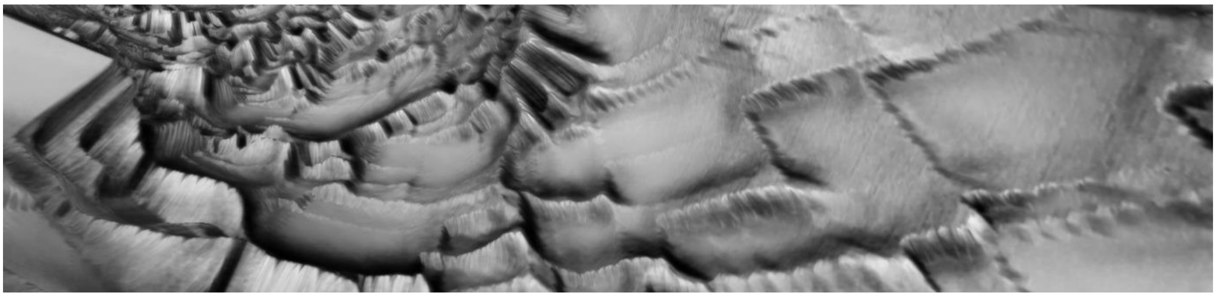

Cover Image: Close-up of *Random Tetra* surface structure

Radically enhanced productivity by innovatively designed and additively manufactured cooling channels - RapidKAT

Additive manufacturing enables optimized distribution of cooling channels for an even or locally increased cooling in injection molding or pressing tools. It is also possible to increase the heat transfer between tools and coolant with the help of complex surface structures, shown in RapidKAT funded by Vinnova. The project aim was to improve cooling in injection molding or pressing tools by investigating how the wall structure of cooling channels affect the cooling performance. This results in tools with more efficient cooling that widens the bottleneck in many production processes through reduced cycle times.

Different surface structures of the cooling channels and its influence on the heat transfer between the channel wall and the coolant has been studied experimentally. Researchers within additive manufacturing and fluid mechanics groups of RISE Research Institutes of Sweden, agreed on four different surface structures which were expected to improve the heat transfer. A reference design of a smooth surface was produced as well to act as a comparison with a smooth/drilled cooling channel. The five surface structures are seen in Figure 1.

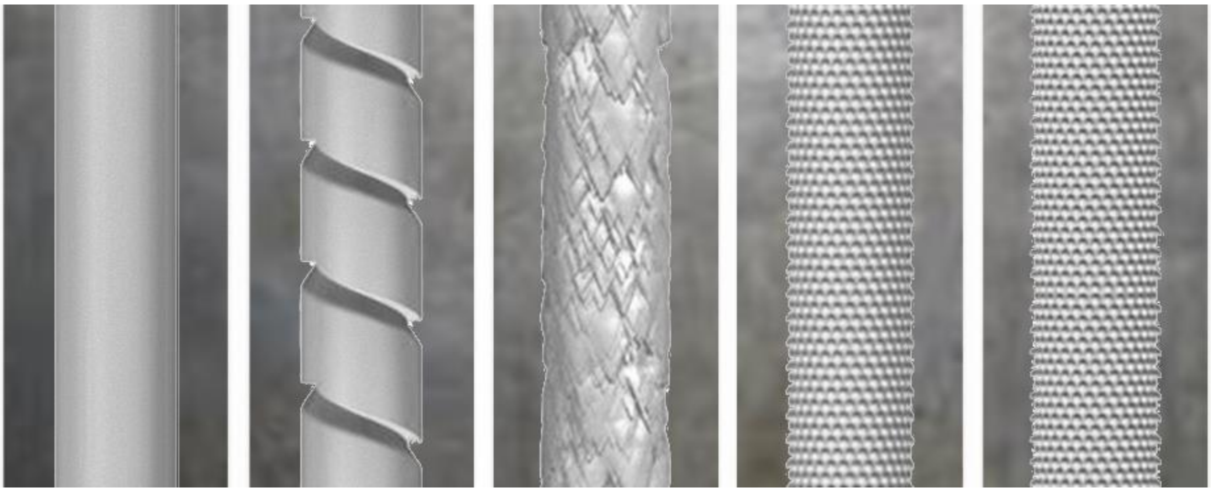

Figure 1. Cross sectional images of the five studied structures. From left to right: Reference, Spiraled chamfer, Random tetra, Dimples (depth = 0.26 mm) and Dimples (depth = 0.41 mm).

The samples were additively manufactured in a modified H13 tool steel with the selective laser melting technique. The temperature difference, heat transfer rate and associated parameters were calculated from experiments performed in a customized temperature bath. The mass flow rate, pressure drop, relative and absolute temperatures from cooling channels and surrounding bath were measured with equipment traceable to national standards. The experiments were conducted with water as a cooling medium. The results at an equal differential pressure, $\Delta p=1$ kPa, showed that the *Spiral chamfer* had a larger temperature difference than other designs, see Figure 2.

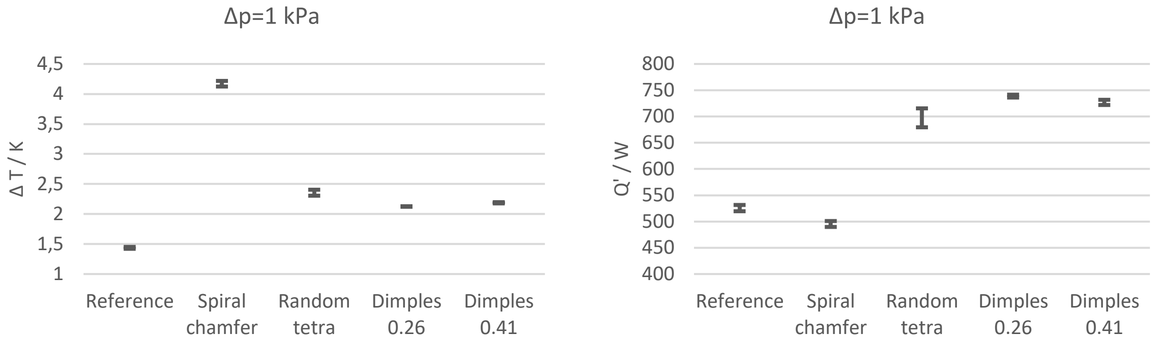

Figure 2. From left to right: Temperature and heat transfer rate for a differential pressure of 1 kPa.

The large difference for the *Spiral chamfer* at a differential pressure of 1 kPa is explained by the design itself. The chamfer restricts the effective cross-sectional area more than the other designs, hence the flow is drastically reduced to reach the assigned differential pressure. The lower flow rate is beneficial for the differential temperature. Accounting for the differences in mass flow at an equal differential pressure, Figure 2 also reveals that the actual heat transfer was higher for the Random tetra and both Dimple designs. Similar results were gathered for equal volume flow rates, see Figure 3.

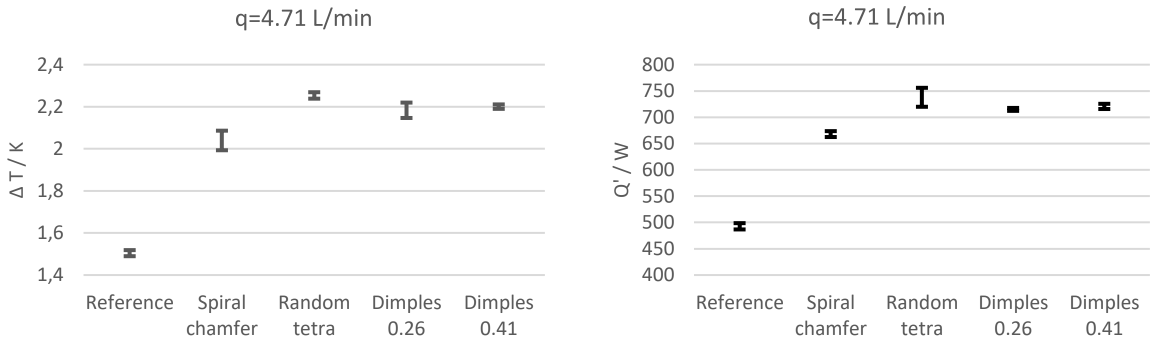

Figure 3. From left to right: Temperature difference and heat transfer rate at a flow of 4.71 L/min.

As seen in Figure 3, the *Random tetra* and *Dimples* cooling channels performed slightly better than the *Spiral chamfer*, also for equal flow rates. There was a significant difference between the results, judging from the statistical uncertainties, which are presented at a confidence level of 95%.

Through practical experiments, we have verified and created credibility for channels developed with additive manufacturing to radically improve cooling capacity in relation to classically designed cooling channels. We see an approximate 37% increase in heat transfer rate with complex surface structures compared to smooth cooling channels at identical differential pressures or flow rates. Results outside the scope of this article indicate that the increased heat transfer rate is attributed to the increased effective area. No effect on the laminar boundary layer and with it the convective heat transfer coefficient has been proven.

The project has been performed by RISE as part of the Vinnova financed venture ”Groundbreaking ideas in industrial development”. For more details, please contact:

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