Achievements and Potentials of Hydraulic Drive Technology demonstrated on plastic injection moulding machinery

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Abstract

This general lecture will give an introduction to the Group 5 on Industrial Hydraulics at the 8th International Fluid Power Conference in Dresden in Germany. At first existing market-relevant injection moulding machine concepts are presented and compared regarding to different areas of applications. It is distinguished between standard and custom made machines, which assume a high level of integrated functions and a much more complex system (e.g. automotive applications). This is followed by a summary of the demands for the different drive axles of injection moulding machines. The focus lies here on force, speed, reproducibility and energy consumption. For the purpose of comparison the electro-mechanical drives are also listed. Furthermore, the competitive situation of electro-hydraulic and electro-mechanical drive technologies in injection moulding machines is illustrated; a prognosis for future developments will be predicted. Finally, trends and requirements for the hydraulic drives are formulated from the perspective of an injection moulding machine manufacturer.

KEYWORDS: injection moulding machines, energy consumption, drive technology

1. The injection moulding process

Injection moulding is one of the most developed and widely used technologies for producing ready-to-use plastic parts in a fully automated process. The produced parts range from very simple geometries to highly complex ones, parts of the daily use as well as high precision construction parts with narrow tolerances. Injection moulding is the technology that produced substantial progress and prosperity in the last 50 years and can be seen as the foundation of a highly developed machine technology./1/

The injection moulding process mainly consists of five sequential and recurrent process steps:

1. Closing of the mould in the clamping unit
2. Applying of the nozzle contact force
3. Injection and holding pressure phase
4. Dosing of the Feedstock
5. Cooling time and reopening of the mould

Within the process steps the molten plastics material is injected into the mould, cools down and is automatically ejected from the opened mould afterwards.

There are different injection moulding machine concepts that can be found at the market. Mainly one has to distinguish between the electro-hydraulic and the electro-mechanic driven machines, furthermore there are machines that use a combination of both for the different machines drive axles or functions. Figure 1 shows a hydraulically driven injection moulding machine.

Figure 1: Hydraulic injection moulding machine design KraussMaffei CX series

1.1. Hydraulically driven injection moulding machines

So called hydraulic injection moulding machines (see Figure 1) use normally a single hydraulic power pack for all the machines drives axles. Therefore the different movements or functions can only be operated sequentially. In some cases hydraulic accumulators are used to permit parallel movements that are needed with reference to the process or to reach higher speed of motion.

Regarding the application of clamping force to close the mould against the injection pressure there am two different functional principles. The direct hydraulic application

force, as shown in Figure 2. Figure 3 shows an example of the principle of hydraulic mechanic clamping force where the force is produced by four separate pressure pads that surround the four tie-bars. After moving the platen for closing the mould, the platen is mechanically locked to the tie-bars and the hydraulic pressure is applied.

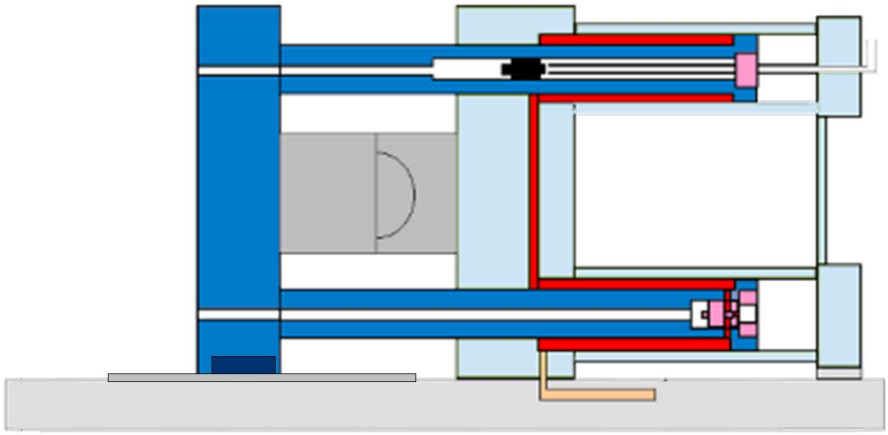


Figure 2: Direct hydraulic clamping unit design KraussMaffei CX series /2/

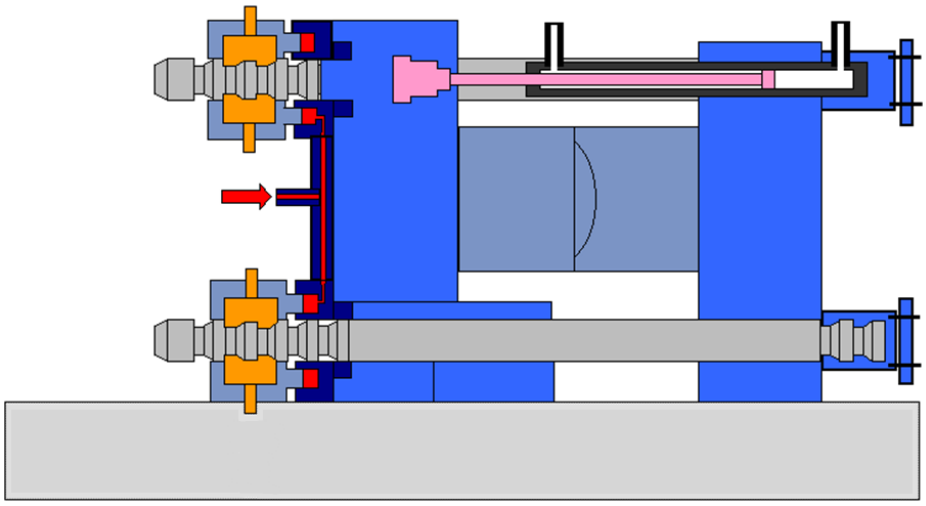


Figure 3: Hydraulic mechanic clamping unit design KraussMaffei MX series /2/

In both cases the functions of force build up and platen moving is separated to fit to the different needs. For moving the platen, high speeds are desired and therefore cylinders with small surface are used. For achieving high clamping forces at moderate oil pressure, large surface cylinders are used.

1.2. Hybrid driven injection moulding machines

So called hybrid injection moulding machines are using a combination of electro hydraulic and electro mechanic drives for the different drives axles. In Figure 4 a hybrid machine is shown that uses electric direct drives for the functions of injection and plastification (rotation of the screw).

Figure 4: Hybrid injection moulding machine design KraussMaffei CX Hybrid /2/

The movement of the mould and the ejector (for moulded parts) as well as the movement of the injection unit are hydraulically driven. The machine, which is shown at Figure 4, is furthermore equipped with some options that allow an operation in clean room areas. Special are the laminar flow box above the mould area, the delivery chute and the clean room qualified colouring.

By using separate drives for the injection unit, the option of parallel plastification and therefore a higher productivity exists.

By the fact that there is no universal definition of hybrid machines, different hybrid machine concepts can be found in the market. There are for example high speed machines that use an electric drive for the movement of the mould and an accumulator powered hydraulic high speed injection system. Other machines use a hydraulically driven clamping unit (also hydraulically driven toggles are used) in combination with an electro mechanical injection unit as shown in Figure 4.

2. Requirements towards hydraulic drives axles used in injection moulding machines

As shown before the demands hydraulic drives have to match are different for the various fields of application. One demand has become more and more important in the last decade. The plastics processing industry is one of the bigger energy consuming sectors, so that the energy efficiency of the machines gets more and more into focus. In many cases the energy efficiency of the equipment is taken into account as well for the investment decision.

2.1. Requirements towards the drives in the injection unit

The injection unit of an injection moulding machine is the part that plasticises the plastic feedstock, stores it in front of the screw for the following production cycle when it is injected through the nozzle into the mould. See Figure 5.

Depending on the field of application the needed injection pressures (of the plastics melt) vary from 250 bar to more than 2500 bar which results in required hydraulic pressures up to 250 bar and more. One special field of application are the so called thin walled parts where the plastics melt has to be injected in a cavity that has a flow path as small as 0,3 mm. The ratio of flow path height to length is usually higher than 300. Due to the fact that the mould starts cooling down the plastic meld immediately after it enters the cavity, the whole mould filling process has to be very fast since the wall thickness is little. Typical injection times in this application (mainly packaging) are below 100 ms which results which results in high performance requirements to the hydraulic drive. The resulting injection speeds have to be as high as 600-800 mm/s.

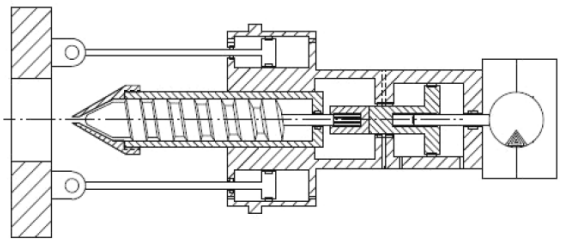
a)  b) 

Figure 5: Principle function of the injection unit of an injection moulding machine; a) hydraulic drive; b) electro mechanical drive /2/

At the same time the cooling time that is need for the thin walled part is comparatively little so that the plastification has to be at high rotation speed to. The rotational speed of the drive for plastification can be as high as 400 rpm/min and needs high torques.

The electro mechanical injection units that are available in the market do not jet reach such high injection speeds, but the electrical ones seem to catch up. Today many machine manufacturers offer electrical driven machines with speed up to 500 mm/s. A challenge the electrical machines have to take in the future is the high electrical peak loads that are needed for achieving the high acceleration rates. The hydraulically driven unit uses normally energy stored in a hydraulic accumulator, which results in are relatively continuous energy consumption. Today there are no relevant options to store high amount of electric energy like in a hydraulic accumulator.

3. Competitive situation of hydraulic and electric drives in injection moulding machines

The markets for injection moulding machines are highly heterogeneous around the world. In Japan for example only 30 % of all injection moulding machines are hydraulically driven the main fraction of 70 % are electrically driven ones. In the United States the ratio is equal at 50 % each machine type. The conditions in Europe again are completely different; here only 12-14 % of the installed injections moulding machines are electrically driven. /3/

Latest market studies on Europe forecast rising numbers of electrical injection moulding machines in the future. In /4/ it is shown that electrical machines in Europe will gain a fraction of 50 % in the clamping force range below 4000 kN, machines exceeding 4000 kN clamping force will almost solely be equipped with hydraulic drives due to technological limitations of the electrical drives.

3.1. Literature

/1/ Catic, I.: Quo vadis Spritzgießen? Gummi Fasern Kunststoffe 9, 2002

/2/ NN.: KraussMaffei Technologies GmbH, Kundeninformation 2011

/3/ NN.: Die neue E-Offensive, Spritzgießen 10_20080

/4/ Urbanek, O.: Euromap Study, Energy efficiency of plastics an rubber machines in Europe, June 2011