Gear Melt-Pump (GMP) Control Modes Comparison

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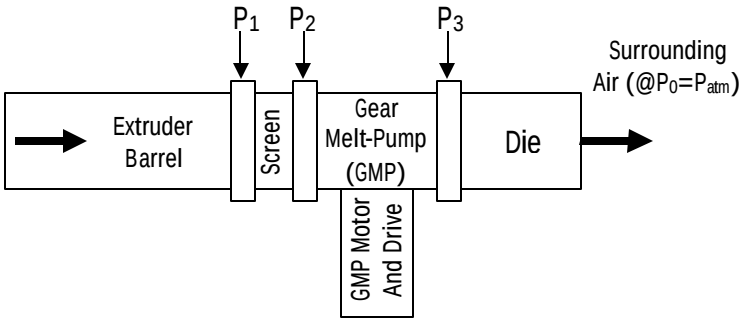
Understanding important hardware components' features and measurement and control characteristics will contribute to effective extrusion setup and improve quality and precision of the final product. The followings are my comments from scientific point of view and based on extrusion observations only, since I was not trained nor have access to any documentation related to the equipment.

After initial extrusion process observation, I like to discuss differences (advantages and disadvantages) between the two modes of control of the extruder's gear melt-pump (GMP). Namely, the GMP is a very important hardware component, which serves to stabilize the flow and pressure fluctuation of the extruder. Through two control loops (modes) its Motor Drive could either maintain constant RPM speed or constant exit pressure. Since it is a positive-displacement pump, its volume flow rate is proportional to its rotational speed (RPM). The pressure before (P_2) and after (P_3) the GMP is measured as well as its RPM. In addition melt pressure (P_1) at the extruder barrel exit is measured, see the schematics below.



During the November 6, 2003 extrusion process, I observed that pressure P_3 was virtually constant (about 350 psi; since the GMP was set in constant-pressure control mode), but its inlet pressure P_2 and extruder exit pressure P_1 were fluctuating significantly within 1000 psi range (unexpectedly, reflecting poor control of feed rate), from 80 to 1380 psi, the difference between the two (P_1-P_2) being about 300 psi (as expected).

The polymer melt flows after the extruder barrel exit (at P_1) through a breaker-plate screen (a passive device, to filter and mix the melt), then entering the GMP (an active device, at P_2) and after the pump (at P_3) entering the die (a passive device) and finally being extruded in (or through) the ambient air (at atmospheric or zero gage pressure P_0),

For a constant melt mass flow rate, $\dot{m}$ (set in KTRON control loop) and constant melt property (density r, viscosity h, etc.) the volume flow rate and the pressure drop across a passive device (like Screen or Die) is constant, i.e.:

$$P_1 - P_2 = P_{1-2}(\dot{m}, r, h)\big]_{\dot{m}, r, h = cons} = const; \text{ if } P_2 \neq const, \text{ then } P_3 \neq const$$

$$P_3 - P_0 = P_{3-0}(\dot{m}, r, h)\big]_{\dot{m}, r, h=cons} = const;\ \text{since } P_0 = const, \text{ then } P_3 = const$$

Therefore, for constant melt mass flow rate and properties, there is no difference between the GMP constant speed (RPM) or constant exit pressure control loops. The GMP will run at constant RPM and constant exit pressure P_3, while P_2, will depend on (and vary with) P_1 (since P_1-P_2=*const*). Extruder barrel pressure P_1 depends on the mass flow rate through the feeder, which is hard to be maintained constant, due to problems with continuous feeding (KTRON control loops), among others. The function of the GMP is exactly to eliminate those feeding mass-flow-rate fluctuations, the latter still to be controlled and minimized for better consistency of the over-all extrusion process and quality of the final product.

However, if properties vary, say density, due to temperature fluctuations, melt inconsistency, etc., then the outcome depends on the GMP control loop choice, i.e.:

1. If the GMP is running in the **control speed (RPM) loop mode**, the volume flow rate will be maintained constant (for positive-displacement pump; within the accuracy of the instrumentation and control loop), but mass flow rate will vary with density change (if present). At the same time viscosity will vary with temperature (also shearing history, etc.) and pressure drop across passive devices will vary, thus P_1, P_2, and P_3.

2. If the GMP is running in the **control pressure loop mode**, then P_3 will be maintained constant (within the accuracy of the instrumentation and control loop), and volume flow rate (thus RPM) will vary to accommodate for other changes (say temperature and melt properties changes). Since viscosity (and density, etc.) may vary, then pressure drop across passive devices (thus P_1 and P_2 may and will vary).

The question is, **which GMP control mode is more appropriate**? Since each mode has certain advantages and disadvantages (that why there is two modes to choose from), the answer depends on particular application. In our case, if temperature fluctuation is a possible issue, then density dependence on temperature is much weaker that viscosity temperature dependence (also viscosity depends on fluctuating shearing history in the screw barrel due to fluctuations in feeding), one may ague that mass flow rate through the die (the objective to be achieved!) will fluctuate more at constant pressure (due to viscosity variations) than at constant RPM speed (thus volume flow rate, due to density variations). Thus, the GMP speed (RPM) control mode may be better than control pressure mode, which is used now. The best way to find out, is to experimentally verify the above.