TITANIUM INVESTMENT CASTING – PRODUCTION, PROPERTIES AND APPLICATIONS

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Introduction

In Titanium investment casting a very old moulding procedure and a young material have made products possible which are unique in their properties.

Increasing demands and requirements of technique and manufacturing industry are:
- optimal material use
- complicated shapes
- independence from quantity
- high dimensional accuracy
- casting ready to be installed
- functional small wall thicknesses

All these requirements are fulfilled at investment casting to the lost wax process with lost models. One further advantage of investment casting is expressed with the slogan, investment casters advertise with: " use investment castings - save machining costs".

Titanium's high strength-to-weight ratio, its excellent corrosion resistance coupled with high specific strength at elevated temperatures make cast titanium and its alloys the logical choice for many applications.

Preferential applications are:
a) high stressed parts for aircraft and aerospace. Fig. 1 shows engine parts.

Fig. 1

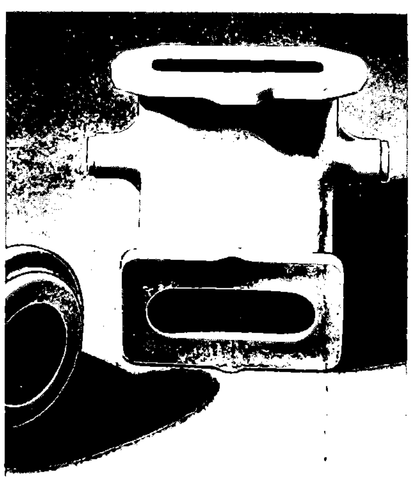
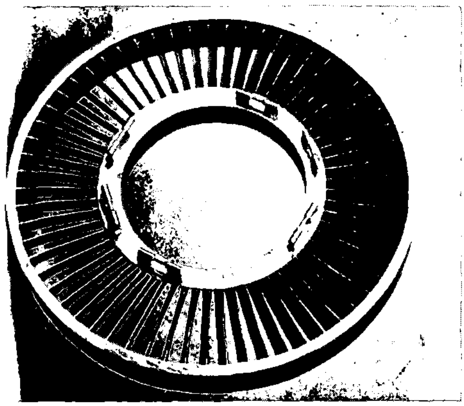


Fig. 2 shows an inlet guide vane housing (680 mm ∅)

Fig. 2



b) mechanical engineering (textile machines), impellers for turbo chargers
c) medical field (implants, artificial joints)

Procedure for melting Titanium alloys

There are two melting processes in industrial use today for reactive metals as Titanium and Zirconium
- melting in an electron-beam furnace
- melting in a vacuum arc-furnace with consumable electrode

It is common to both processes that the melt is molten in a water-cooled Copper-cruible. On the inner side a "skull" of solidified metal grows. The metal actually melts within itself this minimising any contamination. In an electron-beam-casting-furnace the process of energy loading shows advantages and disadvantages. Melting Titanium alloys proves to be problematical when alloy components with comparible high steam pressure are vaparized in a slightly uncontrolled way. This is based in principle on the difficulty of electron-beam-furnaces to distribute the heat, which arises in a thin surface layer on convertion of kinetic energy through impacting electrons, to the melted volume.

Due to the necessity of a high melting vacuum of 10^{-4} to 10^{-5} mbar, the large free surface as well as the primary heating up of a thin surface layer (when melting Titanium alloys) a hardly controllable loss of volatile alloy-components such as Aluminium, Copper, Tin etc. occurs.

In contrast to this process the melting of consumable electrode in a vacuum arc furnace which is closed combined with the development of the Titanium metallurgy, achieved good results and could be introduced successfully into the melting technology.

The classic melting procedure for production of Titanium castings is the Skull-process developed by the Bureau of Mines, Albany/Oregon in the middle of the fifties.

At that time, during research work, it was noticed that under special conditions using a conventional vacuum arc furnace melting Titanium, the liquid pool of melt showed an unexpected depth. This resulted in the development of a casting furnace with tilting, water-cooled crucible out of which the main part of the crucible content could be cast as liquid Titanium into dies. Such vacuum arc furnace casting equipment can cast up to several hundred kilogrammes, and have been working reliably and without problems after installation.

Particularly the fact that the rising evaporation lossed are negligible makes this process superior to the electron beam casting process, above all for production of high-grade investment castings with constant properties.

Moulding Material Systems

Because of the metallurgical reactivity of fluid Titanium high demands are made on moulding materials for Titanium castings. Since about 25 years the "rammed graphite" process is in operation. The moulding process resembles sand castings but uses as a moulding material extremely pure, electrographite artificial carbon with a special binder. The so produced castings show a casting skin which is hardened by diffusion of carbon and can e.g. be removed by pickling. Skin depth is approximately some tenth of a mm.

All known moulding material systems for Titanium investment castings react - if only to a slight extent - with the casting material. These reactions play a great part in the properties of investment castings and are caused by the diffusion of elements of moulding material into the casting surface. Their depth, depending on the casting, can be 0.1 to 0.3 mm.

Three types of moulding systems are in use for Titanium investment castings:-

1. graphite artificial resin binders
2. thermodynamic high solid oxides/oxide binders (ThO_2 Y_2O_3 CaO and others)
3. high melting metals/oxide binders (W, Mo).

To cut down costs the whole shell is not built up out of the moulding materials. Only the front layer which is in a direct contact with the casting metal.

Special features of processing

Titanium investment casting is produced in vacuum using the centrifugal casting process. Centrifugal casting suppresses the development of gas holes and allows a quick die filling. Highly stressed Titanium investment castings for aircraft- and aerospace industries are hipped (HIP - hot isostatic pressing). In order to cure blowholes and gas holes (Titanium has a shrinkage of about 2,5 %). The described casting skin is removed by etching.

Weld repair

Weld repair of Titanium investment castings is generally requested. Weld repairs are done in argon-filled glove boxes using filler materials of the same composition as the casting, exhibit parent metal mechanical properties.

Materials

At the moment only alloy Ti Al6 V4 is specified in the German material performance sheet 3.7264 as an investment casting material. In Europe it covers nearly all applications for highly stressed parts. A complete German specification does not exist of Titanium based casting materials. For this reason there is an international reference to the American specification ASTM-B 367. Typical of pure Titanium is the large increase of solidity at decreasing ductility by comparable small increase of oxygen content (Grade C1 - C4). Grade C5 corresponds to alloy Ti Al6 V4 = 3.7264. The mentioned mechanical properties are guaranteed minimum values.

Applications of Titanium castings

Essentially there are two typical properties of Titanium and its alloys, which impose its application and which are not equalled by other materials in any other way:

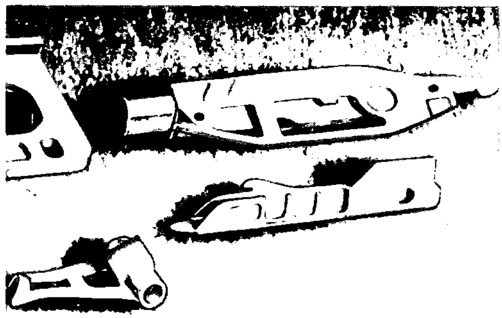
a) great performance ratio from mechanical properties to specific gravity. This property makes Titanium and its alloys in great demand for aircraft and aerospace industries. Titanium investment castings are used in power units, at high stressed planks and mountings, airframe elements and further applications. Fig. 3 shows brackets of airframe elements.

Fig. 3

In all applications a high cutting degree is avoided which can amount up to 96 % when produced out of a forging or a semi-finished product.

The high solidity at low specific gravity of Titanium opens further applications in these areas where high mass forces due to great accelerations must be avoided. Representative of these are textile machines, centrifuges, turbo exhausters, where steel investment casting is more and more substitued by Titanium investment castings.
Fig. 4 shows weaving parts.

Fig. 4



b) Excellent corrosion resistance against oxidizing media. Applications are in chemical installtion for both investment and rammed graphite castings, pump housings, pump impellers, valves, manifolds and similar elements.

Further applicastions are also implants in the medical field such as: implants as teeths roots, joint implants etc. Titanium is one of the few bio-compatible materials which are accepted by the body without mutual reactions and repulsion reactions. There are in process additional developments of alloys for implantation medicine.

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