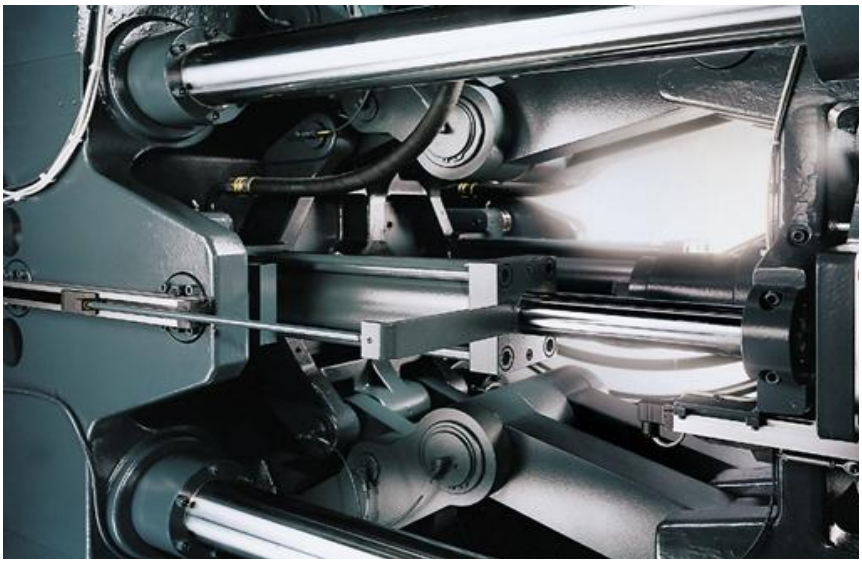
Toggles – Innovation for precise injection moulding

Fast, secure clamping, energy-saving and reliable

Toggles are the most commonly built and used clamping system in Europe. Almost two thirds of all injection moulding machines of over 100 tonnes clamp-force used in Europe employ toggles as the clamping system. That the design is not static, but is constantly being developed and optimised, makes it the most reliable and dependable type of clamping system, with distinct technical and economic advantages.

Innovation is not just a matter of developing new systems, but also of developments which have characterised a whole epoch of injection moulding and which have withstood the test of time. This is the toggle clamping unit for injection moulding machines, i.e. the toggle as the closing, clamping, locking and opening system with one fixed and one moving platen, an end or anchor platen as a fixed pivot point for the toggle links, i.e. as an abutment for the mould clamping and locking force, and four tie-bars to contain the force and guide the moving platen (Photo: BUS: The 5-Point double toggle of Demag machines from 125 tonne clamp-force)

The designers of the first single-screw injection moulding machines in 1956 at Ankerwerk Goller Bros. in Nuremberg put their trust in this closing principle. This was, of course, a toggle of simple construction and it would be a long development road to the computer-optimised 5-point double toggle system (of which more later) in today's clamp units with ramped control of the endpoints. On this road the toggle system has undergone an exemplary, detailed development. It continues to be the guarantor of precise and reliable injection moulding, as this article will show.



The 5-Point double toggle system of Demag machines from 1 250 kN clamp-force

What the clamp unit must be able to do - technically for the moment - is easily said; it must:

- accept the mould,
- keep the mould closed against filling and holding pressures,
- carry out the opening/closing and clamping movements of the mould and
- eject the moulding.

There are in principle only two ways to build a clamp unit: the mechanical, self-clamping (without additional locking) toggle clamping unit, driven by a comparatively small hydraulic cylinder and the fully hydraulic type with closing cylinders and a large clamping cylinder - with variations like the mechanical “block and hydraulic lock” and recently the two-platen and “two-and-a-half platen” machines which dispense with the end or anchor platen.

In no way secondary are the other properties which are demanded of a clamp unit; it should also:

- be robust and reliable,
- need only minimal maintenance effort,
- work with a high efficiency,
- possess sturdy, stiff platens,
- distribute the clamp-force evenly over the entire mounting surface,
- have large distance between tie-bars, daylight and opening stroke,
- be easy, reliable and accurate to set,
- ensure high reproducibility and accurate control of the set values.

Last but not least, with respect to mould movements, it should:

- carry out the actual opening and closing movements quickly,
- slow down the moving platen just before the mould halves touch to protect both mould and machine and
- equally carefully open the mould so that the moulding is not damaged.

Fast toggles

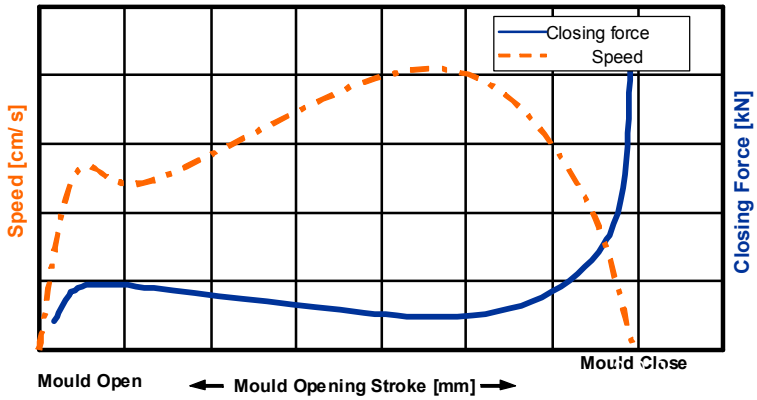
Despite continued development fully hydraulic clamping systems have not reached the speeds of toggle systems. The opening and closing speeds of fully hydraulic injection moulding machines do approach those of toggles, but these have the advantage, because of the toggles and their natural dynamics (compared with the oil column in a hydraulic ram), of opening and closing a mould faster. Taking this criterion into account over the whole cycle, including opening, etc., it represents a gain of several days’ production for a toggle machine over the course of a year!

The short opening and closing times naturally influence the cycle time and thus increase the productivity of the injection moulding machine and so several manufacturers equip their fast-running versions with toggle clamping systems. For the real fast machine manufacturers only toggles are considered.

Toggles right for the process

Properly designed toggles - in contrast to hydraulic rams - have “by nature” a curved speed profile which is just right for the process: slow start, fast travel for the pure opening/closing distance and gentle closing in the mould protection region, falling effectively to zero as the mould faces touch, since the inertia forces are braked automatically by the toggle kinematics; the force is inversely proportional to the speed.

As the stroke sensing is made at the cross-head, there is a ten- to eighty-fold finer stroke resolution than can be achieved by sensing platen movement.



This results in a level of sensitivity in mould safety which cannot be achieved by other clamping systems. The toggle’s smooth, mould and machine saving approach to the end position is further improved by combination with the control circuits.

Safe toggles

The upper limit of the locking force is given by the mechanical strength of the machine and also depends on the quality requirements of the moulding. On clamping, the whole system (end platen, toggles, fixed and moving platens, mould and tie-bars) is deformed within the elastic limit. This deformation can be described by the so-called spring constants of the machine and the mould.

The toggle clamping unit has an inherent locking force reserve, which can be demonstrated by calculation. It depends, amongst other things, upon the spring constants, i.e. the stiffness of the mould, where not only the thickness of its bolsters, but also its construction, e.g. the disposition of the mould cavities, play a role. The filled mould has parts which are compressed and thus shorten and some which are relieved and thus lengthen. The lengthening is compensated by the extension of the tie-bars and hence flash is prevented.

In principle, the advantage of the locking force reserve increases, or is better exploited, and more for small machines than larger ones.

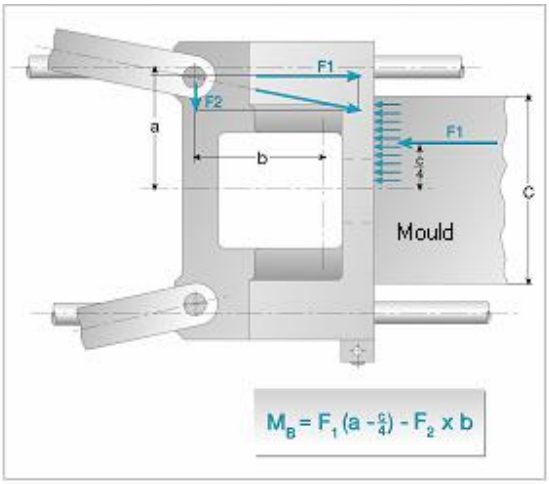
If the force (from filling and holding pressure) driving the mould apart approaches the clamp-force, the mould begins to “breathe” in the case of hydraulic ram machines, because the elastic modulus of the oil is only a fraction of the modulus of steel; the column of oil is more than a hundred times softer than the steel and hence compressible. As a rule one cannot go to the capacity limit of a hydraulic ram machine or precision parts. The toggle machine, by contrast, allows this with no problem: the locking force reserve is perhaps the most important argument for toggles.

Thus the optimised toggle clamping unit offers four key characteristics just right for economical production of large area engineering parts to a high level of quality, such as are commonly required e.g. for the automotive industry: 1. High stiffness and safe locking, 2. Optimum force distribution, 3. High speed and 4. Low energy consumption.

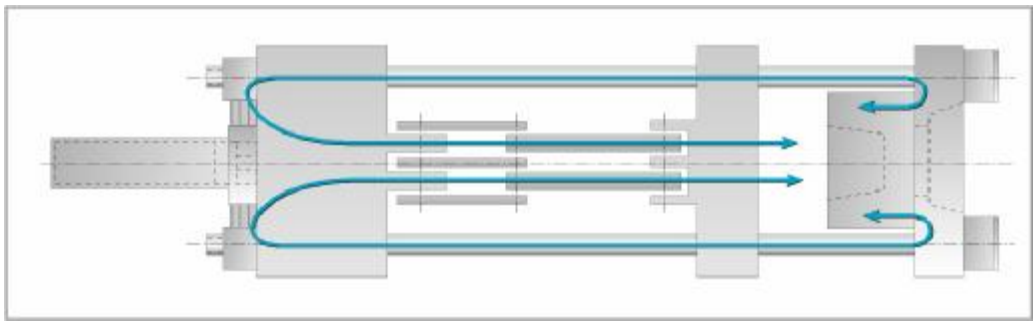
Force-optimised toggles

The ideal transfer of clamping and locking force into the rigid, box-section, hollow cast, accurately guided mounting platens is likewise a quality feature of the toggle system. This naturally has a large effect on the quality of the mouldings. The clamp-force s transferred into the fixed platen via the four tie-bar nuts.

Toggle and ram machines differ considerably in the application of force to the rigidly supported moving mould-mounting platen: With rams this is always central, so with symmetrical centrally injected moulds with cavities sufficiently far from the platen edges the platen deflection is quite small. If these provisos are not met, e.g. with asymmetrical loading, the is a risk that the mould will splay open.



Small bending moment of moving platen

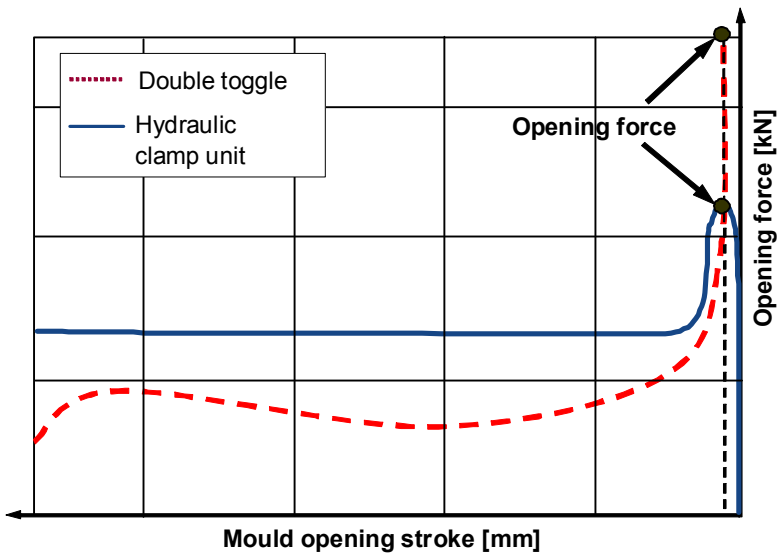


The toggle links, when extended, are angled in towards the machine's centre line, which gives a component of force directed towards the middle, effecting a bending moment opposed to the deflection of the platen under load. This means there is no undue deflection and the pressure is as even as possible over the whole mounting face. And because the toggle links are anchored away from the centre line, even large area or eccentric moulds can be securely clamped without platen deflection.

Toggles with high opening force

Since the mould must not only be closed, but also opened, here the toggle's characteristic of having in the stages of closing, very high forces and at the same time low speeds for clamping just before the toggles lock out, can be used in reverse.

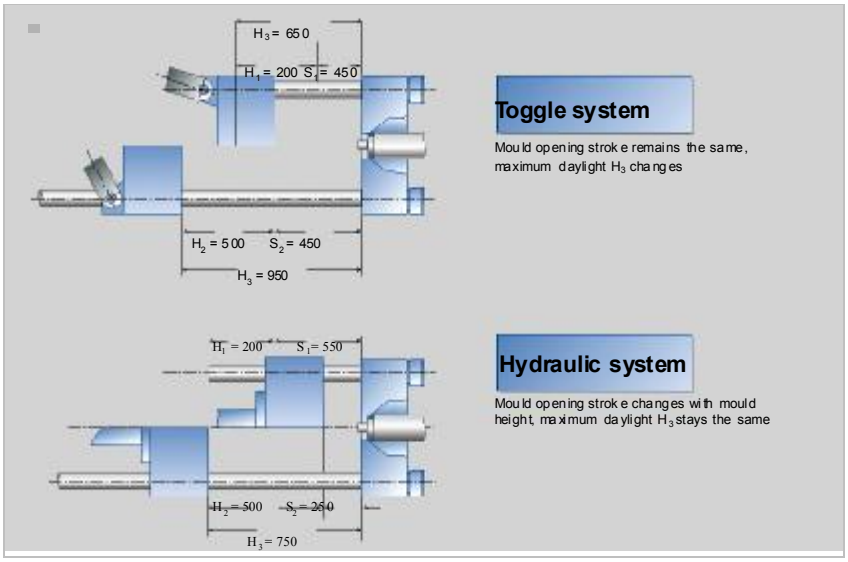
This opening force is always a machine constant; on a Demag 5 000 kN machine is amounts to 25% of the clamp-force; in general it is between 15 and 20% of the clamp-force. In critical cases, e.g. with deep, small draught-angle (possibly over-packed) mouldings the normal opening force of a hydraulic ram machine (7-10% of clamp-force) may not be enough to open the mould.



Toggles with constant opening stroke

A comparison of mould opening stroke on the same size of toggle and hydraulic machine comes to the surprising conclusion that a longer opening stroke is quoted for the ram-type clamping unit. However, it must be noted that the maximum daylight does not increase, so that the maximum opening stroke can only be utilised with minimum tool height: the usable opening stroke gets smaller as the mould height gets larger. This is also true for two-platen machines. It is, of course, the larger moulds that also need the longer opening strokes.

The toggle clamping unit is almost a “closed system” and by contrast the same opening stroke is available regardless of mould height and at larger values of maximum daylight. Large opening strokes can be realised, which allow any application with very few exceptions.



Comparison of the mould opening strokes of toggle and hydraulic ram systems

Reliable toggles

Toggles, e.g. on Demag Machines from Demag Plastics Group are in respect of dynamics, dimensions, and material selection represent mature technology, and this clamping system guarantees reliable and trouble-free production.

This also includes continuous development of the tie-bars, which, as we know, resist by their extension the clamping and locking forces. This affects the shape of the tie-bars, threads and tie-bar nuts, which have been optimised over the years, at times with extensive test series. The threads are rolled in order to achieve up to 200% improvement in strength in the heavily loaded thread root and to prevent scoring or other manufacturing defects. The tie-bars are also necked or waisted in the fixed platen, so that the tie-bars rather than the tie-bar nuts accommodate any bending moment.

Energy-saving toggles

Experience has shown that a toggle clamping unit, because of its mechanical clamping and locking needs about 15 – 20% less energy than a hydraulic ram clamp. This is in part due to the larger masses - and oil volumes - which must be moved in a ram machine, and the high friction and hydraulic drag which occur during mould movement.

Toggles unlimited

The previously laborious adjustments of mould height and tonnage on toggle machines have been consigned to history: both are today set on the machine's control panel and are automatically adjusted by a central sun gear. Tonnage is measured and adjusted during operation on every closing stroke (for expansion from warming up) - mostly during the start-up phase. Although even without clamp-force regulation the toggle system described has less than 1% deviation in tonnage. The maximum clamp-force is constantly monitored to protect machine and mould.

Low-maintenance bearings are fed with oil by a central lubrication unit, which self-regulates the lubrication interval according to the clamp-force used and the number of loadings.

Economical toggles

Toggles are a "fixed quantity" not only in technical, but also in economic comparisons. The simplest way to calculate the economy is from the ratio of the hourly operating costs to the number of good parts per hour. And this calculation shows the cost reducing effect of the classic advantages of toggles:

- their speed,
- their rigid, secure clamping (with locking force reserve)
- their low energy consumption and operating costs,
- their reliability, low maintenance needs and low susceptibility to breakdown and the resulting up-time of the machine.

This reliability is an equally important psychological factor: The management provides a trouble-free means of production to the workforce, "painless injection moulding" so to speak.

When comparing the footprint, the whole machine including ancillaries should be considered. In comparison with hydraulic ram machines – with or without tie-bars – there are no significant differences with toggle machines. Compared with two-platen machines the slightly larger space requirement is compensated by the shorter cycle times, the lower energy usage and the higher up-time of the toggle system.

Another aspect of economics confirmed in practice is that for certain applications a toggle machine "one size smaller" than the hydraulic clamp can be chosen because of the locking force reserve and then discussion about the space saving of the alternative system may be irrelevant, since the hourly costs of the toggle machine can be rated lower.

Summary

Here follow the results of a system comparison for the manufacturer of fast-running parts, in which a US injection moulder compared the productivity of injection moulding machines from several manufacturers: At 27%, the increase in productivity was highest for the Demag toggle machine. The Demag Plastics Group toggle machine scored top marks in the areas of cycle time (up to 16% shorter), energy consumption (up to 40% lower), production output (up to 22% higher) and hence clearly had the best price/performance ratio.