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THE IMPORTANCE OF QUALITY IN TITANIUM PRODUCTION

My name is Dick Goosey and I am very pleased to have the opportunity to present a paper to this meeting on behalf of IMI Titanium and in particular Dr. Farthing and Mr. Barber who are unable to be present today. In this presentation I would like briefly to attempt to outline why quality assurance and quality control is so important to the titanium industry and of course to the users of titanium.

In our view the commitment to quality is arguably the most important issue for the titanium industry and we at IMI Titanium operate a policy of nil compromise on quality. What is quality. We believe it is giving the customers the products that meet their specification and technical requirements on a consistent and reliable basis. To achieve this you need to define and operate a Quality Policy which in our experience should focus on

- the customers needs and expectations;
- the need to ensure everyone concerned with manufacture is involved in maintaining quality;
- that all aspects of manufacture from raw materials procurement to final despatch can and do contribute to quality;
- that processes can always be improved. Allied to this is a recognition that regular hazard reviews to identify potential problem areas of the production processes are essential to an ongoing commitment to quality;
- and last but not least, prevention is better and cheaper than cure;

Lack of effective quality control can lead to a non-standard product and in particular and most seriously the formation of material defects the presence of which may lead to very unfortunate consequences.

Against this background let us examine the titanium manufacturing process and identify the important role that quality control plays in ensuring that the final product is to the standard required. In considering the various stages of manufacture I propose to illustrate some of the defects that can be produced in titanium as a result of inadeguate quality control. I must stress that the "rogues gallery" of defects I shall show did not all originate in IMI products. They cover a spectrum of producers and represent the types of defect that are seen in titanium from time to time and in varying degrees wherever it is produced.

The process - as shown

Considering first the raw materials. Titanium sponge is produced by high temperature reduction of the tetrachloride by magnesium or sodium. Titanium is a highly reactive metal and the product of the reaction process is therefore susceptible to atmospheric contamination leading to the formation of nitrided/oxidised sponge.

Such contamination is a potential source of the classic Low Density Inclusion (LDI) or High Interstitial Defect (HID) in titanium, known to have been the cause of premature failure in compressor discs of gas turbine aero engines.

Alloy additions in elemental form or as master alloys can also be a source of defects. The Mo inclusion shown illustrates the consequences of adding material in a non-standard form resulting in in-complete solution and the formation of a HDI or High Density Inclusion.

Quality control of all raw materials is therefore vital to successful manufacture of defect free products.

Manufacture of raw materials must be to an approved purchase specification by a manufacturer who has been technically approved by the melter and produces the required product to a fixed method of manufacture agreed with the melter. This combined with regular auditing of the supplier and routine overchecking of the incoming raw material should provide a sound basis in quality terms from which to start manufacture of titanium products.

The ability to recycle scrap effectively is of considerable importance to the titanium producer for cost saving but again control is vital if quality is not to be compromised. In broad terms, recyclable scrap falls into two categories:

- solid scrap - which can be of various types/forms
- machined turnings or chips or swarf

Controls on solids include visual inspection and chemical analysis whilst additional precautions on swarf may include use of WC tool tips bonded with magnetic materials to facilitate extraction of tool fragments during swarf processing and X-ray inspection for WC or any other dense metal inclusions in the processed swarf.

100% X-ray examination of processed swarf is a universal pre-requisite to the recycling of such material into alloys intended for critical aerospace applications.

The consumable electrode arc melting process involves the construction of a primary electrode from raw materials, the stages of construction being blending, mixing, compacting, compact welding.

Quality control is vital at all stages and I would emphasise in particular the control exercised over the compact welding process where contaminated welds are on obvious potential source of interstitially contaminated defects. Visual standards against which welds can be assessed are therefore recommended and applied by IMI.

Electrode integrity or strength is clearly important in ensuring that the electrode is consumed by melting and unmelted pieces do not fall off into the molten pool - a situation which could lead in the extreme to the presence of incompletely melted material within the ingot.

Turning now to the melting process, this must be considered the most important stage in determining the quality of the final product, particularly in terms of freedom from defects.

Furnace cleanliness is paramount and the importance of a disciplined approach to furnace cleanliness cannot be emphasised too strongly. In our view adoption of a rigorous cleaning practice linked to an effective inspection procedure is vital to the consistent manufacture of titanium free from melt related defects.

Combined with this of course is the use of controlled melt schedules to give the control of ingot chemistry required by the customer - the latest and largest furnace installed and operated by IMI Titanium is computer controlled to provide a fully automated melt cycle with its consequence advantages with regard to product consistency.

Most products are double melted and triple melting is now specified for many critical aerospace applications.

Current final melt schedules incorporate a so called hot top cycle to minimise ingot cavity formation and the potential yield loss associated with metal rejection due to the presence of both sealed or unsealed ingot cavity.

The disciplined approach to melting is equally important when considering the subsequent conversion of the ingot to product by thermo-mechanical processing.

Specifications especially for critical aerospace components are becoming increasingly demanding in their requirements for consistently reproducible macro and microstructures and hence properties.

The important controls necessary to meet these objectives cost effectively are listed in the table.

Poor temperature control can lead to unacceptable structures, the most obvious being the totally transformed structure associated with overheating above the beta transus in an operation where the aim is to develop an equiaxed alpha morphology by sub-transus work.

In contrast processing at too low a temperature can lead to surface break up and cracking and internally to the formation of strain induced porosity.

A review of the importance of quality in titanium production cannot overlook the future and in this context the increasing interest in the use of cold hearth melting processes should be mentioned. Potential advantages in terms of eliminating high and low density inclusions during scrap and sponge melting are well documented and I intend only to highlight the developing interest in these processes and their likely importance to the titanium industry in the future.

In summary I hope this brief presentation has given some in-sight into the importance of quality in the titanium industry and will conclude with a reminder of the potential consequences of what a lapse in quality can mean.