

How to select Plastic Injection Moulding Machine 3

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2.1.4 Selecting a machine with sufficient shot weight

Shot weight should not be equal to the combined weight of the article (or articles for a multicavity mould) plus runners that could be injection moulded. The latter is set at 85% of the shot weight for articles with low requirement, e.g. figurines; 75% of shot weight for articles with high requirement, e.g. crystal parts. The discrepancy is due the much higher injection pressure when there is a mould. High requirement moulding uses high injection pressure.

Example 3: Figurines made of UPVC (S.G. 1.38) with a combined weight of figurine plus runners of 4 oz. are to be moulded. What size of machine is sufficient?

Shot weight in terms of PS = $4 * 1.05/1.38 = 3.04$ oz. Using the 85% guide line, the machine shot weight needed = $3.04/0.85 = 3.58$ oz.

2.1.5 Selecting a machine which is not too big

An injection moulding machine of a specified shot weight can be used to mould article(s) including the runners weighing from 35% to 85% of the shot weight. The lower limit comes from bending on the platens, barrel resident time of the resin and electric power consumption per kg of processed material.

A small article using a small mould puts undue bending on the mould platens, causing them to deflect (which affects product quality), and to break in the extreme.

If a big machine is used to mould small articles, the melt in the barrel could degrade due to unduly long residence time. Barrel residence time could be estimated as follows.

Barrel residence time =
 (weight of melt in barrel * cycle time) / (actual shot weight)

Weight of melt in the barrel is estimated to be the weight in two times the injection volume.

Moulding small parts with a big machine is inefficient in energy usage per kg of material processed, also known as specific power consumption.

Example 4: The same figurine in example 3 is to be moulded in a big machine. What is the biggest machine that could be used?

Using the 35% rule, the biggest machine that could be used has a shot weight = $3.04/0.35 = 8.7$ oz.

Example 5: What is the residence time of UPVC (S.G. 1.38) in a machine with screw diameter of 55 mm, injection stroke of 250 mm, shot weight (PS) of 567 g, and a cycle time of 10 s moulding shots weighing 260 g?

Volume of melt in the barrel is estimated to be two times the injection volume = $2 * 3.1416 * 5.5 * 5.5 * 25 / 4 = 1188$ cm³

Barrel residence time = $1188 * 1.38 * 10 / 260 = 63$ s

Having multicavities per mould to increase the articles' weight and to increase the mould size are solutions to using bigger machines. Alternatively, lowering the barrel temperature would help avoid degradation due to long residence time.

2.2 Clamping force

Clamping force is an important attribute of the clamping unit of a PIMM. It is the maximum force the machine is capable of to keep the mould closed against the cavity pressure during injection. Insufficient clamping force gives rise to flash at the mould joint. Most PIMMs today use their clamping force (in tonnes) in their model name, e.g. ME125III.

It is advisable to use a sufficient clamping force below the maximum. See section 3.11.8. The sufficient clamping force is proportional to the projected area of the cavity. Projected cavity area is the cavity area projected onto the plane at the mould parting surface.

In this article, tonne is used to denote metric tonne (which is 1000 kg) to distinguish it from (short) ton (which is 2000 lb.) used in USA. Machine specifications use ton in both cases. One can tell them apart by the use of Imperial or metric system for the rest of the specifications. See section 5.

The clamping force needed could be estimated in several ways.

The conservative method is to multiply the projected cavity area by a constant which is different for each material. For example, for GPPS, the constant is 1.0 to 2.0 tonnes/in² for thick wall articles, 3.0 to 4.0 tonnes/in² for thin wall articles. 1.0 tonne/in² = 0.155 tonne/cm² = 15.4 MN/m². Table 3 lists the constants for commonly used resins.

Example 6: A GPPS cup of diameter 79 mm is to be moulded. The cup is 0.6 mm at its thinnest section. Find a conservative clamping force which would be sufficient.

The projected area of the cup (and runner) is $3.1416 * 7.92 / 4 = 49$ cm². This cup belongs to the thin wall domain. The conservative clamping force is $0.62 * 49 = 30.4$ tonnes

A more accurate method takes into account the flow path length and wall thickness. Flow path is the length travelled by the resin from the sprue gate to the furthest point in the mould cavity. See Figure 1. If the wall thickness of a part varies, take its minimum wall thickness.

Example 7: The same GPPS cup has a flow path length of 104 mm. Find a more accurate clamping force needed.

Flow path to thickness ratio = $104 / 0.6 = 173$. From Figure 2, at 0.6 mm wall thickness, the cavity pressure is 550 bar. From the conversion tables in section 5, 1 bar = 1.02 kg/cm². The clamping force = $550 * 1.02 * 49 = 27,500$ kg = 27.5 tonnes.

The above calculation has not accounted for viscosity. It turns out to be still correct as the viscosity factor for GPPS is 1.0. The viscosity factor for common resins is listed in Table 4.

Example 8: The same cup as in the above example is to be made out of ABS. Find the clamping force needed.

Using the viscosity factor of 1.5, the clamping force needed = $1.5 * 27.5$ tonnes = 41.3 tonnes.

The most accurate estimate of clamping force is done by computer simulation after the mould is designed. An example of such a package is C-MOLD. A simplified version called Project Engineer is available for downloading for a 30-day trial period from AC Technology's web site at <http://www.amold.com>. Resin tonnes/in² tonnes/cm² MN/m² PS (GPPS) 1.0 - 2.0.155 - 0.3115.4 - 30.9 PS (GPPS) (thin walls) 3.0 - 4.0.465 - 0.6246.3 - 61.8 HIPS 1.0 - 2.0.155 - 0.3115.4 - 30.9 HIPS (thin walls) 2.5 - 3.5.388 - 0.54338.6 - 54.0 ABS 2.5 - 4.0.388 - 0.6238.6 - 61.8 AS (SAN) 2.5 - 3.0.388 - 0.46538.6 - 46.3 AS (SAN) (long flows) 3.0 - 4.0.465 - 0.6246.3 - 61.8 LDPE 1.0 - 2.0.155 - 0.3115.4 - 30.9 HDPE 1.5 - 2.5.233 - 0.38823.2 - 38.6 HDPE (long flows) 2.5 - 3.5.388 - 0.54338.6 - 54.0 PP (Homo/Copolymer) 1.5 - 2.5.233 - 0.38823.3 - 38.6 PP (H/Co) (long flows) 2.5 - 3.5.388 - 0.54338.6 - 54.0 PPVC 1.5 - 2.5.233 - 0.38823.3 - 38.6 UPVC 2.0 - 3.0.31 - 0.46530.9 - 46.3 PA6, PA66 4.0 - 5.0.62 - 0.77561.8 - 77.2 PMMA 2.0 - 4.0.31 - 0.6230.9 - 61.8 PC 3.0 - 5.0.465 - 0.77546.3 - 77.2 POM (Homo/Copolymer) 3.0 - 5.0.465 - 0.77546.3 - 77.2 PET (Amorphous) 2.0 - 2.5.31 - 0.38830.9 - 38.6 PET (Crystalline) 4.0 - 6.0.62 - 0.9361.8 - 92.6 PBT 3.0 - 4.0.465 - 0.6246.3 - 61.8 CA 1.0 - 2.0.155 - 0.3115.4 - 30.9 PPO-M (unreinforced) 2.0 - 3.0.31 - 0.46530.9 - 46.3 PPO-M (reinforced) 4.0 - 5.0.62 - 0.77561.8 - 77.2 PPS 2.0 - 3.0.31 - 0.46530.9 - 46.3 Table 3. Simple clamping force estimation Figure 1. Flow path length is measured from tip of sprue to an extremity of the article Figure 2. Cavity pressure as a function of wall thickness and flow path length

Thermoplastics Viscosity factor GPPS (PS) 1 PP1 - 1.2 PE1 - 1.3 Nylons (PA6 or PA66), POM 1.2 - 1.4 Cellulosics 1.3 - 1.5 ABS, ASA, SAN 1.3 - 1.5 PMMA 1.5 - 1.7 PC, PES, PSU 1.7 - 2.0 PVC 2 Table 4. Viscosity factor

Section 2.3 to 2.15 describe other attributes of the injection unit.