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Heat Transfer in Additively Manufactured Injection Moulding Inserts

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Abstract

Injection Moulding (IM) using inserts from Vat Polymerization (VP), an Additive Manufacturing (AM) technology, has been investigated for pilot production and rapid prototyping purposes throughout the past years [1]. While the lifetime compared to conventional materials such as brass, steel, and aluminium, is reduced [2-4], the prototyping and design phase can be shortened significantly by using flexible and cost-effective AM technologies. Higher manufacturing volume still exceed the capability of AM inserts, which are overruled by the stronger performance of less-flexible but stronger materials.

One significant difference between the two technologies is the material's heat capacity and thus heat transfer within the insert as well as into the liquid-cooled standard mould made from steel. In order to describe the differences, as well as behaviour of photopolymer inserts, heat transfer simulations were carried out on a model featuring the standard mould, the insert as well as the polymer part.

Verification was performed using InfraRed (IR) thermography on the mould performed directly after the injection process. Simulations and measurements were compared as shown in Figure 1. The cycle consists of injection and packing for 8.5 s, mould opening, cooling, and mould closing for 11.5 s resulting in a total injection moulding cycle time of 20 s.

The temperature distributions of the insert and the injected polymer including the features of the IM insert are shown in Figure 2 visualizing also the gradients potentially leading to thermal stresses and thus faster crack development and propagation.

It could be concluded that the approximately 650x smaller thermal conductivity of AM inserts leads to a significantly longer injection moulding cycle time. Heat transport mechanisms can be explained by the simulation tools featuring the heat flux through the insert and the standard mould into free convection of air or forced convection of cooling liquid.

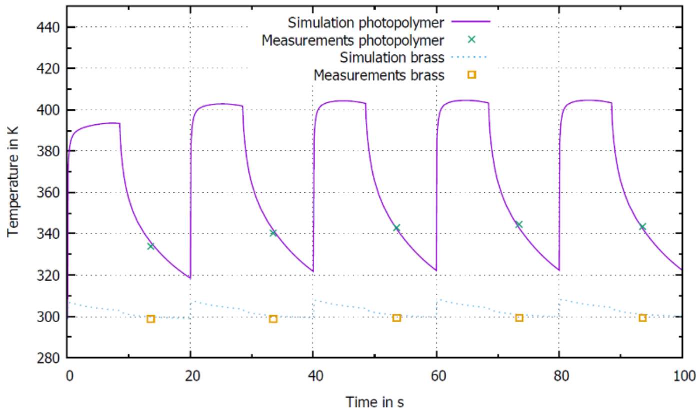

Figure 1 Simulated and measured temperature development over the first five injection moulding cycles [5].

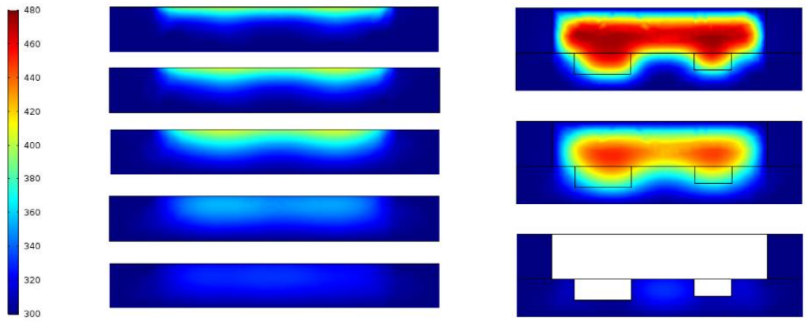

Figure 2 Temperature development in the insert symmetry plane of the insert after 3, 8.5, 12, 17 s (left from top to bottom) and in a feature region of the insert showing the injected polymer at 3, 8.5 and 17 s (right from top to bottom) [5].

References

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