The size of an injection moulding machine

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Summary

Three traditional ways of sizing of an injection moulding machine are discussed. Three new measures of the injection unit power suited to selection for thin-wall moulding are introduced and explained.

1. Shot weight

The oldest method to size an injection moulding machine is by its shot weight. In Hong Kong, shot weight in ounces is still often used.

That shot weight is chosen to size an injection moulding machine is understandable. A moulder has an article to be moulded. The shot weight of the machine must be sufficient to injection mould the article in an n-cavity mould. If one machine does not have a sufficient shot weight, select a bigger model that can do the job.

1.1 Short comings

An injection moulding machine has a clamping unit and an injection unit but shot weight only indicates the size of the injection unit. To be more specific, it only indicates the shot weight capable of this machine using a particular screw.

Many injection moulding machines could be fitted with more than one screw. An example is a 125-ton machine with a 39 mm diameter standard screw. To get a higher injection pressure, a 35 mm diameter screw could be chosen, but the shot weight is reduced. To get a higher shot weight, a 43 mm diameter screw could be chosen, but at the expense of injection pressure. In short, shot weight is screw diameter dependent.

Another short coming of shot weight is its dependence on resin density although most shot weights are specified using PS (S.G. = 1.05 at room temperature). Please refer to Equation (1) below. To be correct, the S.G. of PS at its melt temperature should be used, but this was not known to be used.

Furthermore, due to the backward movement of the non-return valve at the beginning of injection, and the compressibility of the melt, the actual shot weight is less than the theorectical value calculated from swept volume times S.G. Manufacturers have used a factor varying from 0.8 to 1, making comparison among models inaccurate.

$w = k * 1.05 * v$ (1)

$v = 3.1416 * i * d^2/4$ (2)

where

w = maximum shot weight in g,

k = factor from 0.8 to 1,

v = maximum swept volume in cc,

d = screw diameter in cm,

i = maximum injection stroke in cm.

2. Clamping force

At present, clamping force is commonly used to characterize the size of an injection moulding machine as could be seen in its use naming a machine model. In Hong Kong and Japan, the unit used is metric ton. A metric ton is 1000 kgf.

In the U.S., short ton is used. A short ton is 2000 lbs, which is about 10% less than a metric ton. A 20 metric ton machine has a clamping force of 22 short tons.

In Europe, kN (kilo Newton) is used. A kN is about 0.1 kgf. To be exact, one kN is 1/9.807 kgf = 0.102 kgf. A 20 metric ton machine has a clamping force of about 200 kN.

3. Injection unit capacity

At present, injection unit capacity is commonly used to characterize the size of an injection unit in Europe.

$I = p * v$ (3)

where

I = injection unit capacity,

p = the maximum injection pressure of a screw in kbar,

v = the maximum swept volume in cc of the same screw.

At first sight, using Equation (3) to size an injection unit seems puzzling. After some analysis, however, its use is found to be very logical.

3.1 Relationship to shot weight

Since both shot weight and injection unit capacity measure injection unit size, they are related by their dependence on v, but there the resemblance ends. Injection unit capacity is a better measure because

a. it accounts for injection pressure,

b. it is independent of screw diameter,

c. it is independent of resin density,
d. it does not use the not-so-standard factor k.
Injection unit capacity is most useful when comparing among models from different manufacturers. Unfortunately, not all manufacturers have included this metric in their specification. It, however, could be calculated using Equation (3).

3.2 Accounts for injection pressure

In section 1.1, we saw the trade off between screw diameter and injection pressure. If injection pressure is not accounted for, as shot weight is, one could increase the screw diameter to increase shot weight up to a point when injection pressure is too low for a particular resin and mould to injection mould successfully. We conclude that shot weight without accounting for injection pressure is not as useful.

Injection unit capacity explicitly involves injection pressure in its definition. If injection pressure is bigger at the same maximum swept volume (akin to the same shot weight), one has a more capable injection unit.

3.3 Independence of screw diameter

For simplicity, assume the injection unit is operated by a single injection cylinder. From Figure 1, the maximum injection pressure is given by

$$p = P * A / (3.1416 * d^2/4) \qquad (4)$$

where
P = hydraulic system pressure
A = injection piston area (head end)
d = screw diameter

Put Equation (2) and (4) into Equation (3),

$$I = P * A * i \qquad (5)$$

which is independent of screw diameter.

Equation (4) also shows why maximum injection pressure decreases with (the square of) screw diameter.

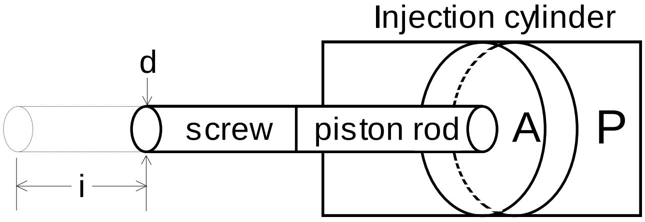

Figure 1

In Figure 1, the cylinder marked by dotted line is the maximum swept volume.

3.4 Interpreting injection unit capacity

From Figure 1, P * A is seen to be the force pushing the injection piston (and screw) forward. During injection, this force is displaced by an amount up to i. Hence injection unit capacity is the maximum work done during injection. The more work is done, the higher capacity is the injection unit.

As defined in Equation (3), injection unit capacity has a unit of 100-Joule, or a tenth of a kJ.

3.5 Increasing injection unit capacity

From Equation (5), one can see there are three ways to increase injection unit capacity.

At present, a hydraulic system pressure of 140 kgf/cm^2 is common. In the last few years, machines with 160 – 175 kgf/cm^2 have appeared. In Europe, system pressure up to 210 kgf/cm^2 has been used.

One rationale for increasing P is to reduce cylinder size, i.e. A, while keeping force the same.

One could of course increase P *and* A at the same time. There is a consideration to increasing A: as A is increased, the piston velocity is reduced at the same pump flow rate. This leads us to define another metric in Section 5 which takes into account injection velocity.

The maximum injection stroke i could also be increased but only up to a certain extent. A usually adopted limit on i is 5 * d, five times the screw diameter. Increasing i has the effect of reducing the effective L/D (length to diameter) ratio of the screw.

Effective L/D = L/D – i/(2d) (6)

As the screw rotates during plasticizing, it retracts up to a distance i. On average, therefore, the screw length is reduced by i/2 during plasticizing. This is reflected in Equation (6).

3.6 Using injection unit capacity

Although injection unit capacity is a better measure of injection unit size than shot weight, it is not very often used, most probably because it was not popularized. Furthermore, its definition is mathematical (p*v). Its interpretation as the maximum work done during injection may help.

Another reason is it does not answer a moulder's question of whether the injection unit is big enough for the job, where shot weight excels.

Injection unit capacity is best used when selecting an injection unit (or injection moulding machine) from among different manufacturers. As a 'supplementary' parameter, shot weight is consulted to determine whether the article could be moulded.

If a machine specification does not show injection unit capacity, it could be calculated from Equation (5). If injection pressure is provided in kgf/cm^2, use

$$I = p * v / 1020 \quad (7)$$

where
p is the maximum injection pressure of a particular screw in kgf/cm^2,
v is the maximum swept volume using the same screw in cc.

If injection pressure is provided in bar, use

$$I = p * v / 1000 \quad (8)$$

where
p is the maximum injection pressure of a particular screw in bar,
v is the maximum swept volume using the same screw in cc.

If injection pressure is provided in psi, use

$$I = p * v / 884 \quad (9)$$

where
p is the maximum injection pressure of a particular screw in psi,
v is the maximum swept volume using the same screw in in^3.

The three equations help compare among machines from Hong Kong/Japan, Europe and U.S.A.

4. EUROPMAP size

Most injection moulding machines from Europe have a EUROMAP size containing two figures: the clamping force in kN followed by injection unit capacity, separated by a -. The combination of course contains size information of the clamping unit *and* the injection unit.

5. The power of an injection unit

It was mentioned in Section 3.5 that injection unit capacity does not account for injection velocity. Injection unit capacity could be increased by increasing A, but this is at the expense of injection velocity. In thin-wall moulding, a high injection velocity is important to get the mould filled before the melt froze in the cavities.

The power of an injection unit Po is defined to supplement where injection unit capacity is not sufficient. It is given by

$$Po = p * r \qquad (10)$$

where

Po = the power of an injection unit in tenths of kW,

p = the maximum injection pressure of a particular screw in kbar,

r = the maximum injection rate of the same screw in cc/s.

Going through a similar analysis that gives rise to Equation (5), we can show that

$$Po = P * A * vel \qquad (11)$$

where

vel = the maximum injection velocity of the screw/piston in cm/s.

In fact, by referring to Figure 1, it can be seen that

$$Q = A * vel \qquad (12)$$

where

Q = the maximum flow rate of hydraulic fluid into the injection cylinder.

If an injection unit is operated without an accumulator, Q is the maximum flow rate of the pump. Otherwise, it is the combined maximum flow rate of the accumulator and the pump during injection, assuming both the accumulator and the pump are driving. Usually, the flow from an accumulator is 2 to 3 times that of the pump. The combined flow is therefore 3 to 4 times that of the pump alone.

Substituting Equation (12) into Equation (11), we get

$$Po = P * Q \qquad (13)$$

which is a measure of the power of the injection unit. Without accumulator, Po is the same as the maximum power delivered by the hydraulic pump.

5.1 Most suited to thin-wall moulding

We recommend using the power of an injection unit in making selection in thin-wall applications. Po is not intended to replace injection unit capacity but to supplement it. Furthermore, maximum injection velocity and rate, maximum acceleration and deceleration, sampling rate, etc. are also useful data in such a selection. Please refer to Section 7.

If a machine specification contains maximum injection rate, Po could be calculated from Equation (10). If only the maximum injection speed is available, maximum injection rate could be calculated from

$$r = vel * 3.1416 * d^2/4 \qquad (14)$$

In thin-wall moulding, *both* maximum injection pressure and maximum injection rate need to be high. Both are accounted for in Equation (10). Note that the definition uses maximum injection rate, not maximum injection velocity. Maximum injection rate tells us how fast a cavity or cavities can be filled. Maximum injection rate is screw diameter dependent. Maximum injection velocity is not screw diameter dependent.

If r is screw diameter dependent, could we increase the power of an injection unit by increasing the screw diameter? The answer is no. Everything else the same, increasing the screw diameter would decrease the maximum injection pressure by the same amount, as the injection force P * A is divided by a bigger screw cross sectional area. In short, Po stays constant irrespective of screw diameter.

5.2 An example

Two brands of injection moulding machines of roughly the same clamping force are compared. Their specifications are shown in Table 1.

	Brand A	**Brand B**	**Brand B with accumulator**
EUROMAP size	800-290	750-258	750-258
Injection unit			
Screw diameter (mm)	36	33	33
L/D ratio	20	22	22
Max. injection stroke (mm)	145	150	150
Max. swept volume. (cc)	147	128	128
Max. shot weight (g) (PS)	132	115	115
Max. injection pressure (kgf/cm^2)	2014	2057	2057
Max. injection velocity (cm/s)		12.4	37
Max. injection rate (cc/s)	78	106	
Clamping unit			
Clamping force (tons)	80	75	75
General			
Hydraulic system pressure (kgf/cm^2)	145	160	160
Pump flow rate (l/min)		82	82
Motor power (kW/hp)	15/20	15/20	15/20

Table 1

5.2.1 Shot weight

Despite the shorter injection stroke of Brand A, its bigger screw gives a higher swept volume than that of Brand B. Brand A and B both use the same factor k of 0.85. The shot weight of Brand A is therefore also higher.

5.2.2 Clamping force

Brand A has a higher clamping force than Brand B.

5.2.3 Injection unit capacity

Brand A has a more capable injection unit than Brand B (290 vs 258). Brand B with accumulator has the same injection unit capacity as Brand B without accumulator.

5.2.4 Effective L/D

For Brand A,
Effective L/D = 20 – 145/(36 * 2) = 18.

For Brand B,
Effective L/D = 22 – 150/(33*2) = 19.7.

Brand B uses a bigger maximum injection stroke to increase injection unit capacity. The reduction in L/D (to effective L/D) is more than compensated for by a longer screw (L/D=22).

5.2.5 EUROMAP size

Brand A has a bigger EUROMAP size than Brand B.

5.2.6 Injection unit power Po

For Brand A,
Po = 2014 * 78 / 1020 = 154.
For Brand B,
Po = 2057 * 106 / 1020 = 214.

Due to both a higher maximum injection pressure and a higher maximum injection rate, Brand B has a more powerful injection unit, despite its smaller injection unit capacity. Po is an independent attribute from *I*.

For Brand B with accumulator, according to Equation (14),
Po = 2057 * 37 * 3.1416 * 3.3^2 / (4 * 1020) = 638.

Once again, we see that Po is increased while *I* stays the same.

Since pump flow rate is available from Brand B's specification, according to Equation (13),
Po = (160 / 1020) * (82 * 1000 / 60) = 214
which agrees with the previous value of Po for Brand B.

5.2.7 Pump flow rate

Brand A does not have a pump flow rate in its specification. However, it could be calculated from Equation (13) using the known value of Po and its hydraulic system pressure of 145 kgf/cm^2.

Pump flow rate of Brand A = 154 * (1020 / 145) * (60 / 1000) = 65 l/min.

5.3 Motor power implications of Po

For linear motion, power is defined as force * velocity. From considering the power demand by various motions during an operation cycle, we see that the injection motion needs the highest power. Please refer to Table 2. As a result, the electric motor driving the pump is sized for the injection stroke.

Motion	**Force**	**Velocity**	**Power**
Mould close	Low	High	Medium
Mould lock up	High	Almost zero	Medium
Carriage forward	Low	Low	Low
Injection	High	High	High
Hold	Low	Almost zero	Low
Plasticize	Medium	Medium	Medium
Cooling	Zero	Zero	Zero
Mould open	Low	High	Medium
Ejection	Low	High	Medium

Table 2

Note that power is different from work done. Due to the usually longer duration of plasticizing versus injection, it is plasticizing that consumes most of the energy of an operation cycle. This is why a hybrid (hydraulic and electric driven) injection moulding machine uses an electric screw motor to economize on energy usage.

5.3.1 No accumulator

Without an accumulator, Equation (13) may lead us to think that Po is the power rating of the electric motor driving the pump as the pump power comes from the motor. This is not so as the three-phase induction motor could be overloaded (torque increased) to two times its rated power for a short duration. Most machine maker would overload the motor from 0% to its limit. One manufacturer even resort to cool the motor by water, so as to obtain an even higher overload. As a result, comparing injection unit power by comparing electric motor rating is not conclusive.

5.3.2 Motor overload example

Both Brand A and Brand B use a 15 kW motor. Due to the higher hydraulic system pressure and pump flow rate of Brand B, the Brand B motor has a higher overload than the Brand A motor. To be exact,
pump power in kW = pump pressure in kgf/cm^2 * pump flow rate in l/min * 98.07/60000.
Motor overload = (pump power / motor power) – 1.

For Brand A,
motor overload = (145 * 65 * 98.07/(60000 * 15)) – 1 = 2.7%.

For Brand B,
motor overload = (160 * 82 * 98.07/(60000 * 15)) – 1 = 43%.

A higher motor overload is used to increase the injection unit power of Brand B.

5.3.3 With accumulator

With an accumulator, injection unit power is further removed from electric motor rating. In this case, the size of the accumulator is important in determining Po.

For the Brand B machine, the increase of injection unit power from Po = 214 to Po = 638 by adding an accumulator comes from storing away the motor-generated energy in the form of potential energy which is released in a burst during injection. An accumulator is a device to store such energy, usually during the cooling stage after plasticizing has stopped.

5.4 Electrical drive implication of Po

As no hydraulic pressure and flow are involved, Equation (10) also applies to an electric driven injection unit.

At present, fully electric driven injection moulding machines are limited to the smaller sizes. Furthermore, injection velocity and acceleration/deceleration are inferior to those of a hydraulic driven injection unit. There are a few reasons for this.

Heat dissipation is the main constraint.

To improve speed of response, the servo motor rotor diameter is optimized. This reduces the area through which the overloaded motor could dissipate heat. This is in contrast to a much bigger induction motor driving the injection unit through a pump and a servo valve.

Furthermore, accumulator could increase the injection velocity by up to four times that using the pump alone. No such energy reservoir is available to the servo motor. Until such a device could be devised, electric machine is not expected to outperform hydraulic machine in injection power.

Table 3 displays the specification of three fully electric injection moulding machines in the 85 to 102 tons clamping force range.

	Brand C	**Brand D**	**Brand E**
EUROMAP size	834-190	981-202	1000-234
Injection unit			
Screw diameter (mm)	32	32	35
Max. injection stroke (mm)	120		150
Max. swept volume. (cc)	97	103	111
Max. shot weight (g) (PS)	88		98
Max. injection pressure (kgf/cm^2)	2000	2000	2150
Max. injection velocity (cm/s)		20	
Max. injection rate (cc/s)	128		154
Clamping unit			
Clamping force (tons)	85	100	102

Table 3

All three machines have smaller injection unit capacities than their hydraulic counterparts shown in Table 1. The power of their injection units are bigger, but not as big as that of Brand B with accumulator.

For Brand C,
Po = (2000/1020) * 128 = 251.

For Brand D,
Po = (2000/1020) * 20 * 3.1416 * 3.2^2 /4 = 315.

For Brand E,
Po = (2150/1020) * 154 = 325.

Among the three, Brand C has the least powerful injection unit. This could be understandable as it is also a smaller machine in terms of clamping force.

Brand D has a smaller maximum injection pressure but a higher maximum injection rate than Brand E. Their injection units are comparable in power. It is the *combination* of maximum injection pressure and maximum injection rate that determines injection power.

6. The rates at which power is delivered by an injection unit

The power of an injection unit Po as defined by Equation (12) is the rate of change version of *I* as defined by Equation (3). We could apply the rate of change idea one more time to come up with the acceleration power Pa and the deceleration power Pd of an injection unit.

Pa = p * (3.1416 * d^2/4) * acc (15)

where

acc = the maximum acceleration of the screw in cm/s^2.

Pd = p * (3.1416 * d^2/4) * dec (16)

where

dec = the maximum deceleration of the screw in cm/s^2.

Like *I* and Po, both Pa and Pd are screw diameter independent. This is so despite the appearance of d in Equations (15) and (16). The reasoning is the same as that in Section 5.1. The bigger is d, the smaller is p such that p * d^2 stays the same.

The way Pa and Pd are defined reflects the fact that most machine makers publish their machine's linear acceleration and deceleration but not volumetric acceleration and deceleration.

6.1 What affects acceleration and deceleration?

In getting to up speed, the injection piston in Figure 1 is resisted by the pressure at the screw tip as well as the mass to be accelerated. From Newton's Second Law of Motion,

F = m * acc,

where

F = pushing force = P * A,

m = mass to be accelerated,

we see that for a given force, the smaller the mass, the higher is the acceleration. The design of the injection unit determines the mass to be moved. The minimum mass is that of the screw, the piston rod and the piston combined. If the screw motor also moves during injection, the acceleration is reduced.

The same mass accelerated during start up is also decelerated at the velocity-to-pressure transition. The restraining force during deceleration is smaller since the hydraulic system pressure now acts on the rod end where the area is reduced by the cross section of the piston rod. Please refer to Figure 1. This does not mean deceleration is smaller. On the contrary, it is bigger in magnitude than acceleration since deceleration is helped by the resistance force at the screw tip.

Acceleration is related to energy build up; deceleration to energy dumping. A driver could appreciate a car could brake from a cruising velocity in a shorter time than it could accelerate from rest to the same velocity. We conclude that there is a need to distinguish between acceleration power from deceleration power.

6.2 Significance of acceleration power

An injection velocity of 100 cm/s is considered very high. If the screw starts from rest, acceleration tells us how soon this high velocity could be attained. An acceleration of 5000 cm/s^2 means this speed could be attained in 0.02 s. Such acceleration could only be obtained using accumulator-driven hydraulic power. 0.02 s is also the state-of-art response time of a servo valve.

In a multi-stage injection, injection velocities change between stages. Acceleration and deceleration are again called for.

Pa is not merely acceleration, but acceleration against a resistance force at the screw tip: $p * (3.1416 * d^2/4)$. Naturally, if an injection unit can attain the same acceleration against a higher resistance force, it is more powerful, as measured by acceleration power Pa.

6.3 Significance of deceleration power

If one considers injection as the stage for filling the mould, injection ends when the cavities are completely filled. At this point, injection transitions to holding pressure, which is the stage to make up for part shrinkage. This point is known as the velocity-to-pressure transition.

Before this transition point, velocity is controlled. Injection pressure is not controlled and is determined by melt viscosity and cavity cross section at that particular injection velocity.

After this transition point, injection pressure (now called holding pressure) is controlled. Injection velocity is not controlled and is determined by the rate of shrinkage of the parts in the cavities, which in turn is determined by the rate of cooling of the mould. Compared to the high injection velocity commonly associated with thin-wall moulding, the injection velocity during holding could be considered as zero.

The screw needs to decelerate from the last injection stage velocity to zero at the transition 'point'. During deceleration, the screw travels a distance before stopping, compressing the melt in the cavity. This is called the packing stage, after which the holding stage sets in. Proper packing gives the part its necessary density.

If deceleration is low, the cavities will be overpacked by the advancing screw. Overpacking is characterized by a cavity pressure peak (observable if a cavity pressure sensor is installed). An overpacked part has a higher part weight, a higher built-in stress, and in the extreme case, flashes the mould. Neither do we want underpacking which gives a short shot in the extreme case. A high deceleration or a high deceleration power avoids irregular packing. Repeatability/part stability is guaranteed.

7. Electronic control and other factors

Many design details make an injection moulding machine more suited to thin-wall moulding than another machine. Po, Pa and Pd only characterize the injection unit of a machine.

A modern injection moulding machine is invariably controlled by a digital computer. One characteristic of digital computer is that measurements are not made continuously but only at fixed intervals, called scan intervals or sampling interval. At a scan interval of 1 ms, a screw traveling at 100 cm/s could have traveled 1 mm. Variation of 1 mm in shot stroke gives rise to irregular packing just as low deceleration power does. There are two solutions.

The simple solution is to reduce the scan interval. This may necessitate using a more powerful microprocessor which is the brain of the computer. Alternatively, an analog circuit is incorporated to *continuously* compare the set transition point with the actual value (injection distance, hydraulic pressure or cavity pressure). Once the set transition point is reached, an interrupt is generated to notify the microprocessor which then starts the deceleration and transition to holding pressure control.

Platen deflection affects parts dimensions, which is more critical in thin-wall moulding. In the extreme case, platen deflection flashes the mould. Rigid platen is a requirement in thin-wall moulding.

A thin-wall part does not need a lot of shot weight. A small injection unit as measured by short weight is suitable. Otherwise, residence time would be increased which causes resin degradation. The rule-of-thumb is to use an injection unit two sizes smaller. A 90-ton conventional machine has a 100 g shot weight, a thin-wall machine of the same tonnage has a 20 g shot weight.

8. Experiments

The claim that Po, Pa and Pd characterize an injection unit's suitability in thin-wall moulding is theoretical and mathematical (time rate of change). Experiments are to be performed to bear this out. So far, such experiments have not been carried out. The interested readers are encouraged to do so.

9. Conclusion

The traditional measures of an injection moulding machine size are shot weight and clamping force.

Injection unit capacity *I* was shown to be a better measure than shot weight. In fact, *I* transcends the notion of size. It measures the capability of an injection unit. *I* is most useful when selecting injection units from different manufacturers.

In thin-wall moulding applications, three measures of injection unit power were found to be relevant.

Po is the power delivered to the injection unit. If the injection unit is driven by a hydraulic pump, Po is the power delivered by the pump. If the injection unit has an accumulator, Po is the power delivered by the accumulator and the pump.

I was shown to be independent of Po. Po is more relevant than *I* in thin-wall moulding.

Pa is acceleration power. It tells us how much power is available e.g. to start the screw moving from rest. It determines how closely the set velocities could be attained during injection.

Pd is deceleration power. A high deceleration power reduces variation in overpacking.

Both Pa and Pd determine the repeatability of the shot or the stability of the product. They are difficult to achieve in thin-wall moulding. Experiments are to be performed to verify high values of Pa and Pd improve product stability.

Other factors affecting the selection of an injection moulding machine for thin-wall moulding includes scan interval, incorporation of analog comparator, platen deflection and in fact also shot weight.

Table 4 summaries the characteristics of the different attributes of an injection unit.

	Shot weight w	Inj unit capacity *I*	Inj. unit power Po	Inj. unit acc. power Pa	Inj. unit dec. power Pd
Definition	k * 1.05 * v	p * v	p * r	p * a * acc	p * a * dec
Unit	g	kJ/10	kW/10	1/10 kW/s	1/10 kW/s
Screw diameter dep.?	Yes	No	No	No	No
Accounts for max. inj. pressure?	No	Yes	Yes	Yes	Yes
Affected by max. inj. stroke?	Yes	Yes	No	No	No
Affected by pump size?	No	No	Yes	No	No
Affected by accumulator?	No	No	Yes	No	No
Affected by mass to move?	No	No	No	Yes	Yes
Interpretation	Size of shot using a particular screw	Work done by the injection unit during injection	Power delivered by the injection unit, determines how soon cavities could be filled	Acceleration power of the injection unit, determines how fast set injection velocities could be reached	Deceleration power of the injection unit, determines how fast the v-to-p transition could be done
Suited to selection for thin-wall moulding?	Yes	No	Yes	Yes	Yes

a = cross section area of the screw

Table 4

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