Study of barrel heating and energy saving in an injection moulding machine

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Introduction

This document proposes a study of the barrel heating in an injection moulding machine (IMM) and how energy could be saved. A model is built to be verified by measurements. Once the accuracy of the model is obtained, it could be used to estimate power consumption and power saving for any barrel size.

The model is based on heat transfer theory. Heat is mainly lost by convection, although radiation and conduction will also be studied. Heat transfer theory is well-known and empirical studies have been well documented. Ref. 1.

Various types of barrel covers will be studied. The insulated cover is expected to reduce heat lost the most.

Both resistance heating and induction heating will be studied. The energy saving of induction heating would be a result of this study.

An industrial standard in IMM energy-saving established in 2009 by Chinese IMM manufacturers will be followed. This includes the material, barrel temperature and mould design. Ref. 2.

Scope

The study is restricted to injection moulding machines. Although extrusion and blow moulding machines have similar barrels, back pressure setting and a reciprocating screw are not there.

The end cap and nozzle are also heated but by heaters of smaller diameters and power ratings. As induction heating does not take care of heating the end cap and nozzle, their modeling and measurement will be done in a separate project. Furthermore, a barrel cover does not cover the endcap and the nozzle.

Barrel cooling by powered fans will be studied in a subsequent project.

The accuracy of temperature control is not an objective of this study.

How energy is saved?

In a nutshell, energy not wasted is saved. Energy saving in barrel heating has to do with reducing heat loss by convection, radiation and conduction. Heat transfer models enable heat loss to be quantified, to be compared with actual measurements, which verify the models.

Heat transfer model

The barrel being a circular cylinder with an outer diameter and a length, its transfer model is straight forward.

The barrel heating system is an open system in the following sense. Cold pellets come in at one and hot melt is injected out at the other end. Its modeling is not so complicated.

Heat is not only generated by the heaters, but also by friction of the screw motor turning, against back pressure. The modeling and measurement are a bit involved.

How much of the power in injection goes to heating the material in the barrel is not clear without further research. It is suggested to omit it in this study.

When there is no barrel cover, heat is lost from the heater surface by convection and by radiation to the surrounding.

Heat is also lost at the nozzle which is in contact with the sprue bushing of the mould. As the mould is a bit removed from the barrel, the heat loss by the barrel to the mould could be neglected.

At the other end, heat is lost by conduction to the water collar near the hopper. The modeling is not so involved here.

When there is a barrel cover, the heat loss by convection and radiation from the barrel cover is to be modeled. Due to the lower temperature of the cover versus the resistance heater or induction coil temperatures, heat loss is reduced despite its bigger surface area.

I. Resistance heaters

Resistance heaters are wrapped around the barrel in the form of bands, so they are sometimes referred to as band heaters. The barrel is divided lengthwise into 3 or 4 temperature control zones which have their own thermocouples. Each zone is controlled by two band heaters one on either side of the thermocouple.

The principle of operation of resistance heater is Ohmic heating. Electrical power is converted to heating power by the relationship $P = I^2R$. As the power factor is 1, measurement of current I gives us P. Note that R has to be measured at the temperature of the band heater, which is higher than that of the barrel temperature setting. Infrared and contact-type thermocouple will measure the surface temperature of both the heaters and the exposed parts of the barrel. The outer diameter of the heater is to be used in the heat loss model.

Band heaters on a barrel

With the barrel cover on, the cover temperature is to be used. The barrel cover in the following diagram has insulation material in between two cylinders made of sheet stainless steel. Note that the outer diameter of the cover is to be used in the heat loss model.

Other types of barrel covers are available. Some are square in cross section. Others have ventilation holes on them to reduce temperature overshoot. In this case, the cover serves to safeguard the operator from the higher heater temperature but energy saving is minimal.

Barrel cover on the band heaters

Measurements

Other than the measurements in the last paragraph, room temperature, water collar in and out temperatures, water flow rate, machine cycle time, barrel temperatures, melt temperature as it comes out of the nozzle (air shot), screw rpm, screw motor inlet pressure, back pressure, heater power (nozzle and endcap power not included), heater on and off time, are to be made.

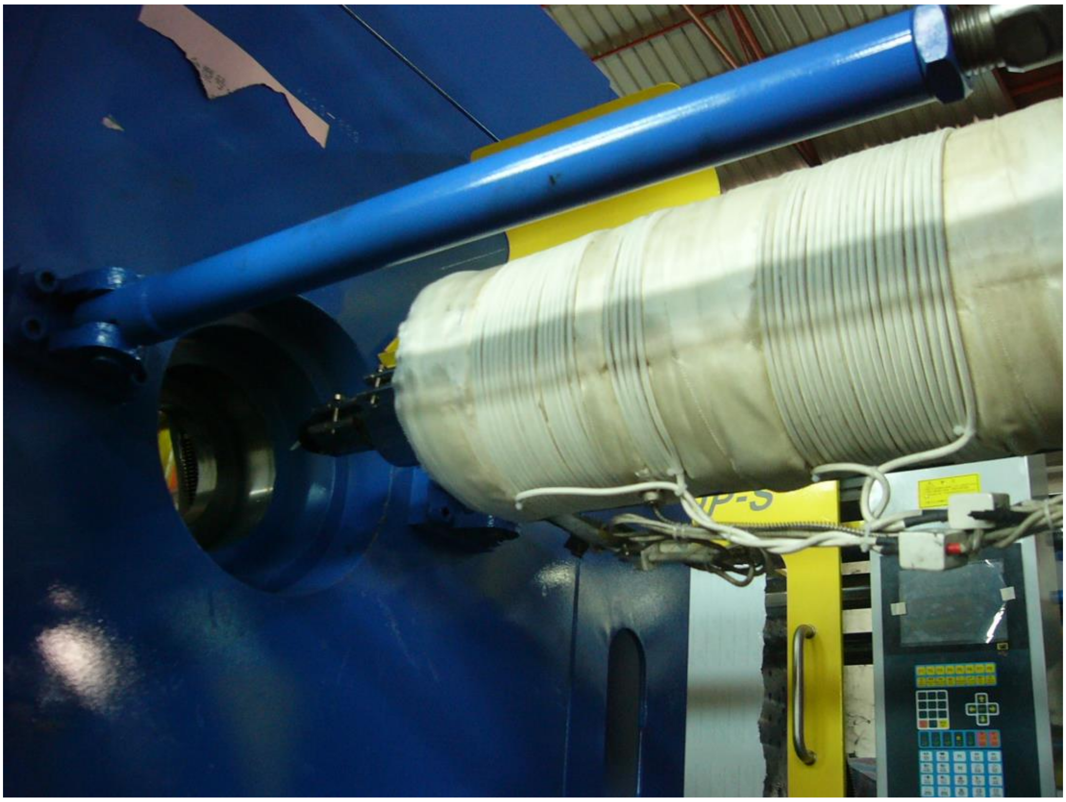
Measuring the torque of the screw motor is not easy as it rotates. A lower cost substitution is to measure the inlet pressure at the screw motor and look up the specific torque from the manufacturer's specification. It would be interesting to find out how much of the heating comes from heaters and from friction.

Dimensions to be measured include barrel diameter, heater outer diameter, barrel cover diameter, barrel length, heater length and barrel cover length.

II. Induction coils

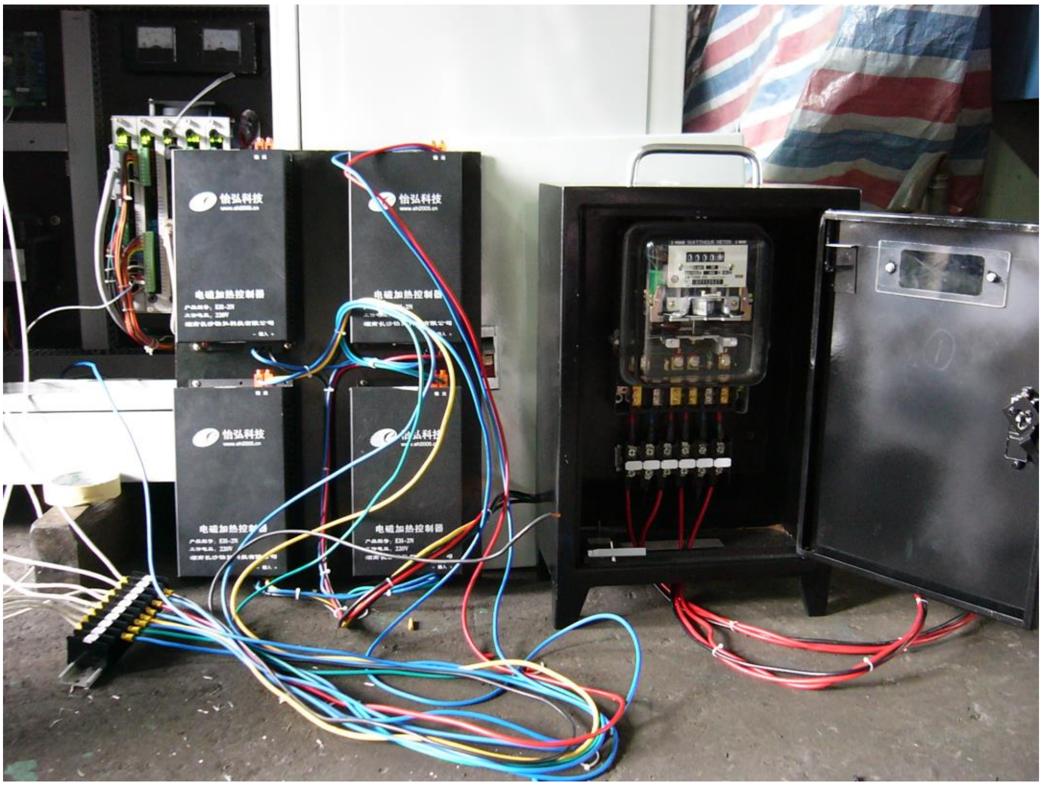
Induction heating generates heat by inducing eddy currents in the material of the (ferromagnetic) barrel by passing a high frequency alternating current through the coils wrapped around the barrel. The frequency is between 20 kHz and 40 kHz. The higher is the frequency, the deeper into the barrel steel can eddy currents be generated.

To reduce heat loss, insulation material is wrapped around the barrel before the coils are wound (over the insulation). A barrel cover over the coils would further reduce heat loss.



Induction coils on insulation material

The high frequency (and high current) AC is generated by electronics and power transistors, which form the controller to a pair of coils. Note that the controller itself consumes power. It is suggested to measure their power consumption separately. The power factor of this device would also be interesting.



Four AC generating devices and a kW-h meter

Economic analysis

Based on the amount of power saved using induction heaters vs resistance heaters, the return on investment and payback period could be calculated based on a tariff in Dong Guan, for example.

Epilog

It is hoped that this study precedes the more complicated power saving study involving the drive of an IMM. The modeling of the steps in an injection moulding cycle, e.g. plasticizing, and its verification could be carried out. Power consumption using asynchronous motor vs servomotor could be measured and economic analysis performed.

References

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