On/off barrel cooling control

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The following lists the advantages and disadvantages of on-off control and advice on limiting the effect of the disadvantages:

Ideally, it would be better to cool using true proportioning. Unfortunately, practicality dictates that cooling be on-off primarily because, if true proportioning were used, cooling would have to be applied uniformly around the barrel. This is not the usual case. When heating, heater bands do apply heat uniformly.

To illustrate uniform cooling, we can look back at the Willert vapor cooling system with which I would say most of you are not familiar. In this system, a jacket of liquid coolant, under pressure, surrounds the barrel and it is maintained at the same temperature as the barrel. To remove heat, the vapor pressure is reduced using a remote (actually on top of the extruder) heat exchanger to cool the vapor. The coolant boils uniformly around the entire barrel. This is a very effective way of removing heat and is used primarily for extrusion of very heat sensitive materials. However, this type of cooling system is no longer being built because of maintenance problems, primarily system leaks (pinholes in welds, etc. since the coolant is under considerable pressure) and the cost, the latter which reflects the practical aspect of cooling system design.

Now, if we look at a simpler system, such as water cooling, the usual approach is to have water enter a cooling jacket at a single point. If we pulse (the on-off approach) water into the jacket, water can reach every part of the jacket before flashing into steam.

It is important to get the water distributed throughout the jacket quickly before it changes stale, since about eight to ten times more heat is removed during the change of state from water to vapor, than occurs with the rise of the temperature of the water. Otherwise, cooling is localized which creates many problems including bowing of the barrel. This will also occur if we use true proportioning and the water trickles into the jacket at one point. Then we end up with localized cooling because the water in liquid phase may never reach other parts of the jacket.

If we look at air cooling, there is no phase change; however, the air rises in temperature as it moves across the face of the jacket. If the air moves quickly, the temperature rise will be less and heat removal greater.

So, if we want to use true proportioning, we really have to have multiple entry parts around the jacket— the more the better, but this gets expensive. Controls for on-off temperature control are also less expensive.

While on-off temperature control does cause some swings in barrel temperatures, it can be minimized by using jackets of relatively large mass and by keeping time proportional (or on-off) control bands relatively narrow. Actually, as the on-off (or time proportioning) frequency increases, control approaches true proportioning with its attendant problems. A compromise, though, can be affected. On-off control is best implemented with solid-state controls for low maintenance.

— William K. Foerster, P.E.

In answer to your query on temperature controllers — on—off vs. proportioning of some type sends me back to the saturable core reactors that proved disastrous on dies when we got to adiabatic operation. They wouldn't turn off.

The point is that there are three (or more) types of heating loads in plastic extrusion:

1. 1 is the steady state load. Extrusion ought to be thought of as a steady-state process and it ought to be designed to be almost adiabatic. For this kind of load, al most any heat control is sufficient, but should act as a trimmer, much as trimmer controls act in airplane controls. It should be measured close to the beat source,

such as on the heater band, while the plastic itself is inside the barrel.

I personally feel very strongly that both heating and cooling should not be applied to a single extruder zone. Assuming the trimmer effect is effected, there is a tendency for any control like this to overshoot. As it does, it brings in the opposite to correct. There are many ways to correct for this, but still on-off control should suffice.

1. 2 Load is beat-up load. Completely different from running, yet the same instrumentation is asked to take over. Here, the ideal control would be to turn the system on at high level, then turn it off at the exact point of overshoot to let it "coast" to control point at the time the extruder is started. Impossible in practice, but theoretically easy.

Some instrument manufacturers point out that their instruments accommodate warm-up. A more sophisticated program might help.

1. 3 Load is process change load. Changing extruder speeds, for instance. I suspect much of the sophistication in instruments is designed for this change. No doubt, current proportioning would work better here.

However, I doubt if one operator in ten would understand the implications of the tool he is using.

I contend that we should design extruder barrel temperature control only for steady-state. Ninety percent of today's operations could get by with the worst of instrumentation available, as long as the instrumentation is working. The balance require something more, with multiple-mode being well within the capability of most basic program writers.

SO MUCH FOR EXTRUDERS — Die temperature control is another story.

We generally assume that the die generates no heat in itself and that it should operate slightly above melt temperature. Here current proportioning that can go to zero works well. We often use powerstats with hand control. On-off cannot be applied easily with different time lags through different cross sectional metal depths.

Finally, the total energy concept should be kept in mind. Preheating the feed to annealing the finished product are within the control parameters and should be kept in mind.

— Robert L. Miller

This is in answer to your question about extruder cooling.

Before we look at the heating and cooling mode of the extruder barrel, attention should be given to the materials we are moving through the barrel.

Some materials are temperature forgiving — possess more temperature tolerance. However, rigid PVC loaded or unloaded must be treated with respect. Other materials I have worked with — ABS, Styrene, high and low density PE and EVA are much less heat sensitive.

Years ago, I was pioneering a rigid vinyl compound highly filled with asbestos fibers. This viscous material was processed through an extruder (the extrudate then molded) and the frictional heat was high. Air cooling was not enough to maintain barrel temperatures. Oil cooling was better, but still not enough. Water cooling was the answer for this tough compound. Barrel heating was not a problem since much of the heat was generated by the milling action of the screw.

Today, rigid vinyl compound is quite easy to control. The use of current heat proportioning is good — it has worked well

for me. Likewise, air cooling has been quite satisfactory — air has a gentle affect on the barrel. Water cooling is instant but results in a sudden shock to the barrel. In rigid vinyl, it is recommended that the screw be oil cooled (temperature controlled). Air cooling in the screw is OK except a high volume of air is required to keep the screw from over heating.

If one has experience in the rigid vinyls, he should not have problems with materials listed above. With the present current proportioning heaters and air cooling, one should not have difficulty achieving satisfactory production.

However, a common mistake — blaming the poor performance on the heaters and cooling devices. It may be the result of improper screw and/or die design. In rigid vinyl and high density polyethylene, I had success with modifying the screw and die, resulting in smooth, proportional heating and air cooling, increasing production far greater than estimates given by the material suppliers.

On-off heaters do not provide for smooth barrel heating. Too much heat will result in more difficulty in handling the profile. Current proportioning will smooth out the barrel heating. Air cooling is gentle — does not shock the barrel. This keeps the material viscosity constant, resulting in easier handling and cooling of the profile.

To sum up the discussion, current proportioning heaters on the extruder barrel work well — does not impart excessive heating, resulting in a fairly uniform material viscosity. On-off air cooling is good. It is gentle and does not shock the barrel as water would. Before you blame the heating and cooling, take a close look at the screw and/or die design.

—Don Biklen

See also

Barrel heater maintenance and installation

Extrusion screw wear

Feed screw temperature control in the single screw extruder

Heating modes for extruder barrels

Optimization of cast aluminum barrel coolers

Temperature control

Two stage extrusion Water cooling extruders