Tips for Optimizing Twin-Screw Extruder Performance

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Abstract
A collection of 17 techniques (tips) is presented for increasing the performance of twin-screw extruders. Processors may be aware of some of these tips, but many are not well known. All are based on solid scientific principles, and have been proven in dozens of extruder installations. Also, all the techniques presented are easy to apply, so the benefits can be realized quickly.

Introduction
There are many techniques known to operators and plant engineers for increasing the performance of an extruder.

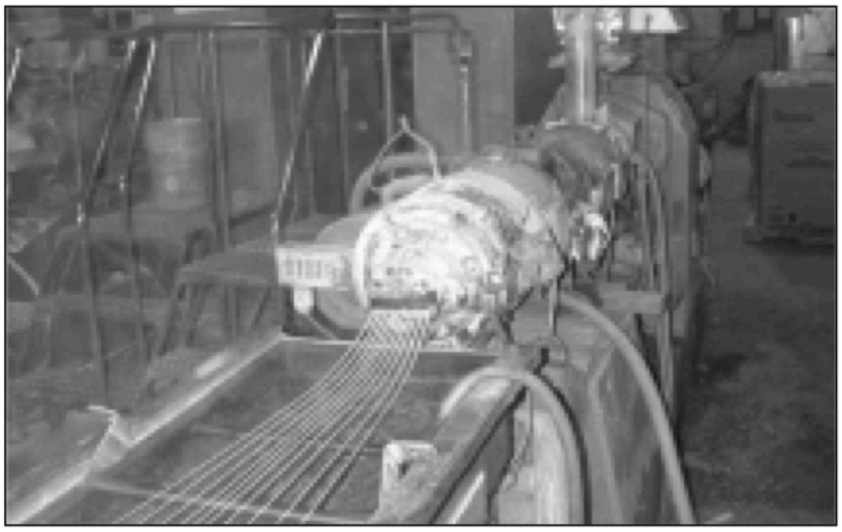

FIGURE 1 Typical color compounding production extruder

Because of their informal nature, however, most of these methods do not appear in any equipment manuals. Nor are they generally mentioned in textbooks and technical papers. But, sometimes, attention to several small details can add up to making a big difference in extruder performance.

The tips described in this paper fall into three broad categories:
1. Processing techniques
2. Machine modifications
3. Maintenance procedures

TIP #1:
Install a thermal insulator gasket after the feed barrel
The feed barrel in almost all cases is water-cooled. But because this barrel is bolted flange-to-flange up against barrel #2, which is heated, heat is continuously transferred from the hotter barrel to the cooler barrel. As a result, barrel #2 is often not able to maintain a high enough temperature. In a typical case, the operator has a set point of 180°C for barrel #2, but it can never get above 135°C because of heat loss to the feed barrel.

The easiest way to solve this problem is to install an insulator gasket between the flanges of the feed barrel and barrel #2.

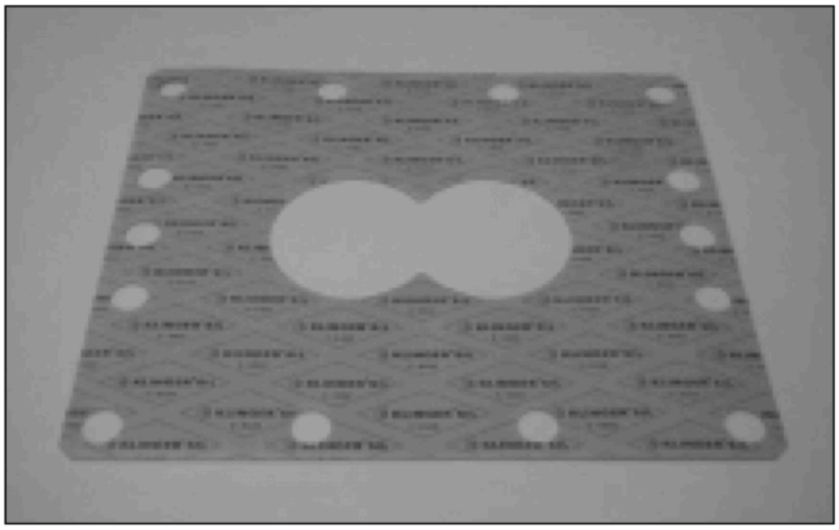

FIGURE 2 Thermal insulator gasket

These gaskets are typically 1mm thick, and it's recommended to stack two together for better insulating performance. There will still be some heat conduction through the bolts, and of course the screw shafts, but not nearly as much as without the insulation.

New extruders come standard with the insulator in place, but many operators don't realize the importance of it and throw it away when disassembling the barrels. Also, after several years the insulator gasket should be replaced, as the material tends to degrade and crumble.

TIP #2:
Set zones 1 and 2 to higher temperatures to decrease wear of plasticating screw elements
In most plastic extrusion processes, the first task (after feeding) is to melt the material. This must be done relatively quickly, in a short amount of machine length, to leave adequate extruder length for following process tasks. In order to continuously plasticate cold materials, which are introduced to the machine, a large amount of energy must be imparted to the material. This energy can come from only two sources:

A. Mechanical energy (friction, shearing, kneading, squeezing, etc)
Or:
B. Heat

In a twin-screw extruder, both mechanical energy and heat are acting on the material. But many operators rely too much on mechanical "brute force", and don't use heat effectively. Running the process this way causes the extruder to use too much torque just for melting, resulting in less torque available for other process tasks. Also, usually this causes rapid wear of the first kneader group, because it is being forced to do a disproportionate share of the melting work.

Many people ask: why do screw elements wear, when the material isn't that abrasive? This can be understood from Newton's 3rd law, which says that for every force, there is an equal force acting in the opposite direction. So if the kneader lobe is pressing against the cold pellets, the pellets are also pressing against the kneader lobe.

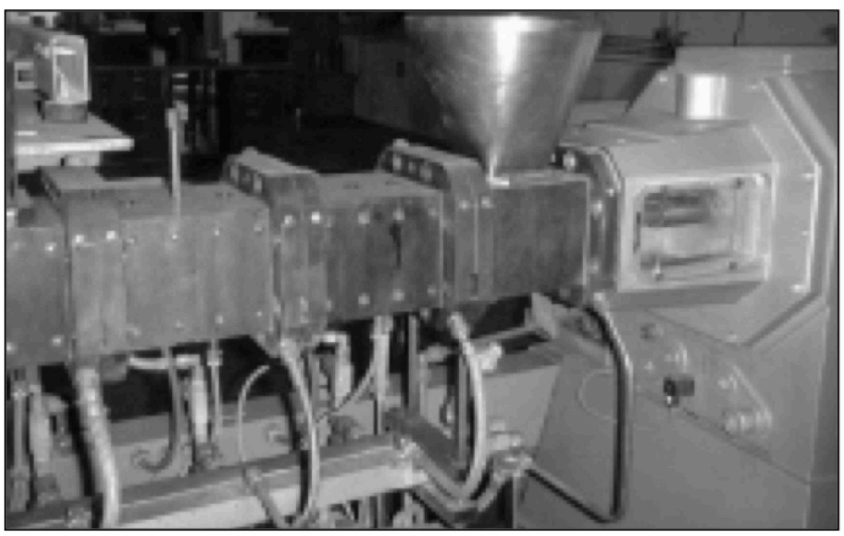

FIGURE 3 Plasticating zones 1 thru 3

Many customers set zones 1, 2, and 3 at too low a temperature, which means the energy for melting must come primarily from mechanical work. If these zones are set to higher temperatures, it will lessen the workload on the first kneader group, thus reducing the wear rate.

The reason most customers do not set the temperatures higher is because they don’t want a high melt temperature. But in fact the melt temperature will not be any higher, as the material is moving through the plasticating zones in a matter of seconds. It is common to have a barrel set point of 250°C in order to transfer a lot of energy into the material to cause it to melt, but end up with a melt at 180°C.

TIP #3:
Side stuffing of powders

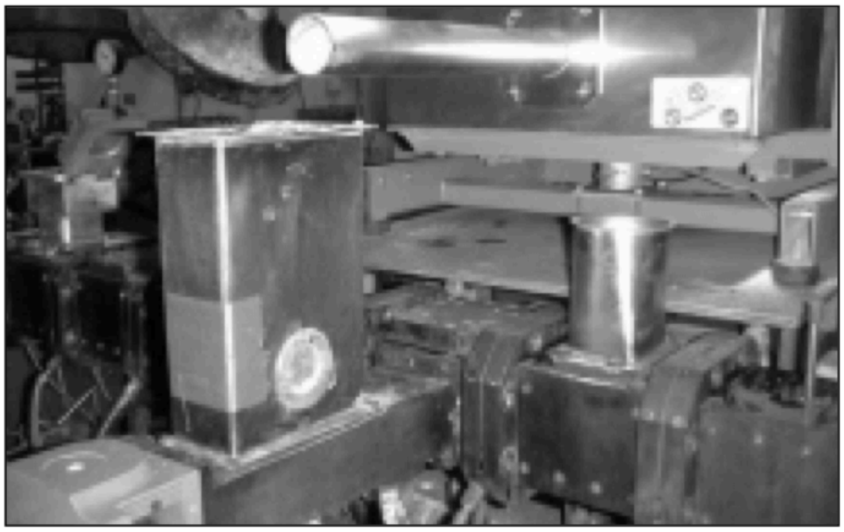

FIGURE 4 Side stuffing of powders

Side stuffing is widely used with twin-screw extruders for feeding of various fillers. Many processors desire very high % loadings of fillers, many of which are low bulk density (fluffy) materials. The ultimate % that is attainable is usually limited by two parameters:

A. Volumetric capacities of the side stuffer and main extruder screws
B. Venting capacity, to allow air to escape the extruder

The volumetric capacity is based on the free volume geometry of the side stuffer screws, as well as the main extruder screws, and of course the RPM of both sets of screws. Usually if a test is made running the material through only the side stuffer (with the stuffer unbolted from the extruder, discharging into a drum), it will easily feed a high rate of material. But when the stuffer is attached to the extruder, capacity is often limited by the amount of material the main extruder screws can accept.

In terms of extruder screw design, it is best to have flighted elements with a long pitch (long flight advance) at the stuffer location, extending 2 to 4D downstream of the stuffer. This is to keep the melt material in the extruder moving rapidly forward, to allow the maximum free volume for the filler to enter. If the screw design causes any “dam-up” of material downstream of the stuffer, this will severely limit the amount of filler that can be fed.

Important factors:
Back-venting: The object of venting is to allow air to escape easily, while preventing large amounts of filler being lost out the vent. The best configuration for this is to have a top vent in the barrel immediately upstream of the side-stuffing barrel. Sometimes a small slot vent insert can also be used in the top of the side-stuffing barrel.

Feeder drop height: Ideally, the feeder should be positioned as close as possible above the side stuffer, to minimize the drop height. If a fluffy material is allowed to drop through air, it becomes aerated to the point where the bulk density is significantly reduced. This can have a net effect of limiting the throughput rate of the entire line.

Feeder agitation type: Make sure the agitator in the filler feeder isn’t aerating the material, reducing the bulk density. Many feeder manufacturers have special agitator designs for powders, to preserve bulk density.

Make sure stuffer hopper is vented: Along with the filler, the stuffer also introduces a lot of air into the extruder. This air has to come from somewhere. If you have an open top on the side stuffer chute, then venting is already taken care of. If you have a solid cover on the chute with a round stub up and flex connector to the feeder, it's important to also have a vent opening.

Ground all hoppers/chutes to drain static electricity: Some materials generate static electricity from friction. If static is present, it can cause powder to cling to the inside surfaces of hoppers and chutes, leading to problems such as caking. If you think this could be happening, an easy fix is to run a ground wire (10 gauge wire is recommended) from the chute to a known good ground on the machine frame.

Compressed air blaster: If caking persists, sometimes a special solution is needed. Hopper vibrators can be used, but are tricky to size and mount. Another device that can be used is a "blaster". This consists of air jet nozzles strategically placed within the wall of the chute, directed to break up any cakes before they get too large. The air jets get connected to a sole- noid valve using poly tubing, and a repeat cycle timer actuates the solenoid valve. This way you can set both the blast period and dwell time in between blasts. Just upstream of the sole- noid valve it's best to have a small air accumulator tank, to provide a sharp pulse of air.

TIP #4:
Insulate melt pipes and dies
Very few processors insulate their melt pipe adapters and dies. The reason is because the machine didn't come from the factory with insulation, it takes some extra effort, and it is difficult to see the benefit. But if your control system has temperature trending capability, the benefit can easily be demonstrated.

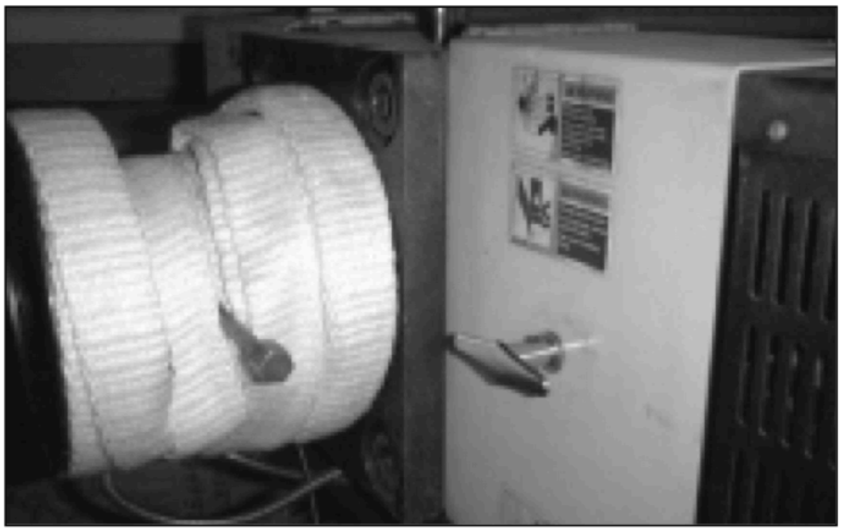

FIGURE 5 Melt pipe wrapped with insulation

As an example, take a heat zone actual temperature that is cycling up and down all the time. The trend looks like a sine wave. Now if you wrap the melt pipe section with insulation, you'll find the temperature trend is much more like a straight line. The reason is because you've greatly slowed heat transfer from the melt pipe to the environment, so the temperature stays the same all the time. If the temperature doesn't fall over time from heat loss, the heater contactor doesn't have to come on. If you can prevent the melt pipe from cooling and then needing heat cyclically, the temperature trend is going to be much smoother.

An exposed, heated steel part like a melt pipe loses a large quantity of heat to the surrounding environment via radiation and convection. This can easily be demonstrated by standing 12" or so away from a heated melt pipe or die. You can feel heat emanating from the melt pipe, even though you are not touching it.

There are some other benefits to insulating melt pipes. Because it slows heat loss, insulation will tend to make all portions of the melt pipe the same temperature. This has the effect of eliminating cold spots from uneven heater coverage. Another side benefit is faster initial heat-up times.

One very important benefit is that insulation makes the equipment safer for operators. Burns are the single most frequent injury around plastics equipment. If an operator accidentally leans against a melt pipe that is wrapped with insulation, he or she will probably not be injured.

– Jim Frankland, Leistritz

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