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The Importance of Monitoring Extrusion Stability

It has long been known that pressure instability for polymer melt entering the die usually results directly in output variation. From 1960 to 1964 various investigators at DuPont and Union Carbide published articles citing examples of situations in which output fluctuations were found to be up to three times the measured pressure fluctuation. However, instrumentation used in these early studies was too delicate and expensive to be practical for routine commercial use. An excellent article written by B.H. Maddock, covering some of his early studies is title "Measurement and Analysis of Extruder Stability". It appeared in the December 1964 issue of the SPE Journal.

Maddock pointed out that a pressure variation at the die entrance could be caused by either an actual variation in temperature (affecting viscosity) of material passing through the die. However, if the pressure fluctuates, there is no protection against output fluctuations unless a gear pump is used. Maddock's article pointed out that "a pressure fluctuation not accompanied by a variation in temperature is almost certain to represent an actual variation in rate (surging)".

If melt temperature is reasonably uniform, variations in pressure (and rate) are likely to originate from one or more of the following sources:

- Variations in feedstock (usually correctable by blending).
- Variations in screw speed (easily detected).
- Variations in barrel-temperature control (long-term variation).
- Poor extruder screw design and/or operating conditions.

Over the years, major manufacturers of pressure-measuring instruments have developed modestly priced models that serve as a combination transducer power supply, indicator and signal conditioner. These instruments (used with improved pressure transducers) also provide auxiliary output signals that can be fed to recorders for continuous monitoring of pressure fluctuations. This monitoring is important to determine if any of the deficiencies

exist, even if a gear pump is used or an expensive gaging system is purchased. If uniform melt temperature and pressure can be achieved by well-chosen extrusion equipment and operating conditions, there may be less need for these additional features. However, in many cases they can still be justified for better quality and increased output.

The studies performed by Maddock and other early investigators involved use of high-speed oscillograph recorders capable of reproducing high frequency pressure fluctuations with considerable fidelity. However, rugged, less delicate instrumentation now available should be capable of showing whether serious output surges exist. In practical applications we often can be content with slower-response recorders that give only approximate reproductions of fast pressure fluctuations up to about 10 cycles per second. If we can successfully manipulate the extrusion conditions to achieve a much steadier pressure (and output), the recorder will deliver a much steadier pressure trace.

It's somewhat like comparing an old Edison record player to a hi-fi phonograph. With the old Edison we can easily recognize the words and music, but the result is not a true reproduction. Likewise, in many commercial applications the pressure recorder need not be a high-fidelity instrument if we can be content with knowing qualitatively the nature of pressure fluctuations affecting output uniformity. Very high-frequency pressure fluctuations (above 10 cycles/second) entering the die are not likely to result in equally serious output fluctuations existing the die lips, especially for processes involving high die swell and low draw-down.

All things considered, modern pressure-measuring instruments that provide an auxiliary output signal fed to a moderately priced rugged recorder of intermediate fidelity merit strong consideration for commercial use to monitor die-pressure fluctuated, which strongly influences output fluctuation. It is important to recognize that a continuous pressure signal must be traced. Most of the instruments can be set to give a damped signal to provide a steadier average pressure reading, which is useless for monitoring pressure fluctuation. Also, some recorders print out average data on a frequent basis, and this type of information is also not very useful for monitoring pressure fluctuations.

Pressure-measuring instruments can monitor fluctuations to help determine the cause.

Vigorous development programs are under way to improve pressure-measuring instruments for production use. Suppliers now offer a programmable microprocessor-based pressure indicator with combined analog and digital displays and user-selectable voltage and current outputs to feed recorders or data-acquisition systems.

In most cases, the recorder is considerably more expensive than the pressure-indicating instrumentation, and its use also involves maintenance and study of the recorder chart

operation. For this reason it is often adequate to attach the recorder to the instrument only when the instrument readings appear relatively steady.

Extruder stability problems can be better diagnosed if pressure is also monitored at the screw tip and near the downstream end of the screw feed section. However, whenever the screw flight passes a transducer in the barrel wall, a pulse in the pressure reading that matches the screw speed for singe-flighted screws will appear and is not an indication of surging.

Unfortunately, some elaborate process-control systems fail to recognize the importance of pressure stability. An obscure die-pressure indication in one corner of a CRT display screen is too easily ignored. The pressure-indicating instrument should prominently display the magnitude of the problem (never damped, in my opinion). In some instruments, it is practical to set pressure alarms appropriately, in order to further dramatize the importance of minimizing pressure fluctuations.

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