Fluxes for melting aluminum

Fluxes for melting aluminum are solid substances (commonly mixtures of chloride and fluoride salts) used in aluminum foundries in order to reduce the melt oxidation, minimize penetration of the atmospheric Hydrogen, absorb non-metallic inclusions suspended in the melt, keep the furnace/ladle wall clean from the built up oxides, decrease the content of aluminum entrapped in the dross, remove hydrogen dissolved in the melt, provide aluminum grain refining during Solidification, modify silicon inclusions in silicon containing alloys, oxidize excessive magnesium.

Common practice of flux introduction is manual application. Most of the fluxes are applied on the melt surface and stirred into the melt. Some of the fluxes (degassing, grain refining) are plunged to the bottom by a clean preheated perforated bell.

Fluxes may also be introduced into the melt by injection in form of a powder in an inert gas (Argon or Nitrogen) stream. The simplest flux injection technique is a lance immersed into the melt. The most effective flux introduction method is injection by rotary degasser.

Classification of fluxes for melting aluminum

- **Cover fluxes**
- **Drossing fluxes**
- **Cleaning fluxes**
- **Wall cleaning fluxes**
- **Degassing fluxes**
- **Grain refiners**
- **Silicon modifiers**
- **Demagging fluxes**

Cover fluxes

Melting point of a cover flux is lower than that of aluminum. Cover flux is applied on the surface of molten aluminum where it melts forming a continuous layer protecting the liquid metal from oxidation and absorption of atmospheric hydrogen. Cover fluxes are composed of a mixture of NaCl and KCl and may also contain some additions of $CaCl_2$, CaF_2 or KF. Fluorides (CaF_2, KF) provide further decrease of the flux melting point and improve its cleaning ability. The disadvantage of fluoride containing fluxes is harmful fumes released by the flux at work temperature. Sodium free cover fluxes are used for melting hyper-eutectic aluminum-silicon alloys (alloys containing above 12.6% of Si). Hyper-eutectic alloys are modified by phosphorus, additions of which cause refining of the primary crystals of silicon. Sodium reduce the refining effect of phosphorus in such alloys.

Drossing fluxes

Drossing fluxes promote separation of molten aluminum entrapped in the dross (sometimes up to 80%). Besides chlorides and fluorides drossing fluxes contain oxidizing component (KNO_3) reacting exothermically with aluminum when heated. Heat generated by drossing flux improves wettability and fluidity of the entrapped aluminum, drops of which coalescence and flow down to the melt. The dross treated by the drossing flux is powdery and dry. It is easily removed from the furnace. Drossing fluxes helps to reduce losses of aluminum, which makes it very economically effective particularly in remelting aluminum scrap (chips, turnings etc.).

Cleaning fluxes

Cleaning fluxes remove oxides suspended in the melt. Similarly to the Drossing fluxes a cleaning flux is composed of mixture of chlorides, fluorides and an oxidizing agent. Cleaning fluxes generate less heat therefore their aluminum separation effect is lower. However they possess better ability to absorb oxides inclusions from the melt.

Wall cleaning fluxes

Wall cleaning fluxes soften oxides built up on the furnace walls. Wall cleaning fluxes contain double fluorides (Na_2SiF_6, Na_2AlF_6) and an oxidizing agent. The oxidizing agent reacts with aluminum generating heat, which promotes penetration of fluorides into the built up oxides softening them. The softened oxides are easily scrapped from the wall by the furnace operator.

Degassing fluxes

Fluxes composed of chlorine and fluorine containing salts are used for degassing molten aluminum alloys. Degassing fluxes are commonly shaped in form of tablets. Degassing operation starts when a flux tablet is plunged by a clean preheated perforated bell to the furnace bottom. The flux components react with aluminum forming gaseous compounds (aluminum chloride, aluminum fluoride). The gas is bubbling and rising through the melt. Partial pressure of hydrogen in the formed bubbles is very low therefore it diffuses from the molten aluminum into the bubbles. The bubbles escape from the melt and the gas is then removed by the exhausting system. The process continues until bubbling ceases. Degassing flux may also be introduced by an injection method. In this case the inert gas serves as carrier for granulated flux. Besides the degassing effect the degassing treatment allows to remove non-metallic inclusions suspended in the melt (cleaning effect).

Grain refiners

Grain refining fluxes composed of salts containing titanium and boron (K_2TiF_6 and KBF_4). The fluxes cause formation of numerous nuclei of $TiAl_3$ TiB_2 when aluminum melt cools down. Aluminum grains start solidification on the nuclei surface. The average solid grain size is determined by the concentration of the nuclei in the melt before solidification. Fine grain structure is characterized by better fluidity during solidification, low Microsegregation of impurities, low shrinkage porosity. Alternative method of aluminum grain refining is introduction of master alloys containing titanium and boron (eg. Al-5%Ti-1%B).

Silicon modifiers

hypo-eutectic and eutectic aluminum-silicon alloys are modified by fluxes containing sodium fluoride. Minor amount of sodium dissolved in the alloys refine the silicon structure resulting in improvement of mechanical properties (Fracture toughness#Toughness, ductility). Hypo-eutectic and eutectic aluminum-silicon alloys are also modified by introduction of metallic sodium or strontium.

Demagging fluxes

Demagging fluxes are used when the melt contains excessive amount of magnesium. The flux helps to reduce the magnesium content by burning (oxidizing) it from the melt. Alternative demagging method is oxidizing the excessive magnesium by gaseous chlorine.

Recycling of scraps and aluminum chips of machining is very important because of the wide applications of this metal, particularly in automotive industry. Recycling of aluminum turnings and chips is a complicated process because of the curl shape, fine size, and their contaminated surfaces with oxides and machining oils. Aluminum melt easily reacts with oxygen and moisture of the atmosphere because of its high reactivity and forms oxide inclusions (often Al2O3) [1]. Molten aluminum often contains various non-metallic inclusions, which they have weak wettability with aluminum melt. Therefore, they are suspended in the melt and act as the nucleation sites for the formation of porosity [2]. The presence of inclusions and intermetallic particles influence the melt fluidity and reduces the performance of the riser [3]. Inclusions also reduce significantly the corrosion resistance and toughness of the casting parts [1].

There are various types of inclusions in aluminum melts, such as: oxides, nitrides, carbides, borides, chlorides, fluorides, and molten salts [3,4]. Oxide films can either float on the melt surface or engulf inside the melt because of the melt turbulence. Although the density of the oxide inclusions is more than the density of molten aluminum, but it floats on the melt surface because of its high area to volume ratio. Oxide inclusions tend to be agglomerated in the melt because they have a little wettability with molten aluminum. Al2O3 inclusions can float to the melt surface by adsorption to gas bubbles [3].

Most of salt fluxes have been made based on the equi-molar composition of NaCl–KCl. They have the eutectic temperature of about 660 $^{\circ}$C [5,6]. The most important reasons for fluxing treatment are [5,7]:

- preventing melt oxidation;
- accelerating inclusions removal;

• recycling metallic aluminum from dross;

• removing oxide build-up from the furnace wall.

Generally, salt fluxes increase the removing efficiency of inclusions from the melts, because they have an appropriate wettability with oxides and inclusions. Most of fluxes contain fluoride compounds, such as Na3AlF6, CaF2, Na2SiF6 that accelerate the wettability [8]. Heterogeneous nucleation of pores on inclusions is very probable [9]. High interfacial energy between inclusions and molten aluminum causes the concentration of solute hydrogen and then formation of hydrogen molecules (H2) in the melt [10].