Effective solutions for Marine Bronze castings

Introduction

Bronze castings for marine applications are high integrity components and subject to strict quality control and assurance procedures. To ensure sound castings it is essential that strict procedures are followed in the manufacture and preparation of the mould, the pouring of the molten metal and the method of successfully feeding the casting to enable solidification without inclusion defects or shrinkage.

The majority of marine bronze components are fully machined, adding significant cost to the process, therefore any defects identified during or after-machining that result in a scrap casting have incurred significant costs both in terms of the raw material value and the processing costs both in the foundry and in the machine shop and a cost to client in terms of missed deliver dates and the on-costs that will be incurred further down the process. Therefore it is essential that within all parts of the process the correct raw material choices are made and these decisions are critical to the successful and repeatable production of defect-free castings and must be combined with the correctly applied application, technical and manufacturing process knowledge.

Fundilusa is a company located in Vilanova de Cerveira in Portugal, its main focus is on the production of bronze components for marine applications such as propellers, blades and hubs (figure 1). It is responsible for the casting, machining and assembly of the components and can produce individual cast components of up to 15 tonnes.

Figure 1: Strict quality control of high integrity castings.

Mould manufacture

For the production of moulds and cores an inorganic binder system has been chosen (CARSIL with VELOSET* hardeners), which provides minimal gas evolution on casting and is free from phenol, formaldehyde and other components considered harmful to health. As an environmentally aware binder system, it is a further development of a traditional sodium silicate, ester cured system, but with improved bench-life to strip-time ratio and superior breakdown after casting. Equally important is the capability of the system to support reclamation of the bonded sand at levels in the region of 80%, which can subsequently be re-used for the production of moulds and cores without detriment to overall performance (figure 2).

Figure 2: 80% reclaimed sand - 20% new silica sand for the production of perfect moulds.

To reclaim the used sand, Fundilusa have installed a mechanical scrubbing/attrition system, the sand is pre-heated to approximately 200° C to ensure the binder is brittle to allowing its easier removal from the individual sand grains.

The tendency for bronze alloys to entrap gases during the casting process and generate pin-holes during solidification is well known; it is therefore essential to maintain precise control of the reclaimed sand quality. This process control is coordinated between Fundilusa and Foseco, with weekly testing of reclaimed sand samples to determine ongoing actions to maintain the sand quality within strict control limits (figure 3).

Figure 3: Precision control of reclaimed & new silica sands to prevent mould erosion and dimensional inaccuracy.

Figure 5: STELEX PrO & SEDEX filters reduce inclusions and eliminate metal turbulence.

Inclusion Reduction

When designing bronze castings for marine applications, significant cost benefits can be achieved by minimising surface inclusions and irregularities to allow for minimal machining allowances. These surface inclusions can be the result of sand particles eroded from the mould face, ingates or running system, metal slags within the molten metal and gas entrapment in the liquid metal resulting in pin holes or blow holes. By consideration of the metal quality, mould design and its preparation these defects can be reduced significantly and eliminated.

i. Melt cleanliness

The quality of the metal being poured into the mould is critical to the final casting integrity, therefore the quality control of incoming raw materials is essential as is the subsequent processing of these materials. The melting of copper-based alloys presents special problems in that hydrogen and oxygen are readily dissolved in the melt and can subsequently combine to form water vapour which creates porosity in the casting. Without the presence of oxygen, hydrogen alone may also cause pin-hole defects. The levels of residual hydrogen is reduced to below 1ppm through the use of degassing units (FDU) with high efficiency rotor designs.

Figure 4: Melt treated with specially designed Foseco fluxes to ensure high cleanliness.

The FDU is an automated, environmentally-friendly melt treatment system for aluminium and copper-based alloys and uses patented rotors (XSR) to create an innovative pumping action that is key to its performance and delivers high levels of degassing and cleaning within a short timeframe, improving productivity and reducing heat loss and energy consumption. Different sized units make it applicable for all bath, furnace and ladle sizes. The pumping action brings the melt into the rotor to ensure excellent contact with the inert gas. The huge number of very small inert gas bubbles created will float to the surface, taking the hydrogen with it resulting in a significant reduction in overall hydrogen content as well as removing oxides, which are also carried to the surface.

Optimised metal cleanliness is obtained using additions of specially designed fluxes for bronze alloys (ALBRAL, ELEKTRO, DEOX* TUBES and SLAX), (figure 4).

ii. Mould filling and metal flow control

The running system design is critical to ensuring a non-turbulent flow of metal into the mould cavity to avoid oxidation reactions and erosion. To ensure the incoming metal is both inclusion free and to eliminate turbulence; ceramic foam filters (SEDEX* or STELEX* PrO) are installed in the running system. The correct application and filter support methods are advised by Foseco to eliminate any potential risk of breakage and ensure maximum benefits are achieved (figure 5).

Figure 6: Insulated sprues, runners and ingates create a highly erosion resistant running system.

The foundry has also replaced sand sprues, runners and ingates that can easily be the source of sand inclusions through erosion with specially manufactured systems (KALMIN* 70 A) that are highly resistant to erosion and offer the benefit over traditional ceramic materials of being highly insulating and hence avoiding the temperature loss observed with other products (figure 6).

Similar materials are used for the feeding sleeves (KALMIN 700), with the high insulation value allowing the feed metal to stay liquid longer, reducing the size of feeders required with the associated reduction in the requirements for liquid metal and post-casting operations to remove and re-work the feeding area. The performance of these sleeves is complemented by the use of highly exothermic (TERMORIT PW) or insulating topping compounds.

iii. Metal / Mould Interactions

Refractory mould coatings are used to improve surface finish through applying a very fine refractory material to the mould surface, additionally this inert layer prevents adverse interaction between the molten metal and the mould's sand and binder components. The coating also provides a barrier to prevent gases evolved from the thermal decomposition of the mould entering the liquid metal and potentially creating pin holes on solidification. The coating applied at Fundilusa (TENO* Coating ZBBP) contains a zircon refractory for ultimate protection and has a very low gas evolution to ensure it does not contribute to gas defects.

Figure 7: Working together

Conclusion

It is only through consideration of the whole process that effective solutions can be provided that combine together to provide optimised and cost effective casting production. In the case described the focus is on the elimination of surface defects that require an increased machining tolerance, resulting in increased costs both in terms of casting yield and machine tooling and process time. However the problems cannot be addressed in isolation as singularly they do not solve the problem, for example good coating practice does not eliminate inclusions from slag related defects. Addressing the true need of the customer requires an approach that focuses on the whole foundry process rather than on the performance of individual products (figure 7).