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HIGH PERFORMANCE MILLING OF EMERGING TITANIUM ALLOYS

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Abstract: *The work here presented is framed in the line of development manufacturing processes for a new generation of slight materials with good mechanical properties, the gamma TiAl alloys. These alloys were developed to achieve a reduction of weight in different components for aviation and automotion where very high temperatures are the main factor. In this applications fields several components must withstand high temperatures maintaining a high resistance. The superalloys of type gamma TiAl are an attractive alternative to nickel-based alloys, due to the high ratio between resistance and weigh and resistance and low corrosion. This work presents the results from milling tests on three types of gamma TiAl alloys. End mill tools made of integral tungsten carbide were used, applying different feeds and cutting speeds. The influence of cutting speed and feed is discussed.*
Key words: *gamma TiAl, superalloys, slight materials, aviation*

1. INTRODUCTION

Gamma TiAl intermetallic superalloys offer excellent mechanical properties as well as low values of density (4gr/cm^3), high resistance under high work temperatures, high electric and thermal conductivity, a considerable resistance to the oxidation, tensile strength higher than 1000Mpa and Young´s modulus of 160 GPa (Aspinwall et al., 2005).

There are three basic types of alloys,

a) TNB type [Ti (44-45)Al-(5-10)Nb-(0,2-0,4)C] for applications at very high temperatures maintaining high values of resistance and oxidation, suitable for aeronautical components.

b) MoCuSi type [Ti (43-46)Al-(1-2)Mo-(0,2)Si-Cu] for use at lower temperatures, but with a high resistance below 650 ºC.

c) The third type is the TNM [Ti (43-45)Al-(5-8)Nb-Mo-(0-0,4)B-C] for applications at very high temperatures, not included in this work (Noda, 1998; Smit et al., 1999).

This work aims to establish a procedure to measure the tool life in the machining of this type of alloys defining valuable parameters for the end-milling operation. Currently there are few data about machining of gamma TiAl, but is well known that all of them present a very low machinability (López de Lacalle et al., 2000; López de Lacalle et al, 2004; Sharman et al., 2001). The obtained results showed these alloys present lower machinability in comparison with other titanium alloys. These materials are very brittle, for that reason especial care must be taken into account to avoid the spalling, chipping and cracking of components during the machining process. In this work the milling process parameters for the two former types of alloys are going to be defined.

On the other hand, two of the big drawbacks for the industrial production of these alloys are their great sensibility to the impurity during the foundry process and their consequent high cost of production.

Nowadays, two manufactured presentations for these alloys are in the market, the alloy solidified as ingot, and the alloys extruded after solidification. The mechanical properties of extruded alloys are higher than those obtained as ingot. It is possible to observe in Figure 1, the alloys melted and solidified as ingot present a structure without any preferable orientation, typical of the no laminated or extruded materials. On the contrary extruded alloys present a structure oriented toward the extrusion direction.

In Figure 1, four mechanical properties and their differences for two types of alloys are shown. It is possible to observe, mechanical properties of extruded alloys are superior, including the yield strength, creep strain and K_{1C}.

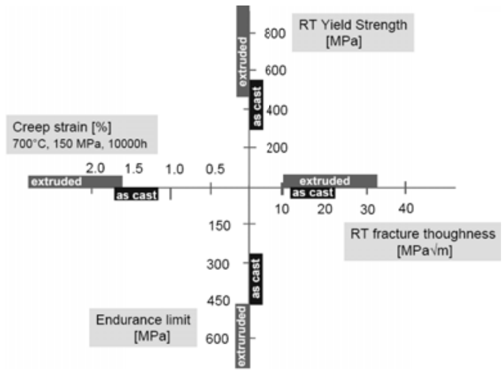

Fig. 1. Mechanical properties of the melted (as cast) and extruded alloys.

2. TEST PLAN

Two different titanium-aluminium allows were under study. The first of them is the MoCuSi type, specially produced for car components, in this case the alloy was studied in both: the ingot and extruded forms.. The second, the TNB type was only studied in the ingot form.

The tests were carried out for each one of the cutting conditions defined by the table in duplicate. In order to assure their reliability, the recorded results were the mean value of the two tests. Tools were integral tungsten carbide end-mills manufactured by Mitsubishi® and designed for the most used titanium alloys (Type Ti6Al4V). This end-mill has six edges, with a light positive primary rake angle of 6º (see Figure 2).

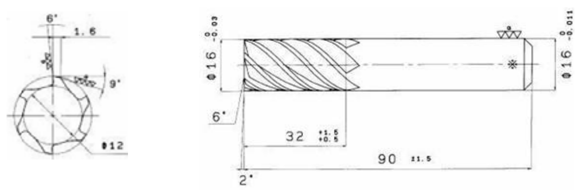

Fig. 2. End-mill used in machining process

The flank wear V_B of each edge and each tool was measured using an optical microscope with an integrated digital camera, from the digitized images were possible the accurate measurement of tool wear.

The milling operation was performed in a spiral tool path. The a_p and a_e values were kept constant in a long machined length, in down-milling condition. Therefore, continuous machining was achieved, without interruptions and with minimum influences of the entrance and exit of the tool in the machining of material. The aforementioned path was useful in order to avoid chipping wear in the tool edges as well as in the part borders. FU 70 W Rhenus® coolant, conceived for aeronautical materials was used in all the tests. This product has neither ammonia nor boron, with a low pH value, 7.5-8.8. Properties are shown in Table 1.

CONCENTRATED		EMULSION	
Viscosity 20 ºC (mm2/s)	Content of mineral oil %	pH Value 5% concentration	Protection against corrosion (DIN 51360/1)
Approx. 150	Approx. 33	Approx. 9,0	Note 0 al 2%

Tab. 1. Properties of Rhenus FU 70 W coolant

The cutting conditions used in the test, are indicated in Table 2. These conditions are in the lower range of those recommended by tool manufacturers for the alfa+beta alloy Ti6Al4V, the most common in several applications. The recommended cutting conditions were a starting point to define the process parameters, as well as a comparison reference respect to other titanium alloys.

Vc[m/min]	D[mm]	f_Z	F[mm/min]	N[rpm]	a_p	a_e
50.00	16.00	0.04	238.73	994.72	1.00	1.00
50.00	16.00	0.05	298.41	994.72	1.00	1.00
50.00	16.00	0.06	358.10	994.72	1.00	1.00
60.00	16.00	0.04	286.48	1193.66	1.00	1.00
60.00	16.00	0.05	358.10	1193.66	1.00	1.00
60.00	16.00	0.06	429.72	1193.66	1.00	1.00

Tab. 2. Default machining conditions

3. RESULTS

The results obtained in the machining of the TNB ingot alloy are shown in the Figure 3. In all the cases, it is clear the strong influence of the cutting speeds on the tool life. The flank wear V_B in function of the machining time for three cutting speeds and one feed rate is shown.

However, cutting speed is the factor with maximum influence on tool life, due to the growing wear originated for friction during milling process.

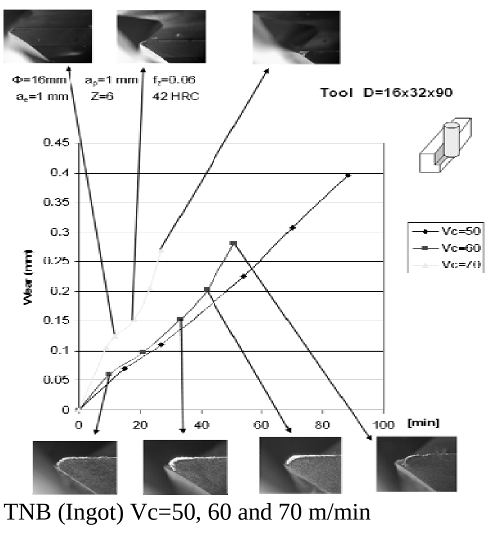

Fig. 3. TNB (Ingot) Vc=50, 60 and 70 m/min

The results obtained for the MoCuSi extruded alloy are shown in Figure 4. It can be observed the feed rate influence over the tool life. Figure 4 shows the flank wear V_B as function of the machining time for three feed rates under one cutting speed.

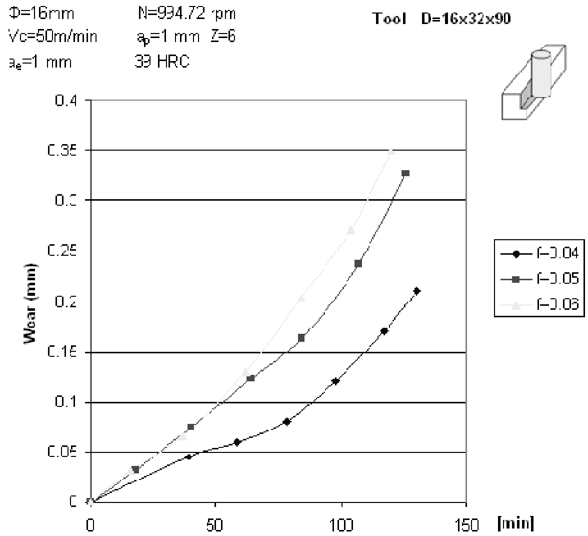

Fig. 4. MoCuSi (Extruded), Vc=50 m/min

4. CONCLUSION

After testing, the flank wear and the effective cutting time with different cutting conditions were obtained. The cutting speed has the principal influence on the durability of the end-milling tools. A small increase in the value of this parameter reduces an important percentage of the useful tool life. The feed per tooth is less important and the second factor to take into account for the tool life evaluation. The obtained values can be used directly in industrial applications for milling of gamma TiAl alloys as the main operation.

5. ACKNOWLEDGEMENTS

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