THE MOLDING EQUATION: HAVE WE BEEN MISSING SOMETHING?

As manager of a molding shop you learned the importance of good, consistent cycles. You saw the effect of good versus bad cycles on the bottom line of the income statement— how much nicer it is to look at the net profit when you have been careful to keep your cycle times to a minimum! (Take a look at our Savings Seconds chart to see just how much you have to gain.)

So, you made a wise decision: to keep track of your cycles and to make sure that your set-up men reproduced the best possible cycle each time a mold was set-up. To do this you would make sure that an accurate record was kept of all the machine settings, as well as the overall cycle time, which in the old days you probably checked with a stopwatch but on newer machines “it is” accurately displayed on the computer. Now you are all set to precisely reproduce the best possible cycle you can achieve on that mold, right?

Wrong! Despite the fact that you may have accurately measured the overall cycle and it’s the same as it was on previous runs, there is still a potential for a considerable degree of error in the set up, this derives from the fact that the overall cycle is composed of at least four distinct phases--mold opening, mold open, mold closing and the clamp closed.

On some machines ejection can only occur after the clamp is fully open. So mold open could be called ejection time.

At first glance it would not seem to be very important to distinguish between these phases. After all, if the overall cycle is right, that’s all that matters, isn’t it?

If the time to open the mold takes one-half second more than it did during the last run, then the time to close the mold and/or the time the mold is closed will be one-half second less to compensate. Without being analyzed, this would seem to be quite unimportant--and therein lies a trap into which every molder seems to fall; for the neglected fact is that for every change made in the clamp end of the machine a compensating change in the injection end will be required. But because of thermal delays in the mold and injection unit it may take hundreds of cycles to show up.

In order to illustrate the trouble you may be letting yourself in for, let’s go into the production room where a set-up man is just now putting in a mold that runs on an all overall five second cycle. Although he doesn’t have these figures available (except the overall cycle), the breakdown of the cycle during the last run was this:

The mold running was a 4 cavity P.C. fire extinguisher window and the machine was a 125 ton H.P.M. with ejection on the fly. So ejection took place during the mold opening time.

Clamp opening time:	0.60 seconds
Clamp open time:	0.00
Clamp closing time:	0.70
Clamp closed time:	3.70

Overall cycle:	5.00

Now he has set the mold and he (and his supervisor) is happy that he has again achieved an overall cycle of five seconds. Only this time, because the timers found on most injection molding machines in the mid 1970's were not so precise, and there is no time out put from the machine for the movement times of closing to injection and opening to ejection completion even on the newest machines.

Clamp opening time:	0.90 seconds
Clamp open time:	0.00
Clamp closing time:	0.90
Clamp closed time:	3.20
Overall cycle:	5.00

The mold is opening 0.3 seconds slower and closing 0.2 seconds slower than it did on the last run. These times can not be measured with a stop watch. To compensate, the mold closed time is 0.50 seconds less. This seemingly insignificant change represents a difference of—believe it or not—more than 13%! If you do not believe it, get out your calculator and follow through with the calculations:

Original clamp closed time:	3.70 seconds
Current clamp closed time:	3.20
Difference:	0.50

$$\text{Percentage difference} = \frac{0.50}{3.70} \times 100 = 13.51\%$$

What will be the significance of this change? Obviously the molded part is clamped in the mold 13% less time than it was during the last run. That's bad enough, but there's more.

Less obviously, it will also affect the injection end of the machine. For example, the screw now must retract 13% faster, since it can only retract while the mold is closed. (Unless a nozzle shut-off valve is used.) That, obviously, will affect the melt condition. In order to plasticize the same volume of material that much faster and keep the same melt condition, more heat will be needed. Say this mold is running a polycarbonate part and the barrel temperatures were 525°F. If the heat were to be increased by 13%, the temperatures would then be:

$$525 \times 1.13 = 593.25°\text{F}$$

It would be highly unlikely that a change such as that, however, would be made. It almost certainly would result in discolored parts due to degradation of the plastic. (Just to emphasize how much a 13% difference is, say the barrel temperatures were changed to 13% lower than they should be:

525 x .87 = 456.75°F

Let's return to the molding room and see what's happening.

The set-up man has started the mold. Everything is set exactly the same as the last run according to a set-up data sheet taken at that time, except that the mold closed time is a little less and opening and closing times are a little more, as we have noted. He has also had to increase the screw speed in order to get a full shot. Everything has come to equilibrium, but the parts are still short. Without analyzing why (which we know is because he is dealing with a colder melt) he knows he must make a change. He could increase the barrel temperatures, but as we have noted, this would be unlikely, especially if he is an experienced set-up man.

He could, instead, increase the mold temperature. His set-up sheet from the last run might indicate that the mold heater was set to 180°F. If he opts for this route and readjusts the water temperature upward until the parts are good he will probably have a temperature of 203°F, which is 13% more than 180 (1.13 x 180 = 203°F). (Again to demonstrate the gravity of a 13% change, if the mold temperature were changed so that it was 13% less than it was supposed to be, the temperature would then be 0.87 x 180 = 156.60°F).

Most likely, however, he would first change injection pressure. If the part was supposed to have been molded at 15,000 p.s.i. injection pressure, a 13% increase here would result in a pressure of 16,950 p.s.i.—a considerable difference. (A 13% decrease, again illustrating the degree of the change we are talking about, would mean a pressure of 13,050 p.s.i.)*

Although good parts are now being molded, consider that a great deal of time has been wasted in arriving at a new cycle, whereas, if each phase of the mold stroke had been set precisely as it should have been to duplicate the previous run, good parts would have been made almost from the beginning. Moreover, the whole process might be repeated again by the next shift! If a problem develops, the next set-up man's first reaction might be to try to duplicate the last run by resetting the machine according to the set-up data sheet again. Or, he might make additional "corrections" to the cycle. For example: after the mold has been running for a while the fact that the clamp closed time is 13% less than it should be might start to create problems—the parts have less cooling time and sinks could develop. He might increase pact-out but then find that additional clamp closed time would be required because the parts now stick in the mold.

Suppose he has to increase the clamp closed time to 3.7 seconds—the same as it was for the last run—but he doesn't decrease clamp closing or opening time (he almost certainly will not think of that). Now the overall cycle is 5.50 seconds instead of five seconds. Already the cycle is slower than standard and without knowing why it now "has" to be that way in order to make good parts! Even this change, however, may later result in further corrective action and the problem mushrooms as the cycle drifts further and further from standard.

In summary, we have seen how a seemingly harmless change of just half-a-second in the mold stroke—originally not affecting the overall cycle—has now led to a longer overall cycle. We have arrived there via a route of wasted time and rejected production; a very expensive way to get there. Taken together it will show up on the bottom line as missing profit.

So, in order to put that profit back into the picture, remember: the molding equation is:

<u>Good parts</u> = correct injection settings PLUS correct timing of the four clamp functions, not just the correct injection settings.

There are four dissident and different parts of a cycle, they can not and must not be treated the same. The injection machine builder should display these times to the molder because no cycle can be reproduced by the set up person without this information.

*please note that not all the “corrective” measures to compensate for a 13% change in clamp closed time are directly proportional. We are presuming that they are, however, merely for illustrative reasons.