SAVE COSTS - USE INVESTMENT CASTING

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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 costs”.

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 aero-space industries. Titanium investment castings are used in power units, at high stressed planks and mountings, airframe elements and further applications (Fig. 1).

   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 substituted by Titanium investment castings.

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

Further application are also implants in the medical field such as: implants as teeth 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 (Fig. 2).

CASTING PROCESS

For several reasons, including the very high reactivity of molten titanium with other materials, casting is a particularly specialised process.

A consumable-electrode method of vacuum melting is employed, special mold materials are used, and the molds are usually spun in a centrifuge during pouring in order to ensure that the molds are completely filled.

Mold techniques are similar to those used for casting other metals.

Because of the mechanical properties of cast titanium and its alloys are very close to those of wrought material, castings can be used for critical structural parts.

The ability to cast complex shapes to close tolerances and with good surface finish results in:
high material utilisation, reduced machining costs, welded and mechanical joints avoided by casting shapes that cannot be machined from a single piece of metal, improved strength and stiffness or equivalent weight reduction by casting hollow or deeply-ribbed shapes.

Therefore, any parts that could benefit from any of the above, are usually good candidates for casting.

All alloys can be cast, although CP and Ti-6Al-4V cover most requirements.

Post-casting operations include removal of ingates and risers, etching to remove surface contamination, HIP treatment when appropriate, inspection including X-ray and penetrant, and quality control including chemical analysis and tensile tests of samples cast with every pour.

DESIGN PRINCIPLES

While most shapes can be cast, quality and cost-effectiveness are both improved if the design embodies good casting principles. Broadly these are to ensure complete filling of the mold, to avoid shrinkage cavities and porosity, to avoid unnecessary tooling complexity, and to take advantage of the freedom (relative to machining) that casting allows in optimising shapes for structural or other reasons.

Mold filling is facilitated by providing for adequate ingates and risers close to heavy sections, preferably on surfaces that are machined in the finished component (for example joint faces) or that can be fettled to a simple shape. The design should also avoid isolated masses that can only be filled through thin-walled areas.

Shrinkage occurs as metal solidifies. The thinnest sections cool and solidify first, with adjacent molten metal drawn in by the shrinkage. The last parts to solidify are in the centres of the thickest masses, and inevitably this causes the formation of cavities of some sort. By designing the part with sections tapered out to riser faces solidification will progress from thin to thick metal ending in the risers, where cavities are of no importance.

The mold system selected (RG or investment shell) will depend on size, complexity, tolerances and finish required, and production numbers. The part should then be designed to allow the simplest construction of the patterns or dies, with suitable draft angles and with no needless undercuts (which can be made only at the expense of added tooling complexity)

Shapes can be easily cast that would be expensive or impossible to machine from forgings, including deep ribbing to improve the strength or stiffness of the finished component, elimination of unwanted heavy sections, and the inclusion of hollow features. Fig. 3 shows aerospace part these could not reasonably be made than by casting.

Another factor which should be considered in the design of a Titanium casting is the utilization of HIP. The primary stumbling block for the acceptance of more castings in critical applications has been the high level of mechanical property data scatter which is typically encountered with cast material. While the average property levels of cast and wrought material are nearly equivalent, the two sigma minimum design levels are considerably lower for cast material because of the data scatter. Since the designer must use minimum design curves, wrought material is favored in most cases. This is where HIP comes in. The application of high temperature and inert gas pressure to castings produces a twofold change; the casting microstructure is homogenized and internal gas and shrinkage voids are eliminated. Both changes are advantageous in that they reduce mechanical property data scatter. HIP also allows production of components which are not castable from shrinkage and gas defect standpoints. Rejectable, internally detective cast components can be HIP processed into acceptable parts. Internal voids are transformed into dimples on the casting surface which are, in most instances, within blueprint requirements.

Again, and it can’t be overemphasized; the approach to obtaining the optimum casting design is of utmost importance. The casting designer must assume that the designer’s specifications are not flexible, if no communication exists between them. It is only through mutual understanding of performance requirements and casting limitations by both customer and foundry designers that the most cost and performance effective configuration can be achieved.

COST COMPARISONS

When comparing a cast component with one machined from a forging or other wrought stock, it is important to assess the cost of the finished article.
The casting itself may be of similar cost to the equivalent wrought material, and the real savings are likely to be in reduction or simplification of machining or in avoiding joints by replacing several pieces by a one-piece construction.

If a cast titanium part is compared with one made of a different metal it may be worth assessing life-cycle costs because in some environments one titanium part may outlive several made in another material.

It is not practical to give numerical data on costs because they change continually and because machining costs vary between different companies.

By means of the so-called Spoiler the wing of the Airbus A 310 is hinged and actuated (Fig. 4)

Originally, this integrated “highly stressed” bracket used to be an assembly construction composed of 9 titanium parts that were machined all over and therefore did comply with the very conventional technique applied for the construction of airplanes. The development of foundry technique, especially with regard to the casting of titanium alloys to the “lost wax process”, was the basis for the necessary conditions to manufacture this very intricate component which is well castable tram the point of view of geometrical shape. This very part as a titanium investment casting - the external dimensions are 320. 400. 150 mm - is 100 g lighter. The titanium bracket could be optimized by the investment casting process which has a favourable impact on the fatigue behaviour.

Based on a production quantity of 1128 pieces. important data reveal assembly production of former times and today's manufacture of investment castings. If the eminent difference of 96 % in machining costs (along with assembly costs) can be considered as almost normal - because of “investment” - it is surprising that the material costs differ by 3.5 % only, this in favour of investment casting.

Semi-finished products on the one hand and rough castings ready to be assembled in large lots on the other hand are compared here.
One reason is the much higher material utilisation.
As a matter of fact, the difference in assembly costs of approximatively 86 % is evident. However, since relatively low amounts are involved - 483,- DM and 67,- DM for castings- the influence on the productions costs is not that important. The difference of about 50 % amounts to savings of 6.418,- DM per piece.

HINGING FOR COMPONENT OF WING OF AIRPLANE

	Formerly	Today
Production	Assembly	Investment Casting
Alloy	Titanium	Titanium
Weight	4500 g	4400 g
Costs for jigs and fixtures and tools respectively	100 %	64.6 %
Material costs	100 %	96.5 %
Machining and assembly costs	100 %	3.9 %
Production costs	100 %	50.5 %

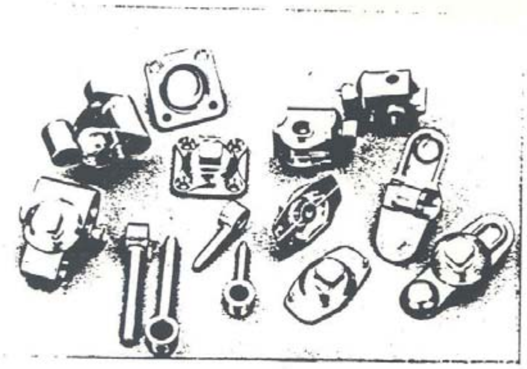

Fig. 2

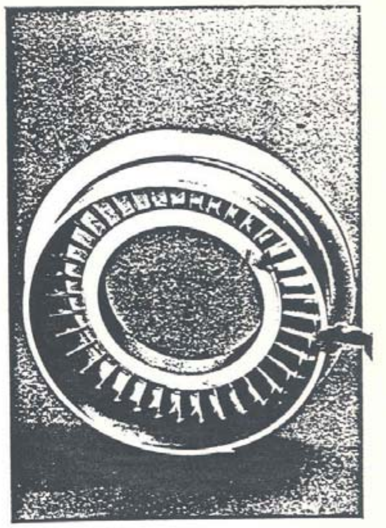

Fig. 1

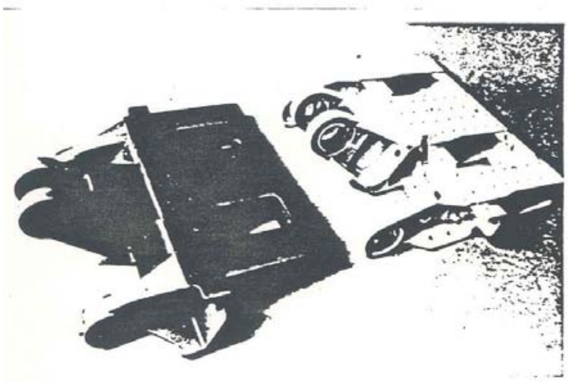

Fig. 4

Fig. 3