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Direct measurements and process monitoring for High Pressure Die Casting (HPDC) process

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Process variables have a direct impact over High Pressure Die Casting (HPDC) quality parts. The measurement of metal temperature and the intensification pressure directly from the injected part, the vacuum pressure and flow and other parameters permits to determinate if the injected part is under the desired range on the controlled parameters.
This work demonstrates how it's possible to have a better control of the HPDC process increasing final part quality by combining different sensors and actuators.

Keywords: *High pressure die casting, squeeze pin, sensor, vacuum casting, process parameters.*

1. Introduction

High Pressure Die Casting (HPDC) is the most usual method to produce aluminum and magnesium castings, due to the excellent balance of cost and properties for high production volumes. Nevertheless, conventional HPDC process presents certain limitations in terms of final mechanical properties, due to the intrinsic porosity of HPDC castings, the alloy composition and all the parameters than can interfere in the quality of an injected part. More than 400 parameters can have influence over the final part quality. The real values of process parameters in the cavity are an important criterion for the consistent quality of these parts [1-4]. In the case were there is a tendency to promote shrinkage porosity, squeeze pins are employed to reduce the porosity by a local pressure multiplication pin [5]. The results from the temperature control and monitoring of the die, machine, vacuum and sensors in direct contact with the injected metal can achieve minimum scrap rates and ensure constant quality.

2. Experimental conditions

In order to obtain the results, a base AlSi9Cu3Fe1 alloy has been employed. The base alloy composition is in table 1.

Table 1 Composition of base alloy (mass %).

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Al
8.4	0.7	1.56	0.13	0.03	0.03	0,04	0.94	0,04	Bal.

In order to determinate the temperature directly from the injected part, a replaceable insert was designed to place the thermocouples (T1, T2 and T3). To measure also pressure (P1, P2) and metal contact (C1, C2), the same external shape was employed for all the different sensors. Also two bayonet RS 621-2221 K type thermocouple (T4, T5) were placed in the die. Sensor placements on the die are shown on figure 1.

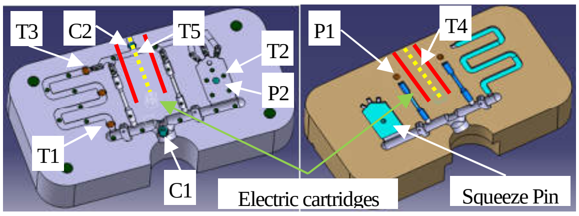

Fig.1 Sensors placements on the die.

To determinate directly the specific pressure of the injected metal, a Kistler cavity pressure sensors Type 6175A2. To determinate the contact of metal with the cavity, a FKS-03 sensors and for vacuum, humidity, gas and air quantity a MASS multi-sensor from Electronics. All the data were registered with a FieldLogger 512K data logger, a Siemens Simatic S7-300 PLC and an Advantech PCI-1711 PCI card.

For achieving an accurate temperature measurement over the injected part, a new sensor design was developed. Due to the HPDC short cycles times related with a rapid cooling, the thermocouple has been designed with a wire diameter of only 0.15 mm embedded in a H13 tool steel insert with 42 HRC hardness and with the two thermocouple wires separated 2 mm one from the center of the other welded by laser to the contact surface. The two thermocouple wires are isolated with a no conductive ceramic material along the insert.

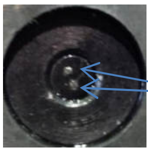

Fig. 2 Detail of direct contact thermocouples.

The thermal control of the die was obtained by a combination of water and oil (2x16kW Tool Temp - TT-388/2) tempering circuits and four Aloña 800W electrical heating cartridges. The 10 water and 2 oil circuits were equipped with individual flowmeters, water exit temperature thermocouples and actuator. The flow of lubing agent, air pressure and lubricating time was registered.

Trials have been made at Tecnalia's foundry pilot plant, with a 950 Tn HPDC machine equipped with a VDS Controller ProVac PLC-250 and vacuum valve ProVac Standard 1000 and injection parameters diagram (Distance, speed and pressure). 400 kg of aluminum alloy were melted and casted, with a continuous registration of metal temperature.

3. Results and discussion

The system is capable of determining the real temperature of the injected part in different points, as shown in figure 3. The quick response of temperature thermocouples permits to obtain the complete solidification curve, what it gives the solidification curve that can be employed to determinate the real solidification parameters by thermal analysis. We can observe how the maximum temperature variates from T1 = 620ºC, T2= 605ºC and T3=602 ºC, well above the nucleation temperature. Monitoring these temperatures can help us in the determination of part quality and to adjust thermal treatment temperatures with the obtained solidification temperature for the analyzed injected part. In the case of P2 installed opposite to the squeeze pin, a 200 Mpa value is obtained. The squeeze pin is operated by controlling the injected part temperature by T2 or by time. Depending on the solidification curve of an alloy obtained from T2, the temperature set point to apply the local intensification pressure in the semi-solid state is adjusted. In this way, a correct squeeze pin use is guaranteed. In fig. 3 we can also observe the main the vacuum parameters values with a minimum vacuum of 86 mbar and flow of 6.7 l/s. The temperature in a point of the die is smart controlled by regulating the water or oil flow or by the actuation time of the electrical cartridge, with a variation of only ±2ºC.

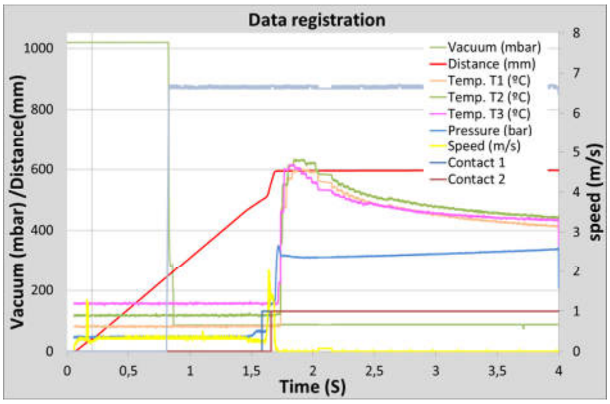

Fig. 3 Parameters control diagram.

4. Conclusions

The determination of HPDC parameters can lead in a better control of part quality. The alloy composition that promotes differences in the fluidity and solidification of alloys can be controlled by adjusting process parameters using temperature, contact and pressure sensors in direct contact with injected metal. The quality control system can be optimized for a determined alloy composition range, obtaining an optimal temperature and pressure value in a determinate point, a maximum filling time and use them also to regulate the use of squeeze pins.

Monitoring the vacuum values can lead to an automatic control of injected parts quality, especially by controlling the vacuum and flow values.

Quality defective rates have been reduced up to a 60% by acting over the process parameters with the obtained data.

Acknowledgements

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