Fachhochschule Bielefeld
University of Applied Sciences

Fast-Cycle Injection Moulding Machines with Tandem Moulds

Enhancing Performance. The implementation of a new mould concept drastically reduces the “dead times” with injection moulding systems. A precise analysis of these dead times shows that shortening them not only results in an increase in output, it also brings an improvement in part quality due to the additional cooling time.

In March 2002, the Fachhochschule Bielefeld presented its tandem mould development concept [1] as a prototype at the KMO in Bad Salzuflen. In December, Wolf GmbH, Vlotho/Germany, started up a first production line with a tandem mould for manufacturing vacuum cleaner bag closure strips (Fig. 2). The concept was recently awarded the bronze “Euromold award” at kite Euromold.

Fig. 2. Closure strip for vacuum cleaner bags

There are many possibilitie6 for enhancing the output of a production lute, but unfortunately they normally involve it considerable amount of time and investment. Calculating when such an investment has actually paid for itself will often reveal that the economic benefit is small when weighed against the technical risks involved. This article describes a surprising new way of how, with slightly modified moulds, an increase in output of 50 % can be achieved on standard injection moulding machines at cycle times of less than 10 s, even with high-speed applications in the packaging segment.

An analysis of the cycle demonstrates the possible savings potential. According to the present state-of-the-art, there are two obvious solutions for raising the production speed: Either we reduce the machine movement times (mould movement, demoulding and possibly handling movement), or we concentrate on the cooling tine and endeavor to improve the tool’s cooling performance. Impressive examples of both alternatives exist, and some of them go close to the physical limits. If we are already using state-of-the-art equipment, any further shortening of the cycle time - in other words any increase in output - will be very difficult indeed.

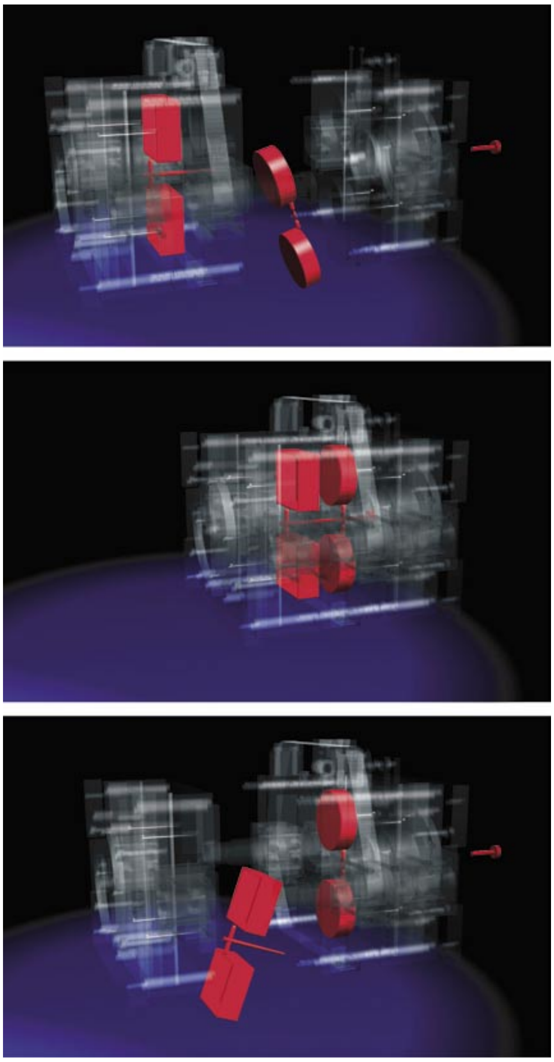


Fig. 1. Alternate opening of two parting lines in a tandem mould

C. Jaroschek, Bielefeld, 3/2003 and 6/2005

However, a closer analysis of the cycle often reveals a "dead time"; in which the machine does not actually do anything. Normally, the dead time is defined as the period in which the machine has already been charged with material and further cooling time elapses until the machine opens. With high-speed applications with parallel driven injection moulding machines, we must define the term "dead time" differently. In this case, it means the time in which the screw is not in action: With a fast 5 s cycle, the screw often waits more than 0.5 s for the next injection process before the mould is closed again. With tandem moulds, these dead times can be utilized, thereby increasing the volume output of the machines.

The Mode of Action of Tandem Moulds

Tandem moulds enable alternating operation. Unlike multi-daylight moulds, the parting surfaces open in a cyclically staggered rhythm: While one side cools down, the other can be demoulded and filled again. At first sight, it may seem that this process has no advantages, but it should be borne in mind that multi-daylight moulds are often not used on conventional injection moulding machines, because to open two parting lines, a larger opening stroke is needed, and to fill double the number of cavities, the injection unit must be considerably more powerful. In the case of tandem moulds, however, only one side is filled and demoulded at any one time, which means that the process itself is comparable with the conventional process (Fig. 1).

For the alternating cycle mode of operation, a bayonet locking system needs to be mounted outside onto the mould (Fig. 3), activated by a rotating toothed belt. The machine needs a special core pulling program that controls the activating cylinder for the toothed belt drive. This action always takes place with the mould closed under clamping force. In this condition, a mould normally shrinks by approx. 0.3 mm, so that the bayonet can lock without force. Only when the clamping force is reduced does the mould relax, as a result of which the bayonet closure is put under tension and holds approx. 20 % of the applied clamping force.

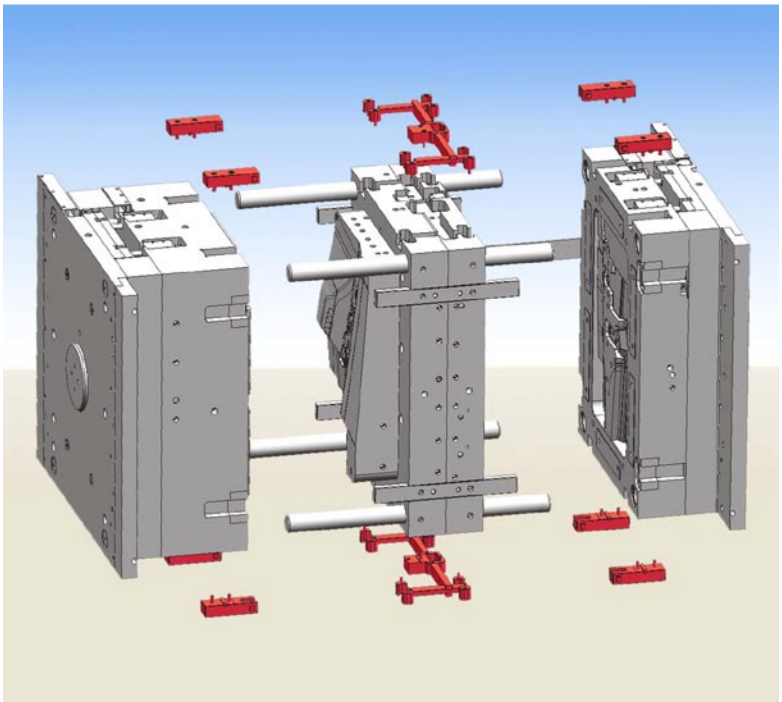


Fig. 3. Arrangement of the bayonet locking system of a tandem mould

Mould movement only begins when the holding pressure phase has finished. Calculations show that, at this point in time, the clamping force requirement of the machine is virtually zero (Fig. 4). Although there is a higher cavity pressure near to the gate, it has at this time normally fallen to 0 bars away from the gate. With this low residual clamping force requirement, there is unlikely to be any excessive injection pressure due to breathing of the mould as a result of inadequate locking force through the bayonet locking system.

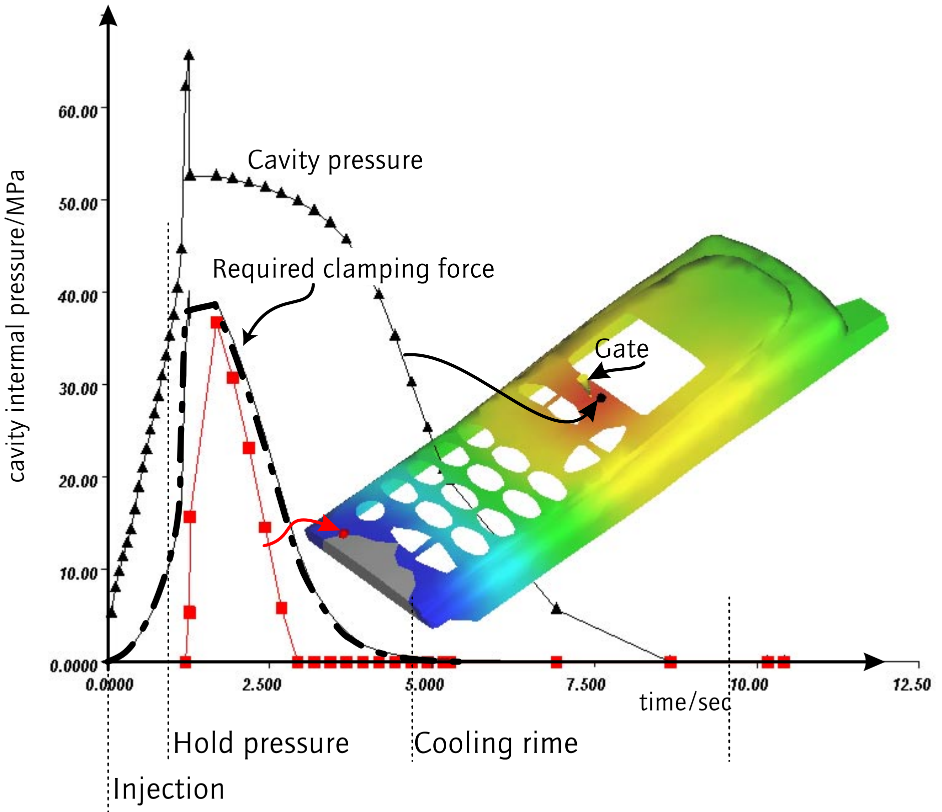


Fig. 4. Calculation of the required clamping force based on the locally prevailing cavity pressure in relation to cycle time

Analysis of a Tandem Cycle

For a comparison of the standard processes with those of tandem moulds, it is worthwhile breaking down the cycle into the percentage times for machine movement, injection, holding pressure, metering and cooling in the form of a bar chart. In the reference production process shown below, the cycle time with the standard 4cavity mould is 4.8 s. It should be noted that the metering time is slightly longer than the cooling time. In the case of a machine with a parallel drive, this does not result in any increase in cycle time (Fig. 5).

For the tandem process, certain boundary conditions are important. When the holding pressure phase at one parting line ends, the mould can be opened at the second parting line. In parallel with this, the screw feeds the melt for the next shot into the second parting line. It can be seen that the injection procedure begins with a certain delay because it has to wait for the end of the plasticizing. If we add together all the times for the individual steps in the cycle, we get a cycle time of 7.4 s. With this cycle time, all the individual times of the standard cycle have been retained. The tandem cycle, however, involves two opening movements of the injection moulding machine. It thus opens every 3.7 s, which is equivalent to speeding up the production cycle by 30 % (Fig. 6).

An interesting aspect is the additional cooling time. Every parting line only opens when the injection and holding pressure phase has been concluded at the other

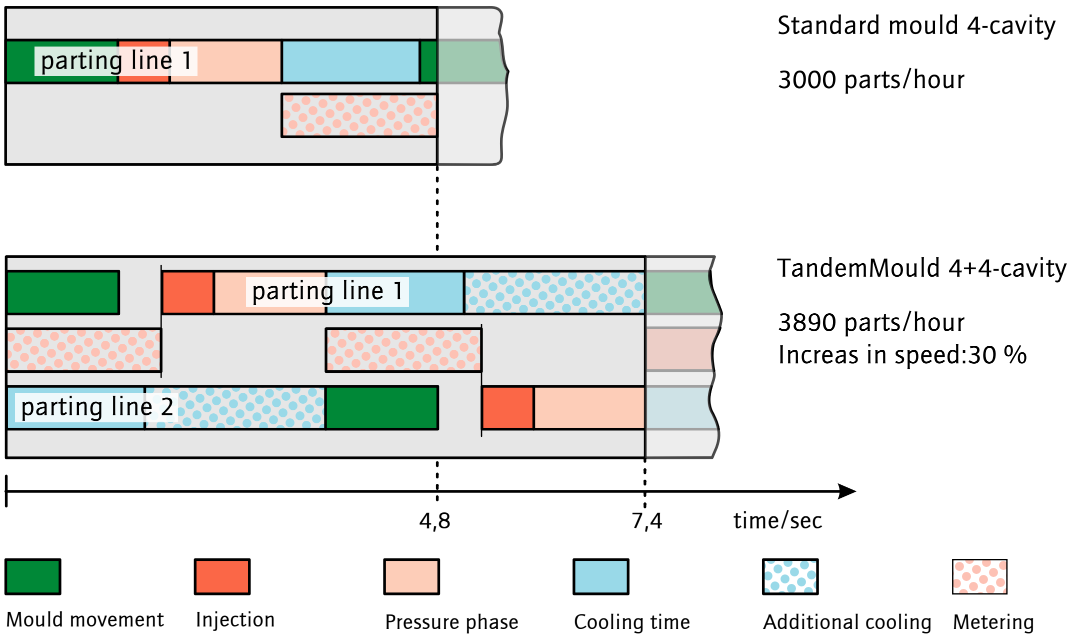
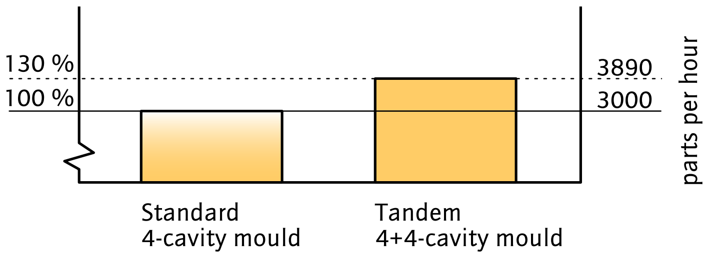


Fig. 5. Cycle comparison: Comparison of a standard injection moulding cycle with a fast-running tandem cycle



Fig, 6. Increase in speed: Comparison of volume output

parting line. Figure 5 shows that the cooling time more than doubles as a result. Nevertheless, the output of the machine is increased by 30 %.

If we arrange the individual phase times from Figure 5, we find that, in the case of a tandem mould, the dead time with a high-speed machine really is reduced to zero (Fig. 7). The picture shows the possible independent machine actions. With the tandem mould, the screw no longer comes to rest. With a very fast cycle of e.g. 5 s, the dead time in a standard process with a machine having a parallel drive will be approx. 0.5 s. This is 10 % unused machine time.

With very short cooling times, the output of the machine cannot be doubled with a tandem mould because the process at the second parting line takes longer than the cooling time for the first. As shown in Figure 7, the output can nevertheless be significantly increased. An interesting aspect now is the additional cooling time at the first parting line, which lasts until the end of the holding pressure phase at the second. Compared with normal short cycle production, not only is the speed increased, the quality of the parts is also improved because they only leave the mould after a longer cooling phase.

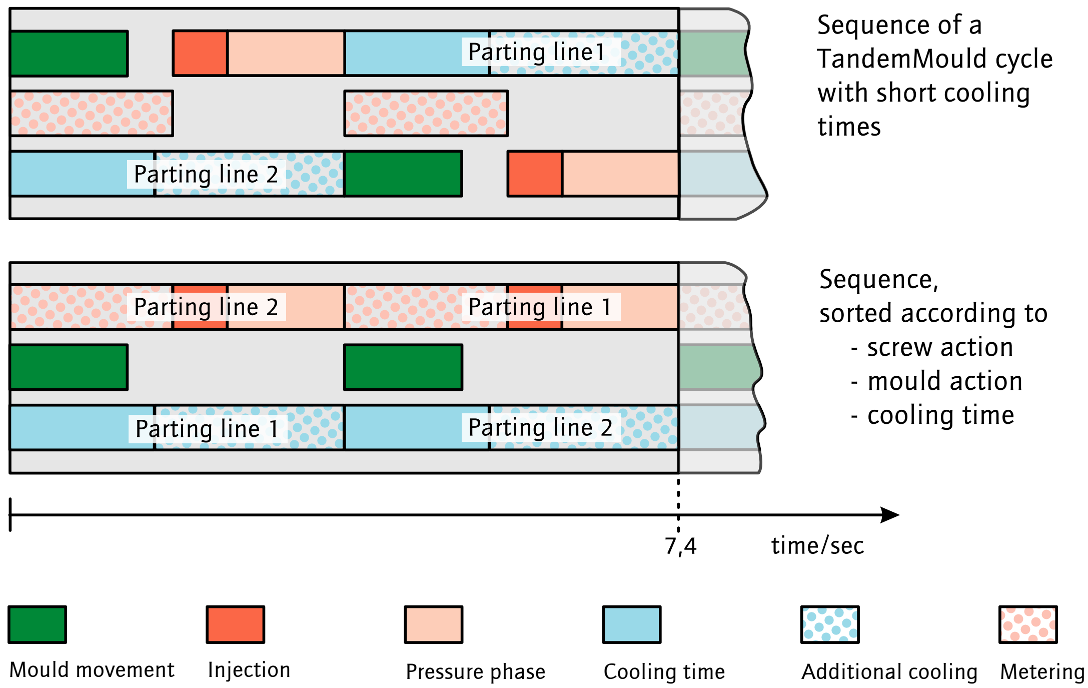


Fig. 7. Cycle time analysis of a tandem cycle, sorted according to machine actions

Concluding Remarks

Tandem moulds have for a long time not just been of interest for thick-walled, slow-running processes. Especially with high-speed applications, tandem moulds yield not only a significant increase in output but also improved quality, because parts from fast-cycle machines are often demoulded at high temperatures after as short a cooling time as possible, and consequently have only limited dimensional stability.

This means that the possible applications for tandem moulds can be considerably extended. Basically, all moderately flat parts produced in high volumes can be manufactured in this way. At present, studies are focused on converting existing moulds for subassembly components into tandem moulds.

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