Specification of Heat Transfer Coefficient at the Casting/Die Interface in Aluminium High Pressure Die Casting & the Effect of the Ram High Velocity and Accumulated Pressure

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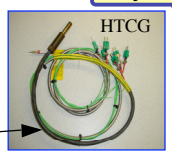
Introduction

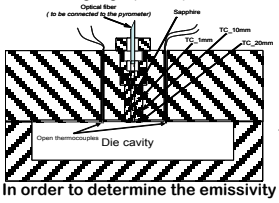
Specification of the heat transfer coefficient (HTC) and the heat flux (q) at the casting/die interface in high pressure die casting (HPDC) is to a great benefit to control the thermal fatigue of the die, simulating of solidification and optimising the parameter process. On the other hand, the structure integrity of the casting depends strongly on the thermal conditions during solidification which is greatly influenced by HTC at the casting/die interface. In die casting, as a consequence of the high thermal diffusivity and conductivity of the die, the solidification is mainly controlled by the properties of the casting/die interface and hence by the HTC. However, the variations and typical values of both HTC and heat flux are not well understood nowadays, because of the complexity of the interface and its variation during solidification. The aim of this investigation is to evaluate the heat flux and the HTC at the casting/die interface during HPDC of an Aluminum alloy (Al-9Si-3Cu) and to study the effect of ram high velocity and applied pressure on the heat transfer during solidification

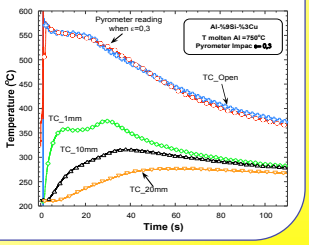
Experimental set up

A. Temperature measurements

- Temperatures in the die (1mm, 10mm & 20 mm from its surface) are measured by K type thermocouples.
- Temperature of the alloy surface is measured with a pyrometric chain (sapphire, optical fiber and pyrometer)
- Both type of measurements are realised by the heat transfer coefficient gauge (HTCG)

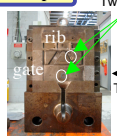






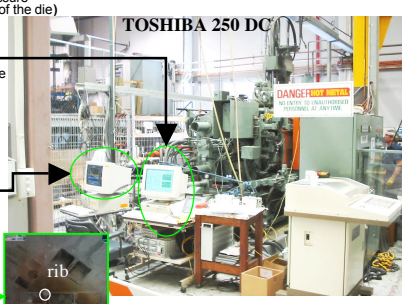
In order to determine the emissivity factor of the alloys surface the pyrometer reading is compared by that of two classical thermocouples during solidification of a gravity die casting

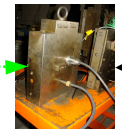
B. Die Instrumentation (set up)



Two Kistler gauges to measure the pressure (Mobile part of the die)

The gauges are controlled by computers





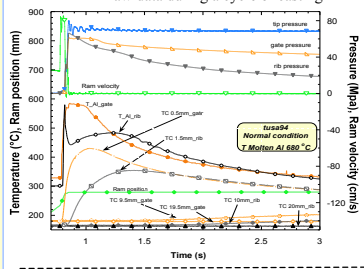
Two HTCG are inserted into the fix part of the die

The surface of the HTCG heads are flashed on the die cavity

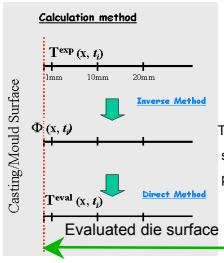
- Pressure at the tip of the piston is measured by Kistler gauge as well
- Piston velocity and its position is also measured by a measurement system developed for this reason

Results

Raw data during a cycle of casting



Measured temperatures are used to evaluate the heat flux and HTC at the interface by an inverse method



HTC

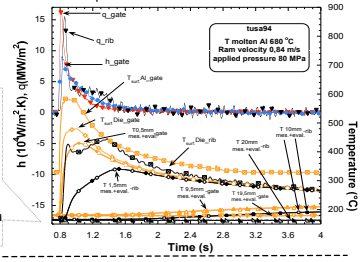
$$h(t)=\frac{\ddot{O}(t)}{T_{sc}(t)-T_{sd}(t)}$$

Heat flux at the interface evaluated by IM

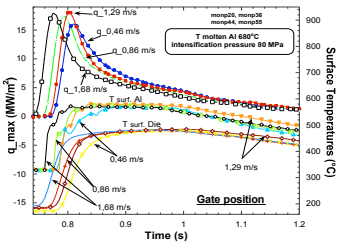
Temperature of casting surface measured with pyrometer

- Max. HTC is about 90 kW/m².K at the gate
- IM is validated by recalculation of the temperatures at the TC positions using evaluated heat flux as a boundary condition

q max. at the gate= 16 MW/m²
q max. at the rib= 15 MW/m²

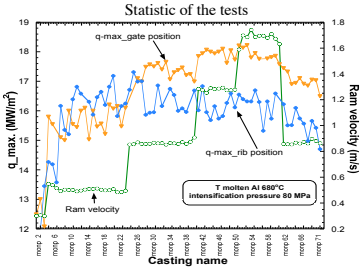


Effect of high ram velocity



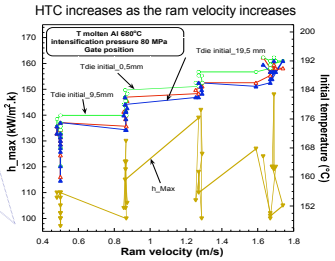
The max. of the heat flux at the gate position increases as the ram velocity increases to about 1.25 m/s where the q max is saturated

- $V_{gate}=130V_{ram}$
- $V_{rib}=75V_{ram}$

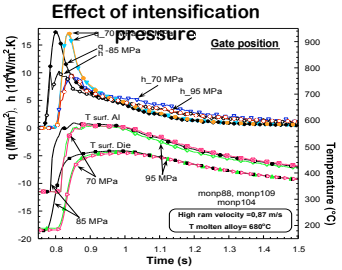


- The big variation of HTC for the same velocity is due to the sensitivity of HTC to the interface ,measurement and evaluation method
- The Initial temperatures at the three positions in the die are well correlated with the velocity

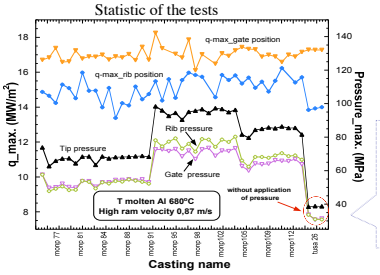
HTC increases as the ram velocity increases



Effect of intensification

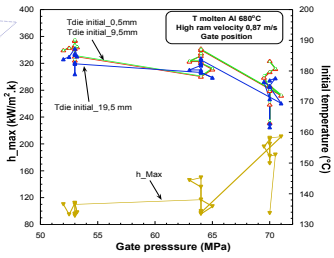


The intensification pressure doesn't influence the variation of the die and cast surface temperatures, q and HTC at the gate & rib positions



At the gate position, the rise of the HTC at 70 MPa is due more to the fall of the initial die temperature than to the pressure rise

The q max. at the gate position is greater than that of rib by about 3 MW/m² even if the max. of the pressure in the rib is greater than that of the gate by 3 MPa



Conclusion

- Heat flux and heat transfer coefficient at the casting/die interface have been evaluated for the presented high pressure die casting
- The maximum of the heat flux and HTC increases as the high ram velocity increases. But at the velocity of about 1.25 m/s the max of the heat flux and HTC reaches their saturations for this die and they remain almost constant event if the velocity becomes bigger than 1.25 m/s
- It seems that the duration heat input from the casting to the die decreases as the high ram velocity increases.
- The intensification pressure has not a remarkable effect on the heat transfer during solidification

Future works

- Evaluating of the HTC at the casting/die interface in magnesium HPDC (studying the effect of the parameter process on the heat transfer) and comparing to that of Al
- Developing a model of HTC that allows to estimate HTC from the thermal contact resistances at the interface casting/die (Gravity Die Casting)
- Studying the microstructure of the castings to combine it with the thermal conditions during casting process
- Perform principal component analyses of all the data to find the correlation between all the variables.