Popular Science Summary of Master Thesis Work

Modelling & Control of an Extruder Cooling System

Christopher Fritzon & Nils Persson

May 2021

Most of us in today's society can agree that the importance of environmental sustainability is growing every day, and the challenges that we are facing are quite substantial. The plastics industry has contributed quite a lot towards the negative impact on the environment over the last decades, and plastics recycling is a concept that has emerged from it. A plastic extruder machine is a piece of machinery that basically takes a piece of plastic and reconstitutes it into any given form. This process is rather complex and involves solving problems within control engineering.

The environmental issues that the world's inhabitants are facing are something that have left few unnoticed, and as of today it is common knowledge that plastic in general is not a good thing. Many different theories on how to avoid and transform plastics have been presented throughout the years, and some of them have led to the invention of the plastic extruder machine. This machine is fed with plastic pellets which in most cases come from recycled plastics. The pellets are heated up in a barrel to a melting point and upon reaching a specific temperature, they begin to fuse together to form a molten plastic mass. This molten plastic mass is then transported via a conveyor screw through the barrel, in and out of heating and cooling zones that control its temperature. When the plastic mass reaches the end of the barrel, it is exiting the machine through a nozzle into a mold that reconstitutes it into any given form. That sounds easy enough, right? Well, in theory this process seems easy but in reality it involves a lot of complex temperature controlling. It is crucial that the plastic mass is heated and cooled appropriately to ensure that the final product is not brittle. In the end, a fragile piece of plastic that breaks easily makes nobody happy, and surely isn't what the environment needs.

B&R Industrial Automation is a company that originates from Austria and has become world leading within automation and automatic control. B&R is actively working within the plastics industry around the globe, and given their line of business their work thus obviously involves temperature controlling of plastic extruder machines. The machine is divided up into different zones, each being controlled by software to follow a specific temperature profile. The zones responsible for increasing the temperature of the plastic are heated with ceramic heating bands. In the opposite case of decreasing the temperature, large centrifugal fans are used to generate airflows that effectively cool down the contact area towards ambient temperature conditions. These fans while spun up stores a lot of rotational energy that keeps the blades rotating long after the fan is disconnected from its power supply. Naturally, this causes some problems since the fan keeps on cooling whatever is placed in front of it for a while even when it is shut off.

While analyzing some data from a plastic extruder machine, B&R noted some nonlinearities in the cooling process of the system. After careful consideration they decided to address this issue by letting the two authors of this article research the system to come up with both the cause and a solution.

A quite intricate energy transfer model was created to simulate the system since, due to the nature of the prevailing times (Covid-19 pandemic), actual tests on the process itself was not possible. After rigorous research and simulation testing (and a bunch of qualified guesswork), the result from the master thesis showed that the main cause of the nonlinearity was the dynamics of the centrifugal fan, see Figure 1, and more specifically the amount of time it took for the fan to stop when switched off. Different alternatives to solve the issue were presented that involved both hardware and software solutions.

In terms of hardware, the options that were presented were to install either brakes or valves in the system. Brakes would work the way brakes work, and typically make the blades of the centrifugal fan stop on request. Valves would instead redirect the airflow that the fan delivers to the ambient air instead of towards the machine when needed. However, adding physical hardware to a piece of machinery would make it more exposed to failure, and we doubt that the manager of a factory, with such a machine in it, would be very happy that a solution to one issue makes the machine go 'poof' more often.

When it comes to software, the level of maintenance needed to keep the system running is considerable lower than that of the hardware. Here, two ways to get rid of the nonlinearity that the fan causes were discussed - both of which involve some crafty programming.

Figure 1. The centrifugal fan used for cooling, which is the main cause of the nonlinear dynamics in the extruder problem considered.

MSc Thesis TFRT-6132
ISSN 0280–5316

Department of Automatic Control
Lund University
Box 118
SE-221 00 LUND
Sweden

Printed in Sweden by Media-Tryck.
Lund 2021

Link to report: https://lup.lub.lu.se/student-papers/