Degassing and fluxing practice for aluminium alloys

Why gas control and cleanliness are important

The highest mechanical properties and quality levels in aluminium castings are obtained from alloys which are poured with a low gas content and inclusion level. Fig. 1 gives a typical example of the reduction in mechanical properties obtained from increasing amounts of gas porosity. Experiments have shown that when H₂ gas levels exceed about 0.15 cc/100 grams there is a lowering of fatigue resistance, a decrease in corrosion resistance and an increased likelihood of leakage under pressure.

Effects of metal temperature

Hydrogen is picked up by aluminium very readily and is taken into solution. The solubility of hydrogen is illustrated in Fig. 2 and it can be seen that there is a massive increase at about 660°C and above. When the molten metal is cooled this hydrogen comes out of solution at the solidification temperature to produce gas porosity defects.

Aluminium alloys also oxidize readily to produce a continuous oxide film. As soon as this oxide film is disturbed or removed to expose the melt to the atmosphere it is replaced, gradually building up a surface skin which can become entrained in the melt if not controlled. The rate of oxidation rises slowly between 630 and 750°C, at which temperature there is a dramatic increase, as shown in Fig. 3.

Sources of hydrogen

- Moisture in the air (but not the hydrogen content of the air, which is very low)
- Products of combustion from gases or other fuels during melting and holding
- Damp charge materials
- Oxides on the charge materials which are usually hydroscopic
- Moisture from furnace linings and refractory repairs
- Tool coatings which are not dried
- Damp fluxes
- Core sand and stubs in charge scrap which contain remnant binder residues

Sources of oxides

- Oxides already present on the charge materials
- Oxidation of the molten alloy during melting
- Oxides attached to the furnace walls

Fig. 1 Influence of dissolved hydrogen on properties.

Fig. 2 Effect of temperature on hydrogen solubility.

Fig. 3 Effect of temperature on oxidation.
• Breaking the surface oxide skin which encourages further oxidation
• Charging damp metallics which allows water vapour to bubble through the melt
• Charging scrap containing sand core residues

Methods of degassing

There are a number of different methods of degassing but bubbling gas through the melt is the most efficient. The gas contains a low partial pressure of hydrogen and encourages the dissolved hydrogen to migrate to the bubbles and be removed. There are three important principles associated with the efficiency of degassing by this method.

• Degassing is far more efficient if the bubbles used are small.
• Degassing using techniques which produce large bubbles is inefficient and in practice may simply produce a large amount of splashing and oxidation without any degassing being achieved.
• Degassing is more efficient at low temperatures and the time for hydrogen removal approximately doubles with every 60°C increase in temperature.

Using chlorine and chlorine mixtures

Chlorine is a very efficient degasser but environmental considerations are seriously restricting its use. Chlorine can be used in one of three ways:

• As pure chlorine gas, bubbled at a rate of about 0.2% of the melt weight.
• As hexachlorethylene tablets, plunged beneath the melt surface where chlorine is released. The addition rate is 0.2-0.25% of melt weight.
• As chlorine/inert gas mixtures. 90% N₂ with 10% Cl₂ and 80% N₂, 10% Cl₂ and 10% CO have been used. Addition rates of 0.25% are typical.

Using inert gas

Inert gases are also used at a level of about 0.2% of the melt rate, although their efficiency is less than that of chlorine as shown in Fig. 4. Argon and helium can be used but are expensive. Nitrogen or nitrogen/5% Freon mixture are the most common.

Introduction of gas

Because of the importance of producing small gas bubbles, open ended tubes pushed beneath the metal surface are rarely satisfactory. This very basic technology has been superseded by the use of tubes with ceramic foam heads or rotary degassers which place the molten aluminium in intimate contact with a stream of small bubbles.

Fluxes for the removal of oxides

Chemical fluxes are normally used to remove the oxide from the surface of the melt, to de-wet the oxides to make them easier to remove and to help suspended oxides rise to the surface of the melt. These materials are therefore scavenging agents designed to lower the inclusion population of the melt. Some fluxes are designed to melt on the surface of the molten aluminium bath to protect from oxidation and gas pick-up.

The most common fluxing systems comprise mixtures of NaCl and KCl to which fluorides (commonly CaF₂) are often added. Melt cleaning fluxes used to remove aluminium oxide are often based on sodium fluorosilicate which help soxide particles to float out. New developments have led to the introduction of low fluoride fluxes with superior environmental properties.

Traditionally these materials have been stirred into the melt, which is not an ideal method to use. The development of the flux feeder has improved efficiency by allowing a smaller amount of flux to be introduced below the metal surface using a lance. Nitrogen or argon gas is used to carry the flux and usually only about 25% of that required for manual stirring is used. The gas-flux mixture also has a degassing effect, as shown in Fig. 5.

Rotary degassing has also been combined with fluxing whereby a fluxing agent is held beneath the metal while degassing is carried out. Evidence suggests that the flux forms molten globules in contact with the aluminium and that the rotor disperses these globules thoroughly through the melt and fragments them, thus providing a larger active surface area. Flux levels of less than 0.05% have proved successful under these circumstances.