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Original Research Article

Brazeability of Grade 2 titanium and AZ31B magnesium alloy under flux cover

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ABSTRACT

The article presents the basic issues related to brazing of poorly brazeable materials such as titanium and magnesium alloys. The text contains exemplary chemical compositions of fluxes used in brazing of poorly brazeable materials and presents the results of composition and technological process-related tests concerning fluxes used for brazing of Grade 2 titanium and AZ31B magnesium alloy. The article also presents the brazing properties of fluxes and test results concerning the mechanical properties of brazed joints as well as the results of metallographic examination utilising light and electron microscopy.

1. Introduction

Titanium and its alloys are becoming increasingly popular in highly modern industries and sectors of economy as well as in the production of medical equipment and implants, sports equipment, jewellery and metal accessories. This trend is related to exceptional physicochemical properties of this metal, such as high temperature and corrosion resistance, low density and high mechanical strength. Titanium is rated among lightweight structural materials characterised by high relative strength (strength-to-density ratio) within a wide temperature range. The relative strength of titanium alloys is approximately 1.5 times higher than that of high-strength alloy steels. The relative strength of other light metal alloys, e.g. Al or Mg is also lower than that of Ti alloys especially at higher operating temperatures [1,3,5].

Magnesium alloys also find applications in automotive industry, aviation as well as in the production of electro-technological and electronic equipment. These alloys belong to the cheapest light metal alloys and are characterised by advantageous properties including relatively high mechanical strength, very low density, good vibration damping ability and high corrosion resistance. In the automotive industry Mg alloys are used in the production of seat and sunroof frames, engine elements, radiator housing, gearbox elements and pedal bearers. Other applications include telephone casings, aerials and videophones [1,5].

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1.1. *Titanium brazeability*

Titanium is a chemically active metal characterised by high chemical affinity for all chemical elements, and particularly for gases present in the air such as oxygen, nitrogen and hydrogen. In the air titanium oxidises relatively slowly. However, a stable TiO_2 oxide formed during heating impedes brazing processes. The intensity of TiO_2 formation is particularly high at 650–700 °C [2–4].

Presently, brazing of highly critical elements made of titanium and its alloys is performed exclusively in vacuum or pure, chemically neutral and controlled atmospheres [7,8,16]. Fig. 1 presents a TWC INVAC-manufactured high-vacuum furnace with removable bottom used for titanium brazing [6].

However, it sometimes becomes necessary to braze big-sized titanium elements or elements permanently fixed to larger structures. In such situations it is difficult or impossible to perform brazing in vacuum. Brazing of elements in the air atmosphere requires the use of highly active specialist brazing flux ensuring the proper course of brazing phenomena. Such flux should reduce the surface tension of brazing metals ensuring required wettability and spreadability of brazing metals as well as ensuring the filling of capillary brazing gaps [2,4]. Flux action also includes chemical reaction and dissolving of oxide layers present on workpiece and brazing metal surfaces as well as the prevention of their re-oxidation during brazing.

Most of available fluxes recommended for brazing of various metals, even those of the most stable oxides, are unsuitable for brazing of titanium as they fail to provide the proper protection of reactive titanium against oxidation at brazing temperatures and do not create appropriate conditions for wetting workpiece surfaces with a brazing metal. Fig. 2 presents the test of Ag 245 silver brazing metal spreadability (45% Ag) on the Grade 2 titanium base under the cover of high-fluoride F47A flux. The flux is produced at Institute of Welding and is used for brazing of stainless (chromium–nickel) steels and brasses. As can be seen, the brazing metal entirely failed to wet titanium.

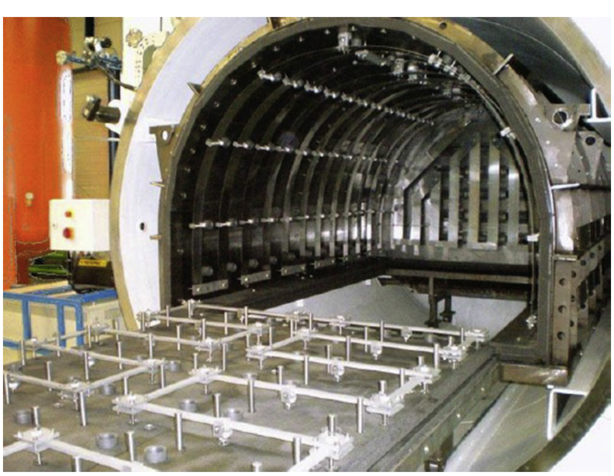

Fig. 1 – TWC INVAC-made high-vacuum furnace with removable bottom used for titanium brazing [6].

Fig. 2 – Lack of spreadability of the Ag 245 silver brazing metal on the Grade 2 titanium base, in the air, under the F47A flux cover.

Specialist reference publications concerned with brazing seldom provide information on the composition of fluxes for flame or induction brazing of titanium in the air. The examples of compositions found (% by weight) are presented below [4,9–11]:

- 45% NaCl, 36% KCl, 10% AgCl, 9% LiF,
- 50% KF, 46% LiF, 4% AgCl,
- 50% LiCl, 25% KF, 25% $MgCl_2$,
- 48% NaCl, 30% $MgCl_2$, 22% LiCl.

However, practical brazing tests revealed that these fluxes fail to provide good brazeability of titanium using silver brazing metals (low brazing metal spreadability) and are not durable after their manufacture [9–11]. The spreadability of first two fluxes on titanium surface was limited and reached 100–120 mm^2. Another two fluxes do not allow wetting of titanium surface using silver brazing metal. They do not contain transition metal chlorides which could react with the titanium and be reduced on the surface.

This has led to the conclusion that it is necessary to develop chloride–fluoride flux for brazing of titanium in the air and meeting the criteria of good brazeability and higher chemical stability.

1.2. *Brazeability of magnesium alloys*

Recent years have seen significant interest in brazing of Mg–Al–Zn–Mn (AZ31B) magnesium alloys. However, brazing of such alloys causes a serious problem as the film of MgO and Al_2O_3 oxides present on the surface is very durable and difficult to remove during brazing. Making brazed joints in the air atmosphere requires the use of highly active flux containing halides of alkaline metals such as Ca, Na and Li [4,11,13].

Similarly as in the case of fluxes used for brazing of titanium, fluxes used for brazing of magnesium alloys should provide good brazeability and removal of oxide layers from the surface of workpieces and brazing metals [4,11,13].