NORDTRIB 2018

The 18th Nordic Symposium on Tribology – NORDTRIB 2018
18-21 June 2018, Uppsala University, Uppsala, Sweden

TRIBOLOGICAL STUDY AND COATINGS IMPACT ON RELEASE FORCES DURING INJECTION MOULDING.

L. P. Nielsen[1], B. Zabala[2], E. Fuentes[2], K. P. Almtoft[1], B. H. Christensen[1], M. Rytter[3] and Stefan Hengsberger[4]

[1]Tribology Centre, Danish Technological Institute, Denmark
E-mail: lpn@dti.dk
[2]IK4-TEKNIKER, Spain
[3]Winther Mould Technology, Denmark
[4]Institute for Applied Plastics Research, iRAP, Switzerland

ABSTRACT:

In the present study we compare *in situ* measured demoulding forces with model tests based on reciprocating pin-on-disc configuration at high temperature simulating the mould/thermoplastic interphase. The ejection force and pin-on-disc friction properties were measured for four industrially relevant polymer types (PP, POM, ABS and TPU). The impact on the ejection force was quantified when adding different surface pretreatments (as machined, grinded, blasted, polished and laser textured) to the involved pin-on-disc surfaces and the injection moulding cores. Different PVD coatings (CrN, CrN-HiPIMS and DLC) combined with post treatment involving high-current implantation of nitrogen were investigated. The results revealed that the ejection force could be lowered by up to 70% for some of the thermoplastic types when applying a combination of a wear-resistant coating and nitrogen ion implantation.

Keywords: Plastic injection moulding; PVD coatings; ion implantation; release forces; friction

INTRODUCTION

Injection moulding of thermoplastic components is a huge business worldwide. The applied moulds are getting increasingly more complex and costly as the 3D-complexity of the moulded component increases. It is therefore important to increase the lifetime of the moulds. At the same time, it is highly beneficial if the overall productivity could be increased by a shorter filling-cooling-releasing cycle without compromising on the quality of the moulded thermoplastic parts.

The Tribology Centre at Danish Technological Institute has optimized PVD coatings and ion implantation treatments to produce wear-resistant non-stick coatings with enhanced properties and performance. This enable mould designers and plastic injection moulding industries to solve release issues and other tribological problems such as diesel/burner effects when moulding in different polymer/filler systems.

It is well-known that it is not always easy to compare model tests and friction measurements based on rotating or reciprocal pin-on-disc experiments with release properties in a real mould. In a recent Eurostars Project (Super Slip, E!7412) we have constructed a mould with built-in force sensor enabling *in situ* quantification of the demoulding forces. In the Eurostars project we also quantified the friction coefficients *ex situ* with a special reciprocating pin-on-disc-configuration at high temperature, simulating the mould-thermoplastic tribosystem.

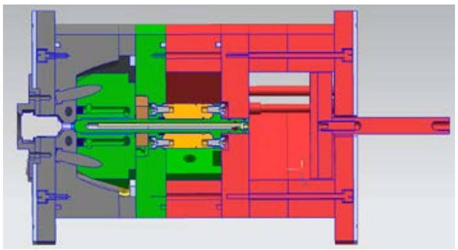

Figure 1: CAD drawing of the constructed mould with built-in force sensor (orange). The moulded thermoplastic part is the blue part around a cylindrical core.

MATERIALS AND SURFACE TREATMENTS

The release properties and friction forces were measured and ranked for different PVD coatings (CrN, CrN-HiPIMS, DLC) in combination with different surface roughness and post-treatment with nitrogen ion implantation. The release forces and friction coefficients were measured for ABS, PP, POM and TPU. The coatings were characterized with SEM, AFM, TEM, nanoindentation, scratch tests, friction and wear tests, corrosion tests, hardness, GDOES and RBS. In this paper, highlights from some of these measurements will be presented.

RESULTS AND DISCUSSION

All the tested thermoplastic types (PP, POM, ABS and TPU) showed a lower demoulding force when the injection moulding cores were coated with chrome nitride. The demoulding forces were decreasing even further when post treating with nitrogen ion implantation (CrN SS and CrN-HiPIMS SS).

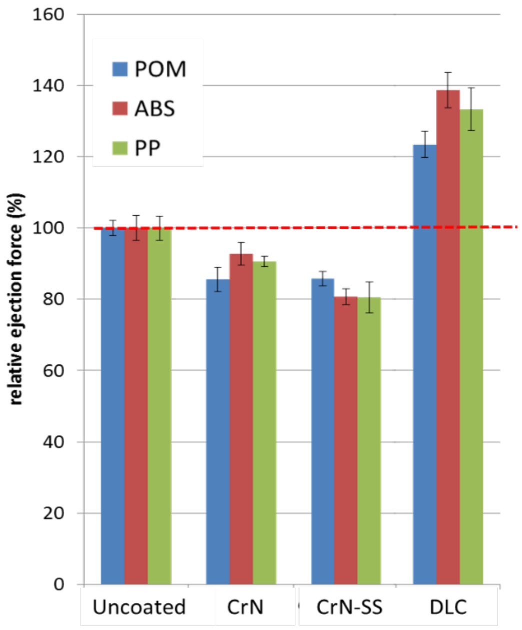

Figure 2: Normalized demoulding forces for POM, ABS and PP for cores coated with CrN, CrN SS (= CrN Superslip = CrN + nitrogen implantation) and DLC in comparison with uncoated cores.

Coating with DLC was observed to increase the demoulding forces. The lowest demoulding forces were observed for cores coated with CrN-HiPIMS followed by nitrogen ion implantation (CrN-HiPIMS SS). The CrN-HiPIMS coating is harder, denser and smoother than the CrN based on conventional reactive DC sputtering. The highest impact was seen in connection with TPU where the demoulding force was lowered by almost 70%.

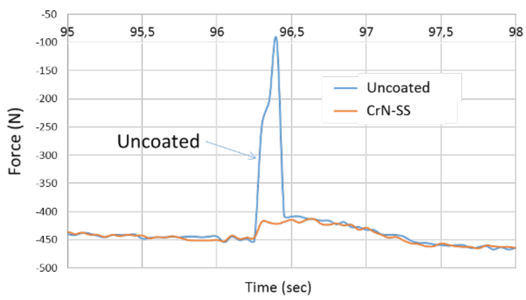

Figure 3: *In situ* force measurements when demoulding TPU.

The reciprocal friction results measured between thermoplastic pins and coated discs with different surface qualities at elevated temperature allow easy performance evaluation of a wide range of configurations. The full matrix of possible combinations of surface finishing (mirror polishing, grinding, degree of sandblasting, laser textured grooves, and laser textured lines), coatings (uncoated, CrN, CrN SS, CrN-HiPIMS, CrN HiPIMS SS) and 3 thermoplastics (PP, ABS, POM) were tested. Following conclusions can be highlighted:

- The wear of the thermoplastic pin and the friction measured was highly related to the surface finishing due to very different surface roughness. In some cases, the wear of the thermoplastic pin generated adhesion to the mould material (disc) resulting in polymer-polymer contact.
- The thermoplastic material ruled the friction value, and the tendency to wear loss of the thermoplastic itself. PP showed in general the lowest friction coefficient (μ ≈0 .1), ABS presented good friction behaviour (μ ≈ 0.12) while POM offered the highest friction coefficient (μ > 0.2), except with mirror polished surfaces, which combined with some solutions can go below 0.1.
- Coatings were effective reducing friction measured in the tribometer mainly in the case of mirror polished surfaces. CrN was effective reducing the friction of POM (~75% reduction) and ABS (~30% reduction). The friction reduction was not so effective for PP. CrN-HiPIMS SS (SuperSlip) was only effective reducing friction for POM (~37%). These results are summarized in figure 4.

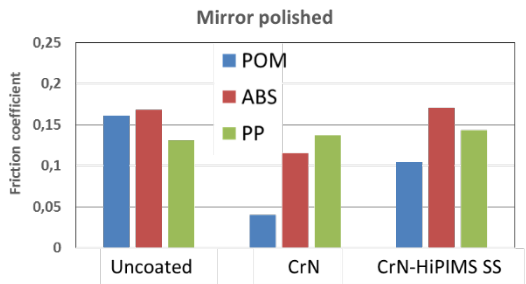

Figure 4: Mean friction coefficient for thermoplastic materials (POM, ABS and PP) sliding against mirror polished 1.2711 disc and coated with 2 different coatings (CrN and CrN-HiPIMS SS). Tested at 100 °C.

CrN coating improves the friction coefficient of the tribosystems in relation to the uncoated reference. In a real moulding process, the tribo-system is more complicated since it involves both friction between the thermoplastic part and the cores as well as shrinkage of the thermoplastic parts around the moulded core. The best performing coating during the demoulding process was the nitrogen-ion-implanted CrN-HiPIMS (CrN-HiPIMS SS). This coating was harder, denser and smoother as compared to conventional chrome nitride based on reactive DC sputtering.

CONCLUSIONS

The *in-situ* measured demoulding forces confirm the empirical knowledge from the thermoplastic injection moulding industry namely that:

- Hydrogenated DLC (a-C:H) increases the demoulding forces.
- Different types of chrome nitride lower the demoulding forces for POM, ABS, PP and TPU.
- Nitrogen-implanted HiPIMS-CrN (HiPIMS-CrN SS) reveals the lowest possible demoulding forces.

Finally, it was shown that *ex situ* reciprocal sliding-friction measurements are helpful to establish differences and understanding the tribological behavior of the different tribosystems. The tests performed using cores provides complementary information about the effect of all the parameters involved in the injection moulding process. Using these tests, it is possible to quantify the benefits of applying tribological coatings on mould surfaces.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the funding from the Eurostars system and the national funding mechanisms in Spain (CDTI), Switzerland (SBFI) and Denmark (Innovation Fund Denmark).