Titanium Research and Development in France

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This plenary paper gives an overview of titanium activities in France since the preceding World Titanium Conference in 2007 in Kyoto. A new Franco-Kasakh titanium ingot processing plant (UKAD) is planned to operate in autumn 2011 and is dedicated to meet the growing demand for long products. Aerospace is still a major driver for research and development and it is anticipated that new programs at Airbus (A350 and A400M) will boost the titanium industry. With regard to aeroengines, important efforts and resources have been devoted to the development of predictive tools from ingot melting to processing of final parts. The reduction of 'Buy to Fly' ratio is of great concern for economical reasons and several companies are involved in near net shape technologies. Titanium is now considered as a key material in marine applications and an increased amount is being used in propulsion systems to manufacture seawater circuits. Biomedical is another field where applications are still growing continuously and some examples are given. The research work is very active and numerous topics are addressed in universities and public laboratories within the framework of national and international collaboration programs. Finally, the mission of the French Titanium Association is highlighted.

Keywords: *Ingot processing, aerospace applications, extrusion, linear friction welding, direct manufacturing, marine applications, biomedical, microstructure, properties, process modelling, machining*

1. Introduction

This paper attempts to give an outlook on recent trends in industrial developments and research activities in France.

Cost which includes the raw material and all the subsequent processing routes is the priority directing the materials development effort. Existing alloys are the first choice for designers and major advances are in manufacturing technologies to reach even closer the final shape. Extrusion, hot stretch forming, linear friction welding, laser welding, direct manufacturing and casting which can achieve economical solutions receive much attention.

Numerous research programs are in progress to investigate microstructure and texture evolution, thermomechanical processing/microstructure/mechanical properties relationships, process modelling and biomedical. A significant work is also performed on welding and machining. No study is carried out on the development of new conventional alloys although there is a renewed interest for advanced TiAl alloys.

2. Ingot Processing

There is no sponge plant and only limited smelting capacities in Europe which are mainly located in UK, France, Germany and Italy. Within this context, the UKAD project between UKTMP in Kasakhstan and Aubert&Duval in France is a very important industrial breakthrough. UKTMP's business is mining of titanium ore and processing it into sponge. It is one of the main producers of titanium sponge in the world. Recently, UKTMP has invested in compaction and melting equipments in order to supply large titanium alloys ingots. Regarding Aubert&Duval, a member of the Eramet Group, the core activity of this company is developing, melting and hot processing special steels, superalloys, aluminium alloys and titanium alloys. Aubert&Duval provides advanced metallurgical solutions in the form of long products or parts required for projects in the most demanding industries including aerospace, energy, industrial tooling steels, medical and motor racing.

UKAD is a 50/50 joint venture between Ardor Holding, commercial partner of UKTMP, and Aubert&Duval. The first talks about the partnership began in January 2006 and the UKAD company was created in December 2008. In the meantime, a memorandum of understanding was signed with EADS Airbus. The activity of UKAD will be the conversion of titanium ingots from UKTMP into long products, bars, wires, plates and sheets. It will rely on an automated short production cycle that uses the most available advanced technology, comprising a 4,500 tons forging press. The production equipments will also include heating and heat treatments furnaces, peeling, sawing and non destructive testing. After the implementation of the equipments, the plant will be submitted to a four to six months period of qualification by the customers.

The first stone of UKAD was laid in April 2010 in Saint Georges de Mons (Auvergne, France) and the plant is expected to open in autumn 2011. The future unit will combine safety, ergonomics, quality and economic performance on the 48,000 m^2 of the site. It is to be noted that environmental impact has been a major consideration in the development of the project.

3. Aerospace Applications

3.1 Airframes

High-strength, light-weight and durable materials are always desired by the structure engineer. AIRBUS always pushes forward the limits of innovation on its airframes to meet the increasing demands of airlines in terms of fuel consumption efficiency, environmental impact limitation, and reduced cost maintenance. Particularly, the new A350XWB aircraft is characterized by the massive use of CFRP (carbon fibre reinforced-polymer) on its fuselage structure. For both thermal dilatation compatibility and corrosion resistance considerations, this introduction of CFRP induces the extensive use of titanium alloys and related technologies. Indeed, their use has nearly doubled to reach around 20% of the structure weight as compared with 10% in A380 aircraft. It is worth mentioning that the anticipated production of A350 represents a titanium consumption of 15,000 tons/year. Titanium is mainly employed to manufacture highly stressed frame parts, landing gears, pylons, attachments and door surrounds. Ti-6Al-4V remains the workhorse alloy of the aerospace industry and is used by AIRBUS in the beta annealed condition which provides an improvement in damage tolerance. Near beta alloys (Ti-10. 2. 3, Ti-5553) are now used for highly stressed parts and particularly for landing gear systems in all new programs (Figure 1) for weight saving, corrosion resistance and protection of the environment (no Cd coating).

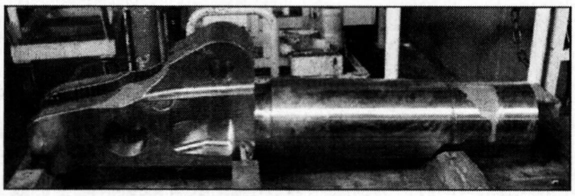

Figure 1. Forged part of a landing gear-Ti-10. 2. 3 alloy

3. 2 Aeroengines

SAFRAN is a high-technology Group with leadership positions in aerospace, defence and security. SAFRAN Group has a Materials and Processes Division wherein a titanium alloys cluster gathers engineers and experts involved in titanium components studies with Snecma (aircraft and rocket engines), Turbomeca (helicopter engines), Aircelle (engine exhausts), Techspace Aero (modules, equipment and test cells for aerospace engines) and Messier Dowty (landing gears). Presently, the great challenge is to develop aeroengines with an obvious reduction in fuel consumption. Since the preceding World Conference on Titanium in 2007, important efforts and resources have been dedicated in SAFRAN Group to the development of predictive tools related to manufacturing processes and microstructure evolution. The main research and development work in SAFRAN Group includes:

- modelling of skull melting: Ti-6Al-4V and Ti-5553,
- comprehensive modelling from ingot to final parts: Ti-17 high pressure compressor disks,
- modelling of microstructure evolution during heat treatments: Ti-6Al-4V compressor disks,
- in-depth understanding of the dwell effect in relation with temperature, holding time and forging processes: Ti-6. 2. 4. 2 engine disks and impellers (Figure 2),
- optimisation of the forging process for improved properties: Ti-10. 2. 3 landing gears,
- development of thermomechanical transformation processes: Ti-5553 landing gears,
- in-service ageing and development of repairing service: Ti-21S engine exhaust.

Figure 2. Ti-6. 2. 4. 2 impeller

4. Reduction of 'Buy to Fly' Ratio

4. 1 Extrusion

CEFIVAL has a very long experience in manufacturing sections and rings dedicated to aeronautical, nuclear, medical and food industries. This company has invested in a new fast extrusion press (19. 5 MN) in 2009. Usually, in order to obtain a titanium alloy part with a final thickness of about 1. 5 mm, the initial extruded section is 5 to 8 mm thick so as to have enough material to eliminate surface defects by machining. CEFIVAL developed a non conventional extrusion process which enables to produce sections of 2. 5 to 3. 5 mm thick with a corresponding improvement in the 'Buy to Fly' ratio (BtF) from 5 : 1 to 2 : 1 (Figure 3). Alloys currently used are Ti-40 (Grade 2), Ti-3Al-2. 5V and Ti-6Al-4V. Alpha-beta alloys can be extruded below the beta transus temperature to obtain a fine equiaxed microstructure. The new press allows an accurate temperature control so that it is feasible to extrude near beta alloys and titanium aluminides.

4. 2 Laser Welding

Laser welding may be an alternative solution to extrusion in some particular cases. For instance, thin sections of A350 aircraft are manufactured using laser

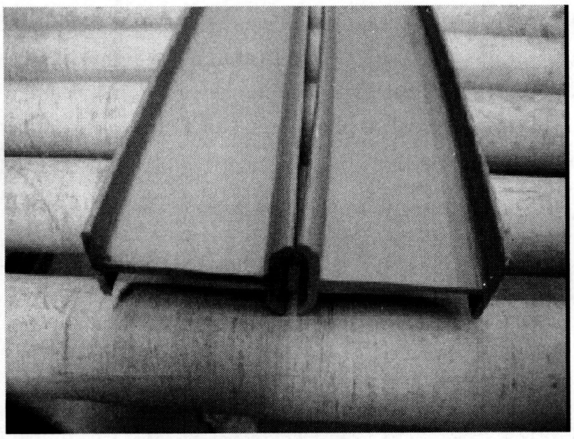

Figure 3. Thin extruded section 3.5 mm in thickness-Ti-6Al-4V alloy

welding, as shown in Figure 4. This process avoids the problem of machining thin thicknesses and there is only very little deformation after welding.

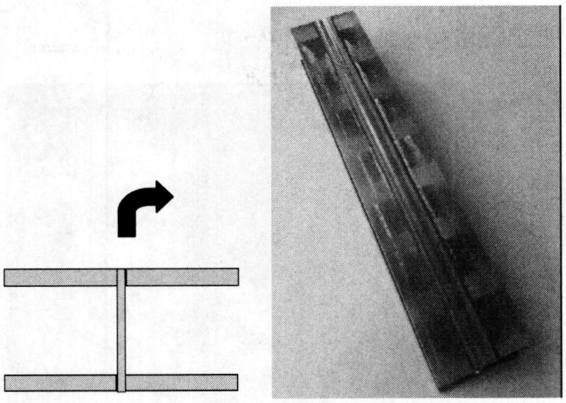

Figure 4. Joining of five elements (Ti-6Al-4V) by laser welding to manufacture a section for A350 aircraft

4.3 Linear Friction Welding

Linear friction welding (LFW) is a 'solid state' joining process able to join two parts with a much reduced thermally affected zone keeping a quality of the joining area extremely close to that of the parent material. ACB company is specialised on metal forming technologies for the aerospace industry (superplastic forming, diffusion bonding, hot stretch forming). Presently, ACB's expertise also covers LFW both for aeroengines and airframes components.

In most aeroengines, blades are fixed mechanically on the disk. The blisk (bladed disk) is a design which eliminates the mechanical assembly resulting in a weight saving of about 30%. Two technologies are employed to produce blisks: machining of a large disk or LFW of blades on a smaller disk. LFW blisks are more economical for blades over 100 mm height owing to a lower material cost and a faster process. Figure 5 illustrates a blisk manufactured by LFW and the estimated BtF ratio is reduced from 30 : 1 to 6 : 1 as compared with a conventional machining operation. As a further advantage, LFW can be used to join different materials. There is also the possibility to manufacture blisks with hollow blades obtained for instance by SPF/DB. Finally, it is to be noted that LFW is the only technique which could become a repairing solution in the case of damaged blisks.

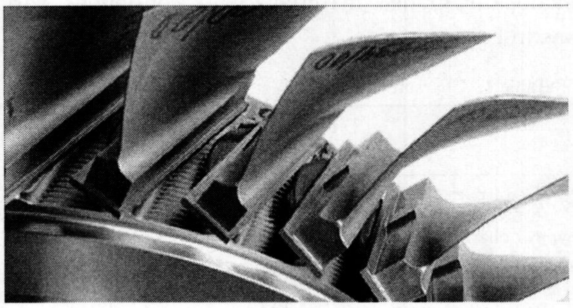

Figure 5. Titanium alloy blisk manufactured by linear friction welding

The best optimization of BtF ratio is obtained for structural aerospace components. Figure 6 shows an example of a titanium gusset with a 'L' shape and the corresponding BtF ratio gain is from 150 : 1 to 3 : 1. Some applications are foreseen on new aircrafts, A350 and B787.

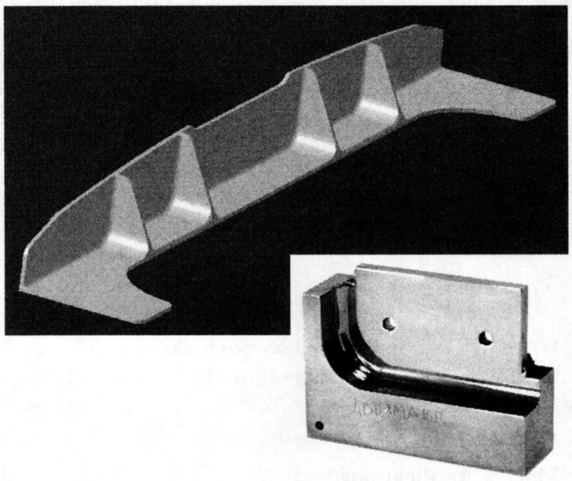

Figure 6. Titanium gusset manufactured by linear friction welding

4.4 Direct Manufacturing

Direct manufacturing is an innovative technology which allows the fabrication of parts directly from computer aided design data by the superposition of fine material layers. Materials are generally in the form of powders which are melted by a laser or an electron beam. This process offers new solutions for design office and manufacturing plants, in terms of lead time, cost and quality of the manufacturing parts, in order to respond quickly to a particular need. Densities and mechanical properties are equivalent to those obtained by other technologies.

There are two main processes for direct manufacturing and their characteristics are reported in Table 1. Direct metal deposition is well adapted to large parts with simple shapes whereas selective laser melting is more suitable to small size and complex parts. Several research institutes and companies in France are involved in the development and the production of parts obtained by direct manufacturing (Figure 7). The next evolution of this technology lies in the ability to make functionally graded materials with continuous variations in composition.

Table 1. Characteristics of direct manufacturing processes

	Direct Metal Deposition	Selective Laser Melting
Size of part	900×900×900 mm	250×250×250 mm
Typical characteristics of parts	Large parts, stiffened structures	3D complex shapes, opened or closed
Laser power	1 to 4 kW	200 W
Coating rate	400μm/layer	50μm/layer
Other application	repairing	—

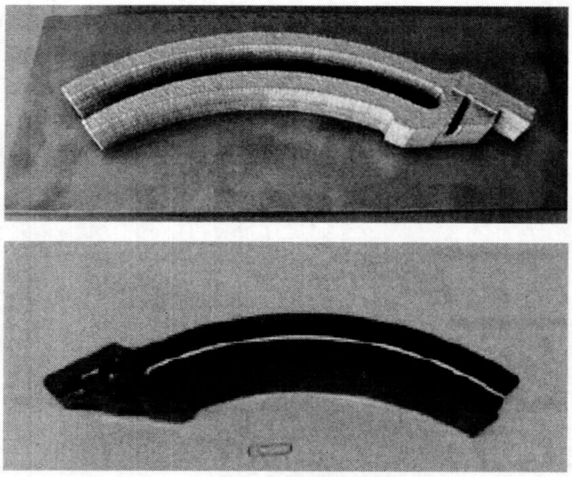

Figure 7. Example of a part processed by direct manufacturing. Top: blank. Bottom: finished part (by courtesy of DASSAULT-AVIATION)

5. Marine Applications

Concerning marine applications, titanium is exclusively used in the defence shipbuilding industry in France. Applications of titanium are increasing due to its exceptional seawater corrosion resistance, mechanical resistance, ballistic performance and non-magnetic properties. In France, the DCNS group is a world leader in naval defence and an innovative player in energy. The group designs, builds and supports submarines and surface combatants as well as associated systems and infrastructures. It also develops solutions in civil nuclear engineering and marine renewable energy.

DCNS essentially employs titanium and its alloys to manufacture seawater circuits in military propulsion systems. Years ago, most circuits in contact with seawater were made of Cu-Al and Cu-Ni alloys but it appeared that they suffered from severe crevice corrosion and that it required heavy and costly maintenance operations. An economical analysis has shown that despite the high price of titanium, it was appropriate to replace Cu-Al and Cu-Ni alloys by titanium owing to its outstanding corrosion resistance in seawater. Figures 8 and 9 illustrate typical applications of CP titanium in propulsion systems.

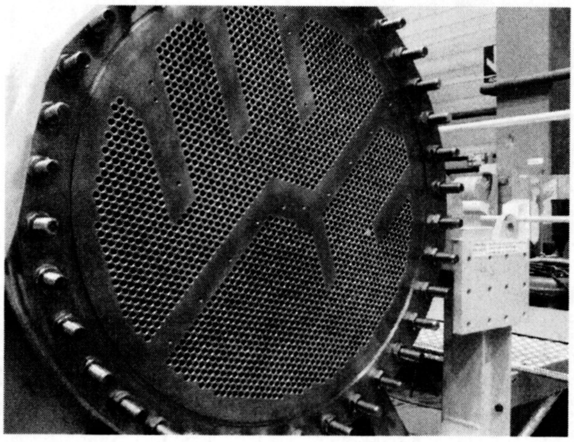

Figure 8. Part of a heat exchanger made of forged CP titanium

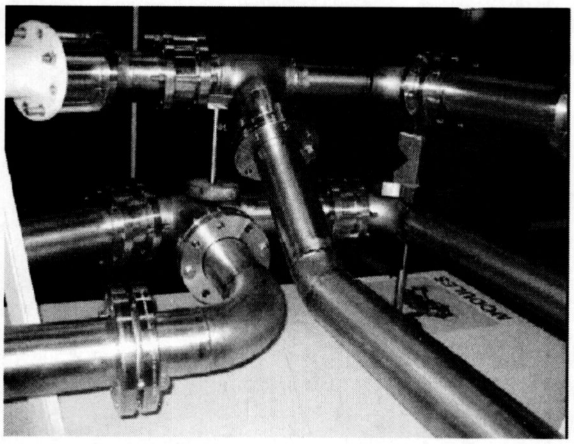

Figure 9. Seawater piping system made of CP titanium

In order to limit the economical impact due to the cost of titanium, a solution has been examined consisting in replacing forged components by similar pieces obtained by casting. The casting process offers several advantages as compared with forging: material saving, reduced machining, suppression of welding operations and associated risks. The potential cost saving is important in the case of some large pieces (Figures 10 and 11). Considering that the casting solution is attractive from an economical point of view, it was important to check that it is also pertinent technically. In fact, it is often that cast parts do not display a material quality and mechanical properties as good as those of a forged material. So, an extensive characterisation program has been carried out on CP titanium and Ti-6Al-4V alloy and it has been found that cast material exhibits equivalent mechanical properties (tensile, fracture toughness, fatigue) in the cast+HIP'ed condition as compared with forged material except for a slight loss in ductility.

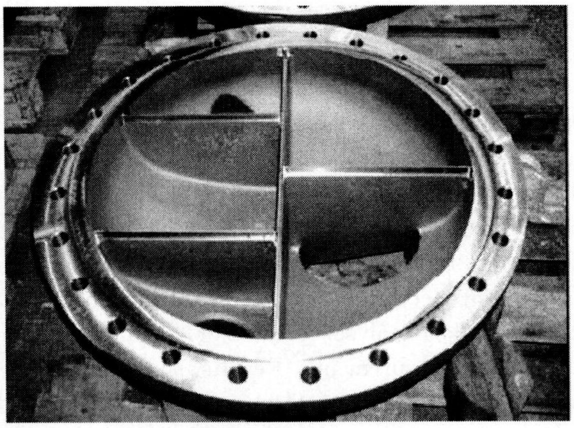

Figure 10. Part of a heat exchanger-cast+HIP'ed CP titanium

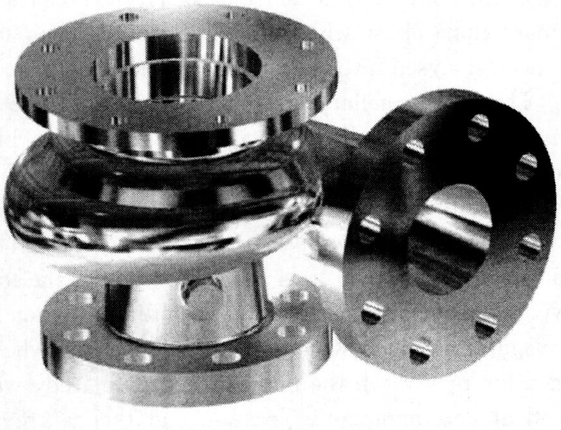

Figure 11. Seawater pump component-cast+HIP'ed Ti-6Al-4V

6. Biomedical Applications

Biomedical applications are still growing continuously because titanium and its alloys display a high specific strength and offer the best biocompatibility among metallic biomaterials. CP titanium and Ti-6Al-4V are the most widely used but metastable beta alloys are receiving an increased attention owing to their lower elastic modulus which is closer to that of human bones. Some companies in France are involved in the development of implants and prosthesis. The research activity in this field is described in § 7. 5.

Screws, plates and nails are currently used for bone reconstruction and fracture fixation. In the 1980's, surgical techniques in trauma began employing a guided wire technology which consists in the use of a small diameter pin around which a drill and then the final implant can be driven. This technology requires the instruments, screws and nails to be cannulated. FORECREU has developed a specific extrusion process to produce cannulated bars for the manufacturing of surgical tooling and orthopaedic implants (Figure 12).

The company PROTiP was created in 2004 on the basis of the research work performed at ONERA in the Powder Metallurgy Laboratory where advanced alloys for aeroengine turbine disks were studied. The expertise of this laboratory allows the development of a new porous material made of unalloyed titanium and applicable to medical implants. The process consists in agglomerating small titanium beads in order to obtain an open porosity material which can be colonised by living tissues. The first implants were porous tracheas which were tested first on rats, then on sheep, with the aim to create an artificial larynx. The porous titanium has also been applied on the surface of phonatory implants which are used for the vocal rehabilitation of people who have to live without larynx (Figure 13). It was also used in dental implants in order to improve the adherence of soft tissues around the implant.

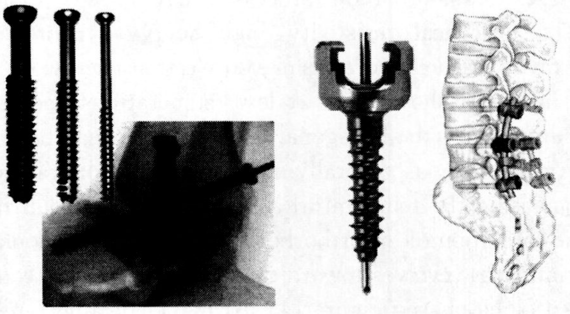

Figure 12. Examples of the use of cannulated screws in trauma

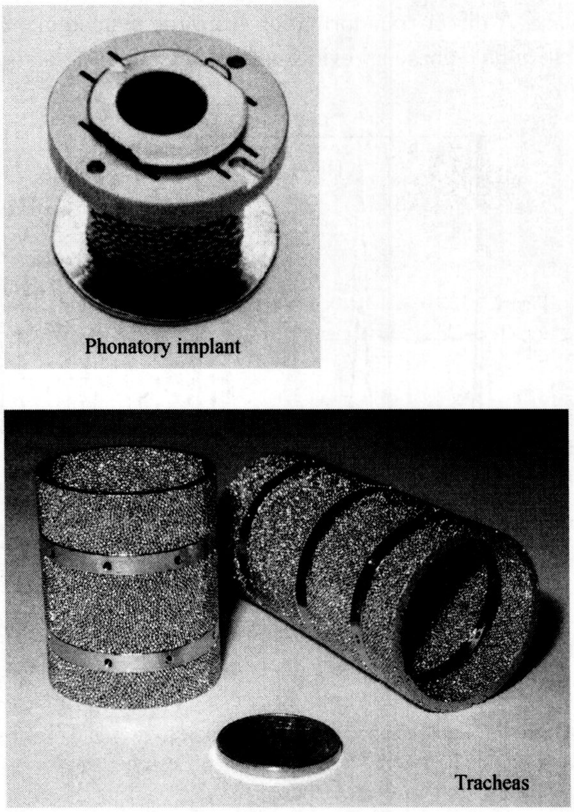

Figure 13. Examples of implants processed with porous titanium.

7. Research Activities

7. 1 Microstructure Evolution

Near beta alloys (Ti-17, Ti-10. 2. 3, Ti-5553) display a better heat treatability than alpha-beta titanium alloys and various microstructures can be obtained leading to a wide range of mechanical properties. In the heat treated condition, their microstructure consists of nodules or elongated platelets of primary alpha phase surrounded by tangled needles of secondary alpha phase, all being embedded in a beta matrix[1]. The morphology, size and spatial arrangement of phases depend strongly on the precipitation sequences occurring during heat treatments. A study has been performed on phase transformation during ageing of the metastable beta phase in the Ti-5553 alloy, in which three parameters have been dealt with: heating rate, ageing temperature and chemical composition of the metastable beta phase. Transformation processes have been studied using electrical resistivity, high energy synchrotron X-ray diffraction and transmission electron microscopy[2]. It has been shown that at low temperatures and low heating rates, the hexagonal isothermal omega phase is formed firstly as generally mentioned in the literature. Increasing the temperature, X-ray diffraction confirms the formation of an orthorhombic phase (alpha double prime) that evolves toward the hexagonal pseudo compact alpha phase (Figure 14). At higher heating rates, omega phase may not precipitate and the orthorhombic phase forms directly and transforms again into alpha phase. A direct transformation from the metastable beta to alpha phase is evidenced at the highest heating rates.

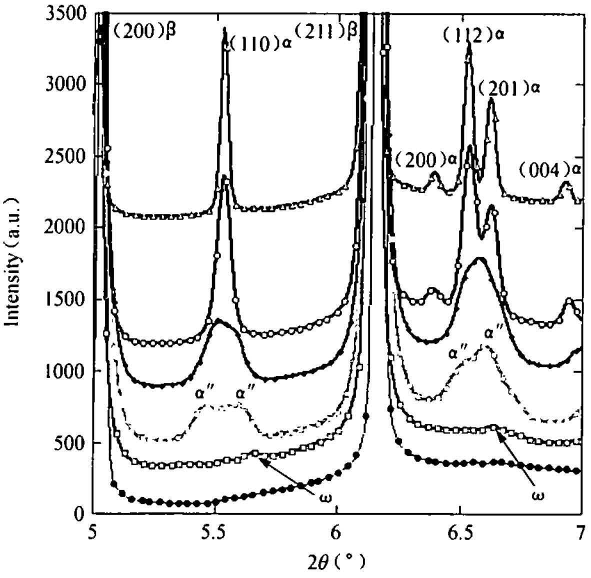

Figure 14. Determination of precipitation sequences in Ti-5553 alloy during heating by in-situ high energy synchrotron X-ray diffraction (0. 1℃/s)

7. 2 Deformation Micromechanisms and Mechanical Properties

The macroscopic mechanical behavior of near beta titanium alloys is only partially documented and in particular their deformation modes and damage processes are poorly identified. Therefore, it remains difficult to define the best microstructure for a given application. A research work focused on the identification of deformation mechanisms in a forged Ti-5553 alloy subjected to monotonic and cyclic loadings at room temperature[3]. Tensile tests were performed *in situ* in a scanning electron microscope. Samples were previously polished to observe the first stages of plasticity with the emergence of slip bands at the surface. The nature of activated slip systems (basal, prismatic, pyramidal) was identified by electron backscattered diffraction (EBSD) and a statistical analysis could be obtained with a great number of measurements. Results showed that two main relevant scales have to be considered: the crystallographic orientation of the initial beta grain influencing the stress-strain distribution due to the elastic anisotropy of the body centred cubic phase and the nodules of primary alpha phase where the slip activity starts and has been analysed through a Schmid's factor approach.

The fully lamellar beta processed Ti-6. 2. 4. 2 is sensitive to the 'dwell-effect' at room temperature like many other titanium alloys. This means that fatigue life is significantly reduced when a dwell time is introduced at the maximum stress level in the loading cycle. The analysis of fracture surfaces generally leads to the following agreement: the fatal crack initiates by quasi cleavage from microstructural heterogeneities whose dimension may reach the millimetre size. A study was aimed at determining the location and the nature of such large heterogeneities in terms of local configuration and crystallographic orientation[4]. A specific digital image processing has been developed to identify them from large sets of images obtained by optical microscopy or scanning electron microscopy. This approach has been validated by EBSD which revealed that these heterogeneities are composed of alpha lamellae colonies.

IMI 834 is a near alpha alloy designed to be used for critical rotating components in aeroengines (compressor blades and disks) and a significant reduction of lifetime has been reported under dwell fatigue conditions. Indepth investigations were performed to better understand how the texture and the microtexture influence crack nucleation and dwell fatigue lifetime[5]. Samples were cut from various regions of a forged IMI 834 disk and then tested under dwell fatigue conditions at room temperature. The fracture surfaces were analysed to identify the crack initiation sites and propagation paths. EBSD orientation maps were acquired directly on the fracture surface after successive polishing steps. The large scatter in dwell fatigue lifetime observed from one sample to another was related to variations in texture and microtexture. The EBSD orientation maps revealed that crack initiation and propagation is connected to millimetre size macrozones displaying a sharp texture with a minimum of 30% alpha grains having their 'c' axis oriented at less than 30°of the load direction (Figure 15).

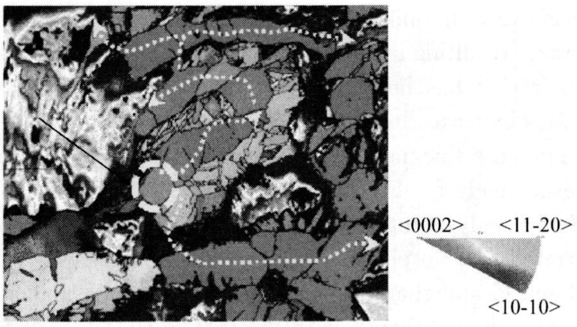

Figure 15. Influence of macrozones on crack initiation and propagation in IMI 834 alloy tested under dwell fatigue conditions

7.3 TiAl Alloys

TiAl-based alloys can be processed using different routes (casting, forging, powder metallurgy, extrusion) and the resultant mechanical properties vary strongly. Figure 16 illustrates the influence of the manufacturing process on tensile properties at room temperature of the Ti- (47-48) Al-2Cr-2Nb (at. %) alloy[6]. It can be seen that a wide range of grain size, yield strength and elongation to rupture can be obtained. Casting offers the advantage to fabricate complex parts but the microstructure is coarse with a grain size of about 350 μm and the elongation to rupture is the lowest. It is difficult to refine the microstructure of cast parts by heat treatments. On the contrary, it is possible to optimize the microstructure using forging or powder metallurgy in order to satisfy the required specifications and mechanical properties of both processes lie in the same scatterband with a better combination of yield strength/elongation to rupture than casting (Figure 16). Finally, the best ductility at the same strength level is achieved with the extrusion process which produces the finest grain size (5 μm). In the light of the preceding results, it is to be noted that the direct comparison of mechanical properties of different TiAl alloy compositions should be made with the very same processing route.

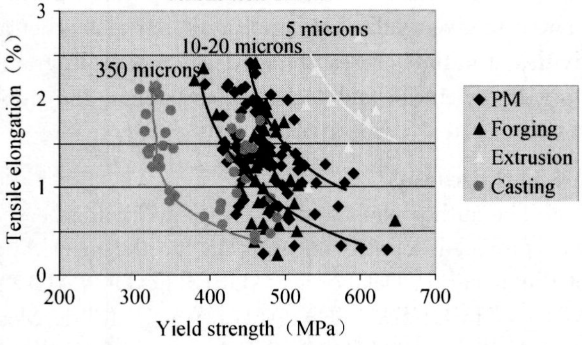

Figure 16. Results of room temperature tensile tests performed on Ti- (47-48) Al-2Cr-2Nb (at. %) alloy processed under different routes

7.4 Modelling

An increasing part of the research work is devoted to modelling and concerns skull melting, manufacturing processes, phase transformation kinetics and prediction of mechanical properties.

A model has been developed which is able to predict the kinetics of beta → alpha transformation in industrial titanium alloys during complex heat treatments[7]. The potentialities of this model have been demonstrated on different titanium alloys. A first illustration has been the study of the concentration evolution of alloying elements in a ternary Ti-V-O alloy undergoing isothermal treatments and it has been found that oxygen has a peculiar influence on the transformation kinetics. Then, the Ti-17 alloy subjected to various isothermal (TTT) and continuous cooling (CCT) treatments, has been investigated. Comparisons with available experimental data on TTT/CCT diagrams and microstructural features have been carried out. Also, calculations of complex thermal paths composed of heating and cooling have been undertaken showing the capability of the model to handle growth as well as phase dissolution processes.

Stress and strain fields associated with the formation of intragranular alpha phase precipitates have been calculated[8]. In near beta titanium alloys, phase transformation at intermediate temperatures around 600℃ leads to intragranular alpha precipitation. In order to analyze the effect of eigenstresses generated by the transformation on the plates morphology and spatial arrangement, computation of local stress-strain fields arising from lattice cell parameters mismatch between beta and alpha phases have been performed using fast Fourier transforms. Calculations have taken into account both the Burgers orientation relationships between beta and alpha phases and the elastic anisotropy of these two phases. Based on the discretization of a volume containing one or several alpha precipitates embedded in the beta matrix, the algorithm allows predicting the orientation and the form of the precipitates which minimize the elastic energy.

Few studies have been focused on deformation modes in near beta titanium alloys and in particular on the role of the beta phase. The aim of a recent research work was to investigate the deformation mechanisms in Ti-17 and Ti-5553 alloys and a multi-scale approach has been used for this purpose[9]. A large data base has been obtained in the framework of a French cooperative project and two types of model have been proposed:

- on one hand, mean field models have been introduced in order to describe the influence of microstructure on mechanical properties. The average behavior of each phase is considered; a simple von Mises criterion is used for the beta phase whereas crystal plasticity is used for the alpha phase. The model parameters for each phase are determined by fitting tensile curves obtained on simplified microstructures,

- on the other hand, an explicit representation of the microstructure (Finite Element Crystal Plasticity) has been used to simulate the global and local behavior of a 200μm thick large grain specimen which has been tested *in situ*. The simulation takes into consideration real grains geometry and crystallographic orientations. The comparison between experiment and simulation is made both on global tension curves and on a meso-scale by considering full field measurements of the out-of-plane displacement and the strain field.

7.5 Biomedical

Several universities are involved in research activities which deal with various topics:

- electrochemical study of the corrosion resistance of Ti-6Al-4V alloy10),
- electrochemical study of the corrosion behavior of Ti-20Mo alloy for dental applications11),
- microstructure, deformation mechanisms, mechanical properties and biocompatibility of Ti-25Ta-xNb alloys12),
- superelasticity and shape memory effect of metastable beta Ti-Nb alloys13),
- influence of thermomechanical treatments on Young's modulus and superelasticity of Ti-Nb-Zr alloys14),
- effect of short-time thermal treatments on mechanical properties of Ti-Nb, Ti-Nb-Zr and Ti-Nb-Zr-Sn alloys15).

7.6 Machining

Machining is a major point of interest aiming at reducing the cost of finished parts. In this respect, water jet-assisted machining16) and high speed cutting17) show great promise. High speed cutting of CP titanium and titanium alloys (Ti-6Al-4V and Ti-10.2.3) is being extensively studied17). The subsurface layer just below the machined surface can be described as a multi-layered material, each layer displaying a specific microstructure, residual stress state and crystallographic texture (Figure 17). By a careful examination of the subsurface, the material can be divided into three layers labelled A, B and C. The zone A corresponds to the bulk material which is not visually modified by the machining operation. The zone B is affected significantly: the grains rotate towards the cutting direction as a consequence of the plastic deformation induced by the cutting process. The zone C is just below the free surface of the work-piece and the transition between zones B and C can be recognized by a drastic change in terms of shape and direction of grains. In the zone C, the severe plastic deformation induced by the cutting process leads to a thinning and elongation of alpha and beta grains resulting in an alignment of grains parallel to the surface. It has been observed that the depth of these zones increases linearly with the cutting speed. For example, the thicknesses of zones B and C are 20 and 3μm respectively for a cutting speed of 260 m/min. Using X-ray analysis together with EBSD, it has been demonstrated that no phase transformation occurred in zones B and C and that the compositions of alpha and beta phases do not change with the cutting speed.

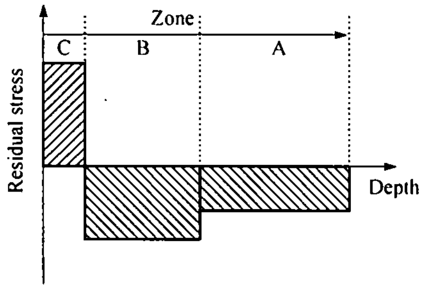

Figure 17. Residual stress state of the subsurface area of Ti-6Al-4V alloy after high speed machining

8. The French Titanium Association

The French Titanium Association "Association Titane" was created in 1995 by a consortium of industries and institutions from the region of Nantes, in the west part of France. Year after year, this association which offers a forum for the French titanium community has a growing influence. It has 120 members in 2011 coming from industries, universities, research institutes and governmental agencies. The guidelines of activities are discussed within a scientific and technical council which meets twice a year and whose president is Prof. G. Béranger. Various topics are addressed in different technical committees: knowledge management, industrial engineering, microstructure-properties relationships, machining, surface treatments and biomedical. Once a year, the association organises a two-day technical symposium in Nantes where presentations are focused on a selected theme. Usually, a foreign guest is invited to give a talk. The association has also other activities: it initiates research and development programs, provides scientific and technical assistance and publishes a 'Letter' twice a year.

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REFERENCES

1) N. Escalé, J. Douin, F. Pettinari-Sturmel, C. Daffos, A. Coujou: *Microstructure and deformation micromechanisms in metastable beta titanium alloys determined by conventional and in-situ straining* TEM, this conference.

2) A. Settefrati, M. Dehmas, G. Geandier, B. Denand, E. Aeby-Gautier, B. Appolaire, G. Khelifati, J. Delfosse: *Precipitation sequences in metastable beta phase of Ti*-5553 *alloy*, this conference.

3) T. Duval, P. Villechaise, S. Andrieu: *Deformation mechanisms and fatigue cracks initiation in near beta titanium alloys in relation with microstructures at different scales*, this conference.

4) I. von Thungen, P. Villechaise, A. Dalloz: *Deformation modes in a beta Ti*-6. 2. 4. 2 *alloy submitted to dwell loading at* 20℃, this conference.

5) N. Gey, P. Bocher, E. Uta, M. Humbert, J. Gilgert: *How texture and microtexture influence dwell fatigue lifetime in forged IMI* 834 *titanium alloy*, this conference.

6) M. Thomas, O. Berteaux, J. L. Raviart: *Designed experiments for optimized mechanical properties in cast and PM TiAl-based alloys*, this conference.

7) P. Di Napoli, B. Appolaire, E. Aeby-Gautier, A. Beneteau: *Modelling of beta → alpha transformation in complex titanium alloys*, this conference.

8) A. Settefrati, B. Appolaire, Y. Le Bouar, E. Aeby-Gautier, G. Khelifati: *Stress and strain fields calculations associated with formation of intragranular alpha phase precipitates*, this conference.

9) G. Martin, L. Nazé, G. Cailletaud: *Numerical multiscale simulations of the mechanical behavior of beta metastable titanium alloys Ti*-5553 *and Ti*-17, this conference.

10) S. Jelliti, C. Richard, D. Retraint: *Electrochemical studies on the stability and corrosion resistance of Ti*-6*Al*-4*V alloy for biomedical applications*, this conference.

11) D. Mareci, R. Chelariu, D. M. Gordin, M. Romas, D. Sutiman, T. Gloriant: *The corrosion behavior of Ti*-20*Mo alloy in non pasteurized and pasteurized orange juice*, this conference.

12) E. Bertrand, D. M. Gordin, T. Gloriant, D. Cojocaru, D. Raducanu, E. Vasilescu, A. Cimpean, I. Dan: *Elaboration, characterisation and biocompatibility of Ti*-25*Ta-xNb alloys*, this conference.

13) A. Ramarolahy, P. Castany, D. Laillé, P. Laheurte, F. Prima, T. Gloriant: *Investigation of the superelasticity and the shape memory effect of metastable beta Ti-Nb based alloys*, this conference.

14) W. Elmay, T. Gloriant, F. Prima, B. Bolle, N. Gey, E. Patoor, P. Laheurte: *A thermomechanical treatment to improve superelasticity and low modulus of Ti-Nb- (Zr) alloys for biomedical applications*, this conference.

15) F. Sun, Y. L. Hao, T. Gloriant, P. Laheurte, W. Elmay, A. Eberhardt, J. Y. Zhang, F. Prima: *Influence of short-time thermal treatments on mechanical properties of biomedical titanium alloys*, this conference.

16) F. Le Maître, Association Titane, private communication.

17) J. D. Puerta Velasquez, A. Tidu, B. Bolle, P. Chevrier, J. J. Fundenberger, Mat. Sci. and Eng. A 2010;257: pp. 2572-2578.