UBE: inventors of new Rheocasting

Saving energy to preserve the environment is a common global goal. Material substitution, for example changing plastics or iron for aluminium or magnesium alloys, has been a major issue in automotive industries for weight reduction and material recycling. The semi-solid casting process has been recognised to achieve thinner, lighter, near net shaped and high quality castings.

The Thixocasting process has been used in mass production of some parts, but it has its faults, for example higher material cost. To reduce material cost, UBE developed a simple Rheocasting process called the UBE New Rheocasting (NRC) process. This process produces a semi-solid slurry including globular crystals directly from molten metal without any mechanical or magnetic stirring. At the same time, this process can do squeeze casting in one system to allow more applications and improve versatility.

Not only the casting machine supplier

UBE developed the squeeze casting process in 1976. This process was in response to an automotive customer's need to obtain a thin aluminium wheel. The machine has a vertical shot unit with high pressure in the solidification after super slow filling into the cavity.

After the success of this vertical shot development, UBE introduced both vertical as well as horizontal clamping casting machine in 1985. The squeeze casting process allows a wider range of aluminium alloy usage, and provides automobile structural and safety parts that are heat treatable. Recently, UBE commercialised the pitless squeeze casting machine, which uses the vertical shot advantage, but does not require a pit.

To drive down further the cost of casting parts with higher or more stable casting quality, UBE began to consider a new process – and the development of NRC process started in 1996.

Research began by discovering how to produce cheaper and better semisolid slurry consistently, with a shorter cycle and in a more simple way than with conventional Thixocasting and Rheocasting.

The key was to start from normal ingot that everyone can buy in the market at the normal price. UBE was determined to find a way to 'cool down the melt to the semisolid state well.' This idea was very simple, but nobody had been able to complete industrialisation before. Of course, there was much trial and error to obtain fine globular crystals suitable for casting. For example, UBE tried to use a cooling plate in pouring the melt to the cup, vibration of copper bar in the poured melt, refiner to the alloy and so on.

Finally, it was realized that the process did not have to be so complex, and the company found the most simple method – the UBE NRC process in use today.

UBE is essentially a machine builder and supplier, but it has enough flexibility to respond to the needs of the customer.

The company always has high technology and the spirit of innovation in mind – the DNA driving global success. UBE can cooperate on a project, taking on the roles of casting machine supplier and process supplier.

The New Rheocasting process

The UBE New Rheocasting process is as follows. Firstly, molten metal temperature controlled to just above the melting point is poured gently into the holding cup. After pouring, the semi-solid metal is cooled down to the target casting temperature by controlled air blowing.

Each holding cup is heat insulated at the top and the bottom with ceramic covers to prevent over cooling in the area of the slurry. Temperature gradient of the slurry is adjusted by heating from outside of the holding cup with a high frequency induction heater.

NRC uses only metallurgical nucleation behaviour to obtain a semi-solid slurry of 50% solid fraction and does not need any mechanical or electrical magnetic stirring. Just cooling the low temperature melt and no stirring of induction heater contributes to the energy saving of the process itself.

The slurry prepared stably in the casting cycle is poured into the injection sleeve by turning the holding cup upside down so that an oxide layer formed at the top surface of the slurry and remains at the injection tip surface. It prevents including the oxide layer in the product. Then, the shot sleeve tilts to the die side, docks to the die and makes a high pressure shot. During solidification and slow filling into the cavity, the slurry experiences no turbulence.

The big advantage of NRC compared to Thixocasting is that NRC can recycle the biscuit and runner in house, so diecasters do not need an outside source for recycling. In house recycling can reduce material cost by up to 30%. The NRC process provides a good semi-solid slurry that has less heat capacity than the conventional liquid process, and can achieve a shorter casting cycle as a result of quicker solidification in the cavity.

Figure 1 shows the layout of NRC system. It consists of a melting/holding furnace, ladling device, slurry making device, cup cleaning/coating device, cup transfer robot, and high pressure casting machine.

The turtable of the slurry making device rotates at a constant speed determined by the casting cycle. Each slurry is cooled through the cooling section by controlled air blowing and, at the final stage, the temperature distribution is adjusted by an high frequency induction heater. A part which is difficult to make by the Rheocasting process due to shape
pouring of metal promotes formation of a fine, equiaxed dendritic microstructure, and with time and slow cooling, the metal can coarsen into non-dendritic semi-solid material. The heat extraction of the cold vessel receiving the metal, coupled with the natural convection of the pour influences this phenomenon.

At MIT, it was realised that this combination of convection and rapid heat removal as the alloy cools through the liquidus is the critical factor for producing non-dendritic semi-solid material. Instead of relying upon container walls and pouring to control the variables of heat removal and convection, an external stirring device was used to control heat removal and convection. Using a rotating copper rod, non-dendritic microstructure ready for semi-solid forming was quickly and efficiently produced. From this idea, the SSR process was born.

Figure 2 is a schematic of the SSR process, which can be divided into three phases. In the first step, liquid alloy is held above the liquidus. A rotating, coated copper rod is then inserted into the melt for a short duration, dropping the temperature of the melt below the liquidus and creating a fine equiaxed grain structure. Amazingly, stirring after the temperature drops below the liquidus has apparently no effect on the creation of a fine microstructure and is useless for creating a non-dendritic semi-solid slurry. The rod is removed and the metal can cool to the desired forming temperature at a wide range of cooling rates, between 0 1-3 °C/s.

Results have been very promising. Al-Si alloys of varying Si content, including A356 and A357 have been used with SSR, as well as Al-Cu alloys. Figure 3 is a micrograph of A356 in the unetched condition after being modified into non-dendritic slurry with SSR. The structure is free of porosity and the solid particles are small, round, and devoid of entrapped eutectic; the proper microstructure for good semi-solid forming and heat treatability. Batches of castings have repeatedly been rheocast with SSR at fractions solid of approximately 0.30 and also 0.45. These castings are currently undergoing mechanical testing, and initial results are extremely promising.

Idra engineers are developing SSR to work with both horizontal and vertical diecasting machines, maintaining the simplicity of the process as much as possible. With the ability to produce solution heat treatable castings over a wide range of fraction solids at operating costs and cycle times similar to conventional die casting, SSR will be the right choice for foundries looking to produce high integrity castings.

Summary

The IdraPrince Group is committed to being the technology leader of the diecasting equipment industry. Technologies such as SSR are allowing foundries to expand the capabilities of their machines, creating parts that were previously difficult or impossible to produce with conventional die casting and instead cast with low volume processes. SSR is an extremely simple and efficient semi-solid process, and IdraPrince is excited to bring this revolutionary product to market.

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or wall thickness can be made by this system employing the squeeze casting process, by changing ladling device position as shown in Figure 1.

This casting machine has 30% larger injection force and 60% higher shot speed than a conventional squeeze casting machine. This means that thick wall and small parts can be cast by the NRC process, and parts which need long flow length with thin wall thickness (1-2mm) are suitable for squeeze casting. This is the main difference between semi-solid and liquid processes.

In 2000, UBE installed a demonstration machine, HVSC800PL NRC at LKR, ARC Leichtmetallkompetenzzentrum Rankhofen GmbH in Austria. It has 800t clamping force and a maximum casting weight of 7.5kg.

LKR is open to customers, so anyone can see a casting demonstration and make a casting trial with his own tools. Figure 2 shows the LKR trial part with Al536 alloy and T6 heat treatment.

This part – an automotive suspension part – shows the possibilities of NRC to cast thin walls; the minimum thickness is 1.5mm in the left side rib. LKR made a tensile test with test pieces taken from A to D in Figure 2. Figure 3 shows the tensile results of this part. The results show that every portion shows high strength and elongation, even in the actual product shape. It should be noted that the data shows quite stable mechanical properties in each portion – that is the one of the characteristics of the NRC process.

Stampal SpA in Italy made a casting trial in LKR, and introduced its first NRC production cell for the high volume serial production of automotive parts September 2001. The second NRC machine installation began production in May 2002.

At present, UBE has delivered 16 NRC machines in total, six each to the USA and Japan and four sets to Europe.

Summary

The need to reduce car weight is a big issue linked to environmental legislation, so there is great competition over part cost and process selection among car manufacturers, automotive parts suppliers and casting machine suppliers.

To win the cost competition, conventional and well established casting processes are transferred to low labour cost areas, and as a result, only parts requiring high quality combined with an acceptable price remain in high labour cost areas. The entire foundry industry, especially those involved in process development, is trying to find the solution to survive in the global market.

UBE proudly offers the NRC process as one of the most competitive processes to produce heat treatable and weldable cast parts, such as safety parts and pressure tightness parts, at an acceptable price.

Reader Reply No.25

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Reader Reply No.307
Rheocasting in a class of its own

The New Rheocasting process is the most innovative development yet achieved in semi-solid forming technology, write Gianluigi Chiarmetta and Paola Giordano of Stampa SpA, the Italian branch of the Euralcom Group.

The semi-solid production of automotive components started in the 1990s with the Thixoforming process. Specially prepared billets, which underwent electromagnetic stirring during casting, formed a globular microstructure and were found to behave thixotropically.

After being reheated to a semi-solid state and injected into a mould, strong shear stress is inflicted on the material. The viscosity drops and the semi-solid alloy is able to fill very complex shapes, with thick and thin walls, leading to the production of high quality, near net shape components.

Despite these advantages, the thixoforming process has always been hampered by high raw material costs and the impossibility of recycling scrap in house. The automotive market, the industry that would benefit most from this technology, could not pay such a big difference in price compared to traditional foundry processes. Therefore there was a need to develop a technology to produce the semi-solid material 'in situ', avoiding additional costs.

The Japanese company UBE Industries recently patented the New Rheocasting process. The semi-solid slurry is produced in a carousel system, with special cups, where liquid alloy is poured in and cooled down to semi-solid temperature. It reaches globular structure, and the material becomes thixotropic. The slurry obtained is then injected into a mould. After T5 or T6 heat treatment components can be produced with the same or even better mechanical properties than those produced via the thixoforming process. In Table 1 the typical mechanical properties of the semi-solid products are shown: the data has been obtained from specimens cut out from industrial components.

In Figure 1 the Thixoforming and Rheocasting processes are illustrated. In Thixoforming, billet casting with electromagnetic stirring and scrap recycling are external operations made by the raw material supplier at a significant cost which is transferred to the final product price. In the Rheocasting process no specific preparation is needed for the raw material, and scrap recycling is possible in the foundry; with considerable cost reductions.

Stampa SpA, the Italian division of the Euralcom Group, has always been a leader in semi-solid technology in Europe. The company began series production of fuel rails for Ford in the early 1990s, and continued with automotive suspension components and engine brackets. It now has four Bühler Thixoforming machines (one 1800t and three 630t presses) and two new UBE 800t machines for the New Rheocasting process (Figure 2). Overall semi-solid production is near 3000t per year, but the high number of parts in phase of development predicts that 6000t of semi-solid formed parts will be produced annually by 2004.

The advantages of the semi-solid process for the end user are well known:
- Production of near net shape components
- High mechanical properties after heat treatment
- High process capability
- Possibility of weight reduction
- High productivity
- Good surface quality
- Production costs very competitive

Applications include structural and safety components for the automotive market. Stampa semi-solid production includes the following components: engine brackets for medium and high volume vehicles, suspension arms, space frame connecting nodes and anti-vibration system brackets.

Stampa is convinced that, considering results obtained up to now, in the future there will be no technology to compete with Rheocasting for the production of safety critical components. Competitiveness will play a crucial role, increasing market development and the range of possible applications for semi-solid products.

As for Stampa, it is forging ahead with R&D activity, with the aim of reducing cost and time to market for new products. In this way, the group aims to remain a leader in semi-solid moulding.

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**Table 1: Mechanical properties of rheocast products**

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Composition</th>
<th>State</th>
<th>UTS (MPa)</th>
<th>YS (MPa)</th>
<th>E%</th>
<th>HB</th>
<th>Fatigue Limit (MPa) Axial 107 cye (R=1)</th>
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<tbody>
<tr>
<td>A356</td>
<td>AlSi7Mg0.3</td>
<td>T5</td>
<td>250 - 270</td>
<td>180 - 200</td>
<td>8 - 12</td>
<td>78 - 84</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>T6</td>
<td>300 - 320</td>
<td>230 - 250</td>
<td>8 - 15</td>
<td>100 - 110</td>
<td></td>
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<tr>
<td>A357</td>
<td>AlSi7Mg0.6</td>
<td>T5</td>
<td>265 - 285</td>
<td>195 - 220</td>
<td>5 - 8</td>
<td>87 - 92</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>T6</td>
<td>340 - 360</td>
<td>290 - 310</td>
<td>5 - 8</td>
<td>110 - 120</td>
<td></td>
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