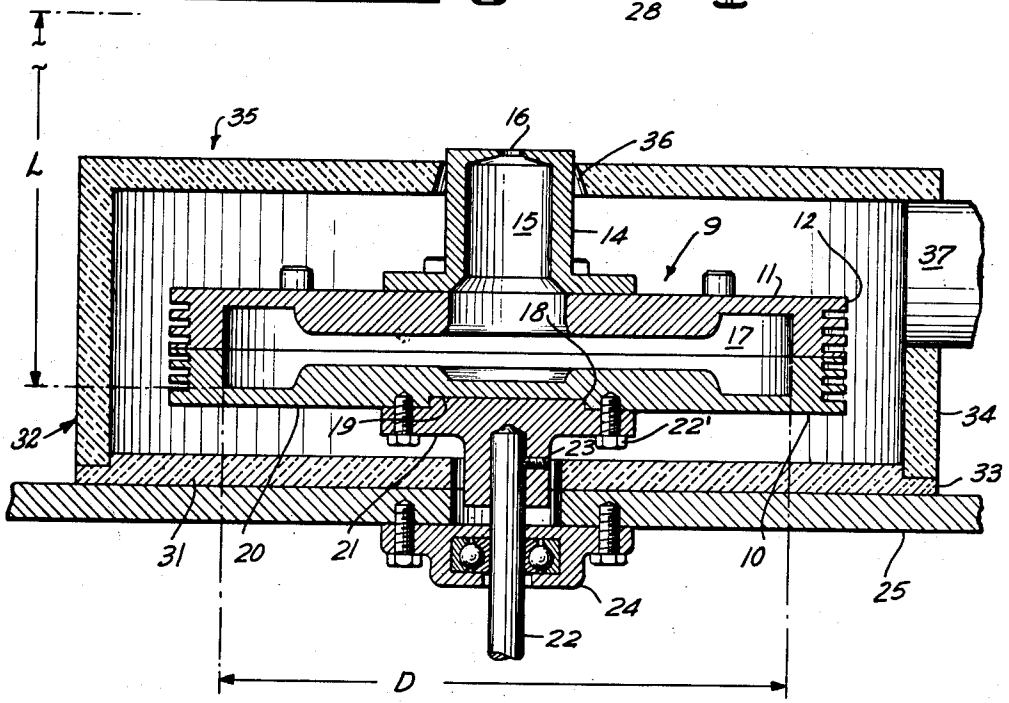


FIG. 2

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PROCESS FOR CASTING THERMOPLASTIC MATERIALS

Filed April 18, 1960 3 Sheets-Sheet 2

FIG. 3

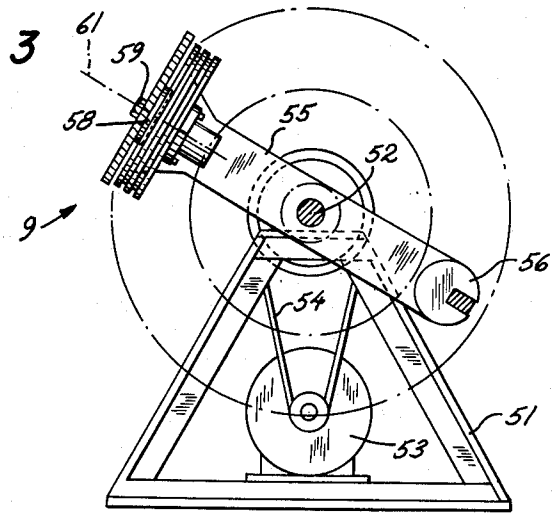
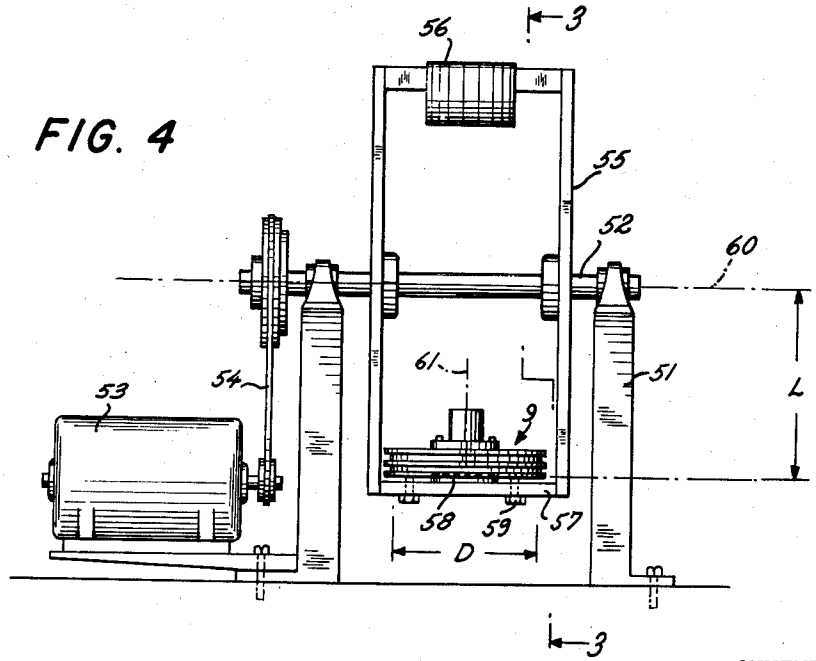


FIG. 4



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PROCESS FOR CASTING THERMOPLASTIC MATERIALS

Filed April 18, 1960 3 Sheets-Sheet 3

FIG. 6

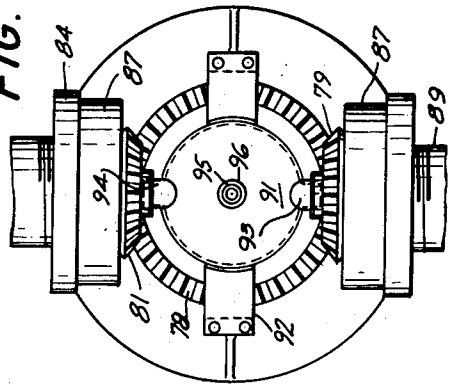
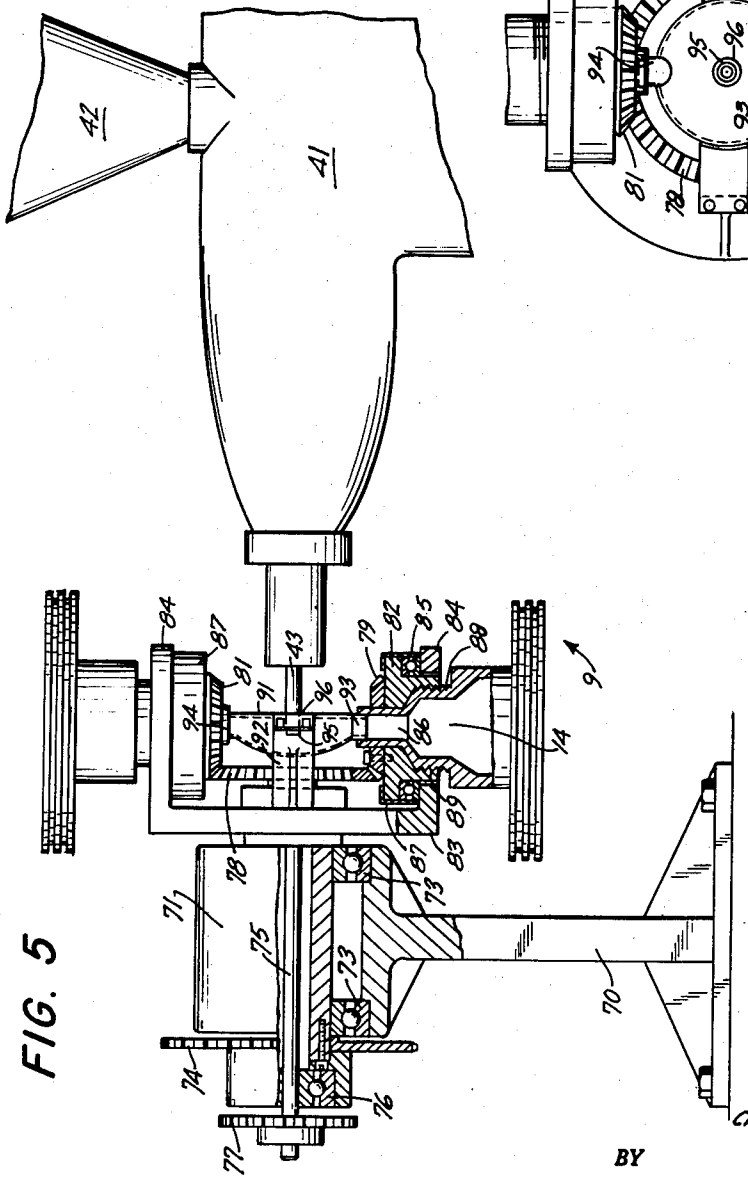


FIG. 5



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3,164,654

PROCESS FOR CASTING THERMOPLASTIC MATERIALS

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Filed Apr. 18, 1960, Ser. No. 22,857
5 Claims. (Cl. 264—311)

This invention relates to the casting or molding of thermoplastic material to produce massive castings. More particularly, this invention relates to the casting of superpolyamides, commonly called nylon, including polymers of caprolactam (nylon 6) and hexamethylene adipamides (nylon 66). In the interest of brevity, these thermoplastic resinous materials will be referred to hereinafter as polyamides.

By massive castings is meant castings of a cross-sectional dimension such that they cannot be cast economically by known compression or injection molding techniques.

This invention is particularly applicable to the casting of polyamide toroids such as gears, bearings, bushings, pulleys and propellers, but is not limited thereto.

The casting of thermoplastc materials such as polyamides to produce sound castings presents many problems. For example, polyamides oxidize readily when molten and hence must be cast under conditions excluding the presence of air or other oxidizing media. They contract or shrink on cooling; this complicates the formation of castings having surface detail reproductions within close dimensional tolerances.

It has been proposed to cast polyamide resins in the form of rods under relatively high piston pressures of the order of 10,000 to 40,000 pounds per square inch not only on the mold proper but also on a body of molten resin in communication with the mold to supply resin to fill the mold space which would otherwise be created by shrinkage of the resin upon cooling. Such procedures are objectionable in that they require the use of molds capable of withstanding such high pressures with consequent high initial cost and also high maintenance expenses. Moreover, they require the feed of the molten resin under such high pressures, which is obviously objectionable. Furthermore, such high pressure casting procedures do not lend themselves to the production of sound, massive castings of toroid shape such as gears and pulleys; invariably the castings are not uniform in density throughout the length of the cast rod. Heretofore to produce massive integrally shaped polyamide articles such as gears and pulleys, it was necessary to machine them from rod or slab polyamide stock.

It is among the objects of the present invention to provide a process for casting massive thermoplastic articles to obtain castings having the desired surface detail within close dimensional tolerances, which process can be carried out under relatively low pressures and hence requires for its practice comparatively inexpensive molds, desirably of light construction.

Another object of this invention is to provide a process for making massive castings of thermoplastic material, including polyamide toroids, of substantially uniform density throughout their cross-sectional extent both vertically and horizontally.

Another object of this invention is to provide a process of casting massive thermoplastic articles, in which process provision is made for escape of gases from the mold which would otherwie be entrapped during the filling of the mold thereby producing castings of uniform density comparatively free of blow holes and other such imperfections.

Other objects and advantages of this invention will be apparent from the following detailed description thereof.

In accordance with this invention, a mold having a mold reservoir communicating with the mold cavity is heated to a temperature above the melting point of the thermoplastic material, and the thermoplastic material fed in molten condition to a discharge point, which point is at atmospheric or ambient pressure, and thence into the mold while rapidly rotating the latter about its vertical axis. The feed of the molten thermoplastic material is continued while rapidly rotating the mold until all of the mold cavity and at least a portion of the reservoir, desirably substantially all of the reservoir, is filled. Thereafter the feed of the molten thermoplastic material is interrupted and the rapid rotation of the mold is continued about its vertical axis to effect centrifugal compaction of the molten material within the cavity in a radial direction toward the periphery of the cavity while cooling the mold and its contents. During or after the filling, the mold and its contents are rotated about an axis at right angles to the vertical axis of the mold to effect compaction of the molten thermoplastic material in a direction at right angles to the aforesaid radial direction and also in a direction towards the base of the mold and away from the reservoir, thus compacting the contents of the mold towards the base of the mold cavity while cooling the mold contents and permitting escape of gases from the casting into the reservoir from which they escape into the atmosphere. This last-mentioned densification or compaction effects compaction of the central or hub portion of the casting and will hereinafter be referred to as the hub compaction; the equipment in which hub compaction is accomplished when separate from that which effects rotation of the mold about its vertical axis, is referred to as the hub compactor.

When the hub compaction has taken place to the desired extent, rotation of the hub compactor is interrupted, the casting removed from the mold and annealed to effect relief from shrinkage and molding stresses. The molded piece is then washed or cleaned to remove any residue from the annealing treatment and when producing toroids employing a mold which does not result in the formation of the desired bore holes, the bore hole machined therein, preferably producing an undersized opening relative to the final bore dimension. If desired, the casting is then moisture conditioned so that it will absorb little or no additional water in use. Upon completion of the moisture conditioning treatment, the casting is cooled to atmospheric temperature and then machined to produce the hub bore of desired final dimensions.

For a fuller understanding of the nature and objects of this invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIGURE 1 is an elevational view, partly in section, showing the extruder for feeding the thermoplastic material to the mold cavity and also showing the mold and the mechanism for effecting its rotation;

FIGURE 2 is a vertical section on an enlarged scale, as compared with the scale of FIGURE 1, of the mold within its housing;

FIGURE 3 is a view, partly in section and partly in elevation, the section being taken in a plane passing through line 3—3 on FIGURE 4, of the hub compactor;

FIGURE 4 is a front elevational view of the hub compactor of FIGURE 3;

FIGURE 5 is a vertical section, partly in elevation, of a mold-spinner in which the molds are rotated about their vertical axes and simultaneously rotated about an axis at right angles to the vertical axes of the molds; and

FIGURE 6 is a fragmentary front elevational view of the apparatus of FIGURE 5.

Referring to FIGURE 2 of the drawings, the mold 9 is a three part mold consisting of the lower cavity member 10, the upper cavity member 11, each having fins 12 on their periphery to facilitate heating and cooling of the mold contents. These two cavity members are suitably detachably secured together as by bolts or other securing members. The upper cavity member 11 is provided with a sprue reservoir 14 constituted of a chamber 15 having a filling opening 16 at its top and communicating at its base with the mold cavity 17. Chamber 15 is of a volume to contain the additional volume of melt required to supplement that within the mold cavity 17 to maintain the cavity full when phase change shrinkage takes place in the mold cavity.

Mold 9, preferably, is machined from aluminum plate. Aluminum can be used because of its high heat conductivity, thus facilitating fast and uniform heating and cooling of the mold and because in the practice of the process of this invention, low fluid pressures are developed. It will be appreciated, however, that this invention is not limited to the use of aluminum molds; other suitable materials of construction can be used.

Base 20 of lower cavity member 10 is provided with a cylindrical recess 18 which receives a congruent projection 19 on drive plate 21. Drive plate 21 is detachably bolted as by bolts 22' to base 20 of the lower cavity member 10. Alignment of the drive plate 21 relative to the mold 9 is insured by the close fit between the projection 19 and the recess 18 in the base 20 of the lower cavity member; this close fit prevents radial run-out and wobbling of the mold when rotated. A drive spindle 22 is suitably secured to the drive plate 21 as by removable pin 23. Drive spindle 22 passes through ballbearing 24 on top plate 25 of the mold table 26 and is driven by a suitable drive such as a high slip torque motor 27 mounted on table 26 through a suitable drive, for example, the belt drive 28 shown on FIGURE 1.

Secured to the top plate 25 of the casting table 26 is the base 31 of the housing 32. This housing is made of suitable insulating material such as cement-asbestos. Base plate 31 is shaped as shown in FIGURE 2 to provide a rabbeted edge 33 for receiving the lower edge of the side walls 34 of the cylindrical cover 35. This cover 35 cooperates with the base plate 31 to form a two part housing; cover 35 is readily removable and replaceable. Cover 35 is formed with an opening 36 at its top through which passes the top of the sprue reservoir 14 and an opening 37 in side wall 34. An acetylene or other fluid fuel nozzle is positioned in opening 37 for supplying fuel which is burned in housing 32 to preheat the mold and maintain it at the desired temperature during filling. Heating of the mold 9 can, of course, be accomplished by other known procedures such as electrical induction, electrical radiant elements, passing hot gases through the housing, etc.

Supply of the molten thermoplastic material to the mold is effected by an extruder 41 of any conventional type, equipped with a heater (not shown), a hopper 42 for receiving the thermoplastic material and feeding it to the body of the extruder where the material is rendered molten and fed to a discharge nozzle 43 through which the melt is discharged into the sprue reservoir chamber 15. The discharge tip 44 of nozzle 43, which tip extends below the filling opening 16, may be directed downwardly or, as shown in dotted lines in FIGURE 1, shaped to extend in a direction away from the axis of rotation in order to aid the filling operation, i.e., to cause the melt as supplied to flow in the same direction as the centrifugal force created by the rotation of the mold 9.

When feeding a plastic melt, which tends to discolor or oxidize in the presence of air, a stream of inert gas, such as carbon dioxide or nitrogen, is supplied through

a line 45 which discharges the inert gas stream to blanket the exposed melt. The amount of inert gas thus supplied is controlled so as not to cool the melt.

The hub compactor 50 shown in FIGURES 3 and 4 comprises a suitable supporting frame 51 in which is journaled for rotation a shaft 52 driven by motor 53 through any suitable drive such as the chain or belt drive 54 shown on the drawing. Secured to shaft 52 for rotation therewith is the compactor frame 55 carrying a counterweight 56. Base plate 57 of frame 55 is provided with a cylindrical projection 58 dimensioned the same as projection 19 of the drive plate 21 and thus making a close fit with opening 18 in base plate 20 of mold 9. Removable bolts 59 or other quick fastening members are provided for securing the mold 9 to the base plate 57 of frame 55.

It will be noted from FIGURE 4 that the sprue opening 16 of the mold reservoir is disposed a substantial distance below the axis 60 of the hub compactor. Generally, the longer the length L (FIGURES 3 and 4), the more massive the construction of the hub compactor with consequent higher initial cost and greater power requirements which increase with increase in this distance L. However, to minimize variations in centrifugal acceleration, which centrifugal accelerations, for a given rotative speed, bear a linear relation to the length of the radius L (FIGURES 3 and 4), it is important that the mold cavity be so disposed with respect to this center of rotation that no portion of the mold cavity (or molded piece) measured normal to the hub center line (61 of FIGURE 4) shall have a dimension, viewed in the plane of rotation (FIGURE 3), which exceeds two-thirds the distance from said portion of the mold cavity to the axis of rotation. In other words, referring to FIGURE 4, D should be equal to or less than two-thirds L.

In practicing the process of this invention, in the equipment of FIGURES 1 to 4 hereinabove described, the extruder 41 plasticates the resin and extrudes a melt filament through the nozzle tip 44 into the mold 9; the molten resin is at atmospheric pressure when entering the mold. Mold 9 is perheated before commencement of the introduction of the melt by supplying heat in any suitable manner to the interior of housing 32. The temperature to which the mold is preheated should be above the melting point of the thermoplastic material and not too high to require excessive cooling times. When casting nylon 6, the mold is preheated to from 400° F. to 600° F., preferably 500° F. to 530° F. In the casting of nylon 6 articles, unless the mold is preheated to a temperature above 400° F., castings result having a rough or porous surface due to premature solidification of the melt.

Nylon 6 melts are heated to a temperature of from 410° F. to 575° F., preferably 430° F. to 460° F., and are fed into the mold at such temperature. Nylon 66 melts are heated to a temperature of from 480° F. to 600° F. and fed into the mold while at such temperature. A higher temperature for a given resin results in a desirable greater fluidity but increases the length of the cooling cycle.

During the preheating of the mold and its filling, it is protected by the housing 32. Prior to filling, the mold cavity 17 may be flushed with an inert gas, such as carbon dioxide, to displace all of the air. After bringing the nozzle end 44 into the sprue opening 16, the mold is rotated and its filling started. Although the speed of rotation is not critical, relatively high speeds are used because high speeds of rotation are helpful in eliminating gas which may otherwise be trapped within the mold. The preferred rate of filling is determined by the mold cavity volume and configuration, the viscosity of the melt and the economical desideratum of effecting the filling in a minimum of time.

The rate of rotation and rate of filling will vary with the equipment used and the geometry of the castings. For the production of a 4 pound nylon 6 gear having a

10 inch diameter, the mold is spun from 100 to 2,000 r.p.m., preferably at a lower speed within this range at the start of filling and at approximately 1,500 r.p.m. towards the end of filling. The mold is spun at 2,000 r.p.m. thereafter for from 5 to 15 minutes, preferably for about 10 minutes thereafter.

By operating under these conditions, gas bubbles from the nylon melt to within a radius of about 1½ inches to the axis of the casting will be eliminated.

Feed of the melt into the mold so that the melt enters the mold at atmospheric or ambient pressures is continued until the sprue reservoir 15 contains molten thermoplastic material in amount such that it will not spill out of the opening 16 while the mold rotation continues. The feed of molten material is then interrupted and the table 26 carrying the mold is removed from the extruder 41 or the latter removed from the table 26. Heating of the mold is generally discontinued shortly after the filling is commenced. Cooling can be started even before filling of the mold cavity is complete. Such cooling may be effected by rotating the mold in the atmosphere, removing cover 32, if desired, or by circulating a cooling medium such as air by means of a blower over the rotating mold 9.

Rotation of the mold is continued for a sufficient interval during the cooling to densify the melt in the mold to within a radius of about 1½ inches from the axis of rotation. Usually, this can be done in from 5 to 10 minutes. The mold is then brought to rest, removed from the casting table drive plate 21 and placed on the hub compactor 50. Cooling of the mold contents continues while the mold is rotated by the hub compactor E. The cooling in the hub compactor should be continued at least until the surface of the casting is solid. How long thereafter the cooling in the hub compactor is continued is not critical.

Hub compactor 50 rotates the mold about axis 60 which is at right angles to axis 61 of the mold. Two objectives are accomplished by rotation of the mold in the hub compactor, namely, (1) to drive gas bubbles out to the atmosphere and (2) maintain a pressure differential which supplies melt from the reservoir to the mold cavity as required to supplant the phase change shrinkage volume. As a general rule, rotation of the hub compactor at an r.p.m. of about one-half that of the maximum speed of rotation of the mold about its vertical axis accomplishes these objectives. Such rotation should be continued for a sufficient period of time to accomplish these objectives, e.g., from about 10 to 15 minutes. It has been found, in practice, that the viscosity of the material in the mold cavity and communicating reservoir when rotated by the hub compactor is so great that none of the material is discharged through the opening 16 even when starting the rotation of the hub compactor about its axis 60.

The hub compactor is then brought to rest, the mold assembly removed, the mold opened and the casting removed. Since the casting is still not completely solidified, care is taken to avoid careless handling that might distort the casting. The casting is then placed in a circulating annealing bath, desirably a wax, mineral oil or salt bath employed for annealing purposes. The annealing temperature and time will depend upon the thermoplastic material used and the geometry of the casting. For nylon gear blanks weighing approximately 4 pounds and having an overall diameter of about 10 inches and a hub diameter of 4 inches, annealing for 4 hours at 350° F. to 375° F. in a wax bath gives major relief of the shrinkage and molding stresses.

After removal from the annealing bath, the casting is treated to remove residue from the annealing bath, for example, it may be washed with a solvent for the wax, mineral oil or salt, as the case may be. Thereafter the casting, if not cast with a bore hole, is drilled at room temperature to produce the bore hole; the bore opening thus produced is slightly undersized relative to the desired final bore dimension.

The casting is then moisture-conditioned. This may be effected by immersing it in water or water-salt solutions, or subjecting the casting to steam, atmospheric air or other appropriate medium. The period of moisture-conditioning depends upon the final desired content of adsorbed moisture, the conditioning medium used, the temperature of the medium, the geometry of the casting and the range of moisture level variation that is tolerable. In 180° F. water, castings having section thickness of approximately one-half inch require from 1 to 2 days to absorb 2½% to 3% moisture, whereas castings having section thicknesses of approximately one inch require from 5 to 10 days to absorb 2½% to 3% moisture.

After this moisture-conditioning treatment and cooling of the casting to room temperature, if at a higher temperature at the end of the moisture-conditioning, the casting is machined to produce the hub bore of desired final diameter.

In the embodiment of the invention hereinabove described, charging of the mold while rotating about its vertical axis and hub compaction take place successively. In the embodiment shown in FIGURE 5 these operations take place simultaneously.

In FIGURE 5, 70 is a standard, in the upper portion 71 of which is mounted for rotation a hollow shaft 72 journaled in ball bearings 73. Shaft 72 has keyed thereto a pulley or gear 74 driven from any suitable source of power, such as a motor, not shown. A shaft 75 is journaled for rotation in ball bearings 76 positioned in the hollow shaft 72. One end of shaft 75 has keyed thereon a drive gear 77 driven by a motor or other suitable drive. The other end of shaft 75 has keyed thereto a beveled gear 78 which meshes with beveled gears 79 and 81 each fixed to a flanged collar.

In the construction shown in FIGURE 5, two such molds are depicted spaced 180° apart so that one mold counter-balances the other. As both molds are filled simultaneously at the same rate, this counter-balancing takes place throughout the filling and subsequent cooling and densification of the mold contents. Since the structure of both molds and their mounting on U-shaped member 83, which, in the embodiment shown, constitutes an extension of hollow shaft 72, are the same, only one will be described in detail.

Each mold is removably mounted in an arm 84 of the U-shaped member 83. The removable mounting shown in FIGURE 5 involves the flanged collar 82 rotatably mounted on the ball bearing 85 fixed to the arm 84. The extension or neck 86 of the reservoir 14 extends through a central opening in flanged collar 82 and through the hub of the gear fixed to this collar. A cylindrical retaining member 87 fixed to arm 84 permits rotary movement of flanged collar 82 and prevents movement of this flanged collar away from arm 84. Reservoir 14 of mold 9 is provided with a threaded exterior 88 which threads into the threaded interior 89 of the collar 82. Mold 9 is thus removably mounted in collar 82 for rotation therewith when mounted therein. By turning the mold 9 relative to the collar 82, holding this collar fixed by means of its flange by a suitable tool, the mold can be removed therefrom and replaced therein.

A housing or collector ring 91, suitably fastened to the rotatable U-shaped member 83, as by the arms 92, has discharge ports 93, 94, spaced 180° apart, and each positioned, with clearance in its respective filling opening of neck or extension 86, as shown in FIGURE 5. The extruder 41 is provided with a nozzle 43 having a discharge tip 95 passing through the opening 96 in housing 91. There is a small clearance between the opening 96 in housing 91 and the walls of the discharge nozzle extending through this opening to permit venting of housing 91 to the atmosphere. Gas escaping from the molds during the filling and cooling of the mold contents enters housing 91 and is vented through this clearance space to the atmosphere. Housing 91 can be removed

for cleaning when the two molds are removed from the threaded interiors 89 of collars 82.

Melt filament discharged from tip 95 passes through the necks or extensions 86 into both molds as they are rotated, in equal amounts, so that one mold counterbalances the other throughout the filling, compaction and cooling. Housing 91, because of its shape and its rotational speed, distributes the melt uniformly to each mold. The amount of melt supplied is at least enough to partially fill each sprue reservoir 14 and thus provide enough resin melt to supplement that within the mold cavities to maintain each cavity full when phase change shrinkage takes place in the mold cavity.

As in the other modifications, the molds are preheated to a temperature above the melting point of the thermoplastic material before charging of the molds in FIGURE 5 is initiated. Such preheating may be effected before or after the molds are mounted on their supporting arms 83.

The time required for effecting densification of the casting and cooling thereof to the point where the casting can be removed from the mold is substantially less when practicing the invention using the equipment of FIGURE 5 as compared with practicing the invention with the equipment of the types shown in FIGURES 1 to 4. A saving of about one-third the time required to produce castings having the necessary solid surface so that they can be removed from the mold for subsequent treatment is effected by utilizing the equipment of the type shown in FIGURE 5.

The following example is given for illustrative purposes as exemplifying the production of a polyamide (nylon 6) gear having 10¼ inch outside diameter and having four pitch involute spur gear teeth 1¼ inches wide. This example is carried out in equipment of the type shown in FIGURES 1 to 4, inclusive. It will be appreciated the invention is not limited to this example.

The mold is preheated to a temperature of from 500° F. to 530° F. Solid nylon, melting point 415° F. to 420° F., which has an apparent melt viscosity of 6000 poises corresponding to shearing stress of 13.6 lb./in.^{2} at a temperature of 450° F. (Plaskon 8201), chips are gravity fed at room temperature into a plasticating screw extruder in which the nylon is melted and the melt extruded therefrom at a temperature of from 430° F. to 460° F. The mold is rotated at 300 r.p.m. at the start of the filling and at 1500 r.p.m. for the final three minutes of filling. Fifteen minutes is required to effect the filling of the mold cavity and communicating reservoir. Rotation of the mold in the atmosphere at room temperature (70° F.) is continued at 2000 r.p.m. for ten minutes after the filling is interrupted. This eliminates gas bubbles in the nylon melt to within a radius of about one and one-half inches.

The mold assembly is then placed on the hub compactor with the base of the mold sixteen inches from the axis of rotation of the compactor, and the sprue opening 16 positioned nine inches from the axis of the compactor. The compactor is rotated for 15 minutes at a speed of 450 revolutions per minute in the atmosphere at room temperature, thus effecting substantially complete expulsion of gas bubbles, while continuing the cooling of the mold.

Thereafter the hub compactor is brought to rest, the mold opened, the casting removed and annealed for 4 hours at 375° F. in a circulating wax bath. The casting is then removed, allowed to cool slowly to room temperature, washed with hot water at approximately 140° F. and machined to remove the excess resin which had been in the hub reservoir and to produce a bore opening having a diameter of 1 13/16 inches. It is then moisture-conditioned by immersion in water at 185° F. for 4 days. It is then removed from this water bath, cooled to room temperature (70° F.) and the hub bored to a final dimension of 1⅞ inches diameter.

It will be noted that the present invention provides a process for producing massive castings of thermoplastic material, including polyamide toroids, having the desired surface detail within close dimensional tolerances, which castings are of substantially uniform density throughout their cross sectional extent both vertically and horizontally and which process can be carried out under relatively low pressures and hence require comparatively inexpensive molds of light construction.

It will be further noted that in the practice of the process of this invention, provision is made for escape of gases from the mold which would otherwise be entrapped during the filling of the mold and provision is also made for supplying the mold cavity with additional thermoplastic material during the cooling to fill the space which would otherwise result due to phase change shrinkage. The process of this invention results in compaction of the melt both in a radial direction and in a direction at right angles to such radial direction. Hence sound castings comparatively free of blow holes and entrapped gases, more uniform and of a highly crystalline nature result.

Since certain changes in carrying out the above process and in the casting equipment hereinabove described and shown on the accompanying drawings for practicing this process may be made without departing from the scope of this invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense. Thus while the axis of rotation of the mold is shown as vertical, which is preferred, this axis may be inclined to the vertical, with the sprue opening 16 situated at the higher end, if desired.

What is claimed is:

1. The method of producing massive castings, such as gears, bushings, bearings, pulleys and propellers, of substantially uniform density, from thermoplastic resinous material which is subject to shrinkage upon phase change due to cooling of the molten thermoplastic material, which method comprises:

(*a*) employing a mold having a mold cavity conforming to the shape of the casting, which mold has a reservoir chamber at its vertical axis, with the vertical axis of the reservoir chamber coincident with the vertical axis of the mold cavity and with the mold cavity extending in a generally horizontal direction radially away from the base of said reservoir chamber in open communication with the mold cavity;

(*b*) heating said mold to a temperature above the melting point of the thermoplastic material;

(*c*) feeding molten thermoplastic material into the mold cavity through said reservoir chamber while rotating said mold about its vertical axis;

(*d*) continuing said feeding until said mold and at least a portion of said reservoir are filled with said molten material to level in said reservoir such as to supply the mold with enough of the molten material to take care of all shrinkage within the mold due to phase change upon cooling of the thermoplastic material;

(*e*) continuing said rotation about said vertical axis to effect centrifugal compaction of said molten material in a radial direction toward the periphery of said mold cavity while cooling the mold and its contents, the mold cavity being maintained full of thermoplastic material fed thereto from said reservoir chamber as shrinkage occurs due to phase change within the mold cavity throughout said cooling;

(*f*) maintaining the thermoplastic material in the reservoir chamber in molten condition at least until (1) substantial solidification of the molten thermoplastic material in the mold cavity has taken place and (2) substantially no further shrinkage of the thermoplastic material in the mold cavity can occur due to phase change upon cooling; and

(*g*) rotating said mold and its contents about a second axis at right angles to said vertical axis, with the distance between said second axis and the portion of the mold cavity nearest thereto greater than the distance between said second axis and the inlet to the reservoir chamber, and with the inlet to the reservoir chamber spaced a substantial distance from said second axis so that rotation of said mold about said second axis effects feed of molten thermoplastic material into said mold cavity from said reservoir chamber through the open base of said reservoir chamber to maintain said mold cavity full notwithstanding phase change within said mold cavity during the cooling and effect compaction of the contents of the mold cavity in a direction at right angles to said radial direction and in a direction toward the base of said mold cavity and away from said reservoir chamber, the said mold being so dimensioned that substantially the entire contents thereof in a direction away from said reservoir is compacted to form a casting of uniform density.

2. The method of claim 1, in which the thermoplastic material is a polyamide, and in which the mold and its contents is first rotated about its vertical axis and thereafter the mold and its contents is rotated about said second axis.

3. The method as defined in claim 1, in which the thermoplastic material is a polyamide and the rotation of the mold and its contents about the vertical axis occurs simultaneously with the rotation of the mold and its contents about said second axis.

4. The method of claim 1, in which the thermoplastic material is a polyamide, the mold in step (*b*) is heated to a temperature of from 400° F. to 600° F., and the polyamide is extruded into the reservoir chamber at a temperature of 410° F. to 575° F.

5. The method of producing massive castings, such as gears, bushings, bearings, pulleys and propellers, of substantially uniform density, from thermoplastic resinous material which is subject to shrinkage upon phase change due to cooling of the molten thermoplastic material, which method comprises:

(*a*) employing a mold having a mold cavity conforming to the shape of the casting, which mold has a reservoir chamber at its vertical axis, with the vertical axis of the reservoir chamber coincident with the vertical axis of the mold cavity and with the mold cavity extending in a generally horizontal direction radially away from the base of said reservoir chamber, which base is in open communication with said mold cavity;

(*b*) heating said mold to a temperature above the melting point of the thermoplastic material;

(*c*) feeding molten thermoplastic material into the mold cavity through said reservoir chamber until said mold and at least a portion of said reservoir

chamber are filled with said molten material to the level in said reservoir such as to supply the mold with enough of the molten material to take care of all shrinkage within the mold due to phase change of the thermoplastic material;

(*d*) rotating said mold about said vertical axis to effect centrifugal compaction of said molten material in a radial direction toward the periphery of said mold cavity to form a uniformly dense melt at the periphery of said mold cavity;

(*e*) maintaining the thermoplastic material in the reservoir chamber in molten condition at least until (1) substantial solidification of the molten thermoplastic material in the mold cavity has taken place and (2) substantially no further shrinkage of the thermoplastic material in the mold cavity can occur due to phase change upon cooling; and

(*f*) rotating said mold and its contents, while cooling the mold and its contents and while maintaining the mold cavity full of thermoplastic material fed thereto in the liquid phase from said reservoir chamber as shrinkage occurs due to phase change within the cavity throughout said cooling, about a second axis at right angles to said vertical axis, with the distance between said second axis and the portion of the mold cavity nearest thereto greater than the distance between said second axis and the inlet to the reservoir chamber, and with the inlet to the reservoir chamber spaced a substantial distance from said second axis so that rotation of said mold about said second axis effects feed of molten thermoplastic material into said mold cavity from said reservoir chamber through the open base of said reservoir chamber to maintain said mold cavity full notwithstanding phase change within said mold cavity during cooling and effects compaction of the contents of the mold cavity in a direction at right angles to said radial direction and in a direction toward the base of said mold cavity and away from said reservoir chamber, the said mold being so dimensioned that substantially the entire contents thereof in a direction away from said reservoir is compacted to form a casting of uniform density.

References Cited in the file of this patent

UNITED STATES PATENTS

1,341,670	Powell	June 1, 1920
1,541,831	Linder	June 16, 1925
2,433,065	Rubissow	Dec. 23, 1947
2,454,847	Slack	Nov. 30, 1948
2,543,303	Rubissow	Feb. 27, 1951
2,629,130	Rempel	Feb. 24, 1953
2,818,604	Miller et al.	Jan. 7, 1958
2,830,325	Bray	Apr. 15, 1958
2,888,714	Bray	June 2, 1959