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INFLUENCE OF THE THERMAL TREATMENT ON THE WC-CO CUTTING TOOL-LIFE. APPLICATION TO THE HSM OF AEROSPACE ALUMINIUM ALLOYS

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Abstract: *The use of high performance emergent materials in the aerospace industry has supposed that nowadays, the machining process of aluminium alloys cannot be considered as a high added value process. In this sense, at the end of the 80´s High Speed Machining (HSM) was introduced in order to improve the performance of that process, being undoubtedly effective in the machining of these kinds of alloys (Arnone, 1998). On the other hand, it can be said that about 4% of the final cost of a machined workpiece can be related to the cost of the cutting tools necessary to produce it (*Spitler et Al., *2003). Because of that, an important improvement of the aluminium based aerospace elements manufacturing processes can be done by increasing the cutting tool life, giving rise to a reduction of the both economic and energetical impact. This paper reports on the results of an improvement in the HSM performance of an aerospace Al-Cu alloy by enlarging the tool life through the application of thermal treatments.*
Key words: *UNS A92024, HSM, thermal treatment, tool life*

1. INTRODUCTION

Machining processes performance can be influenced by a high number of parameters and variables, such as feedrate, cutting speed and depth of cut, toolpath and cooling strategies, or the machine-tool and clamping device characteristics.

When these items are fixed, cutting tools plays a predominant role in that performance. Thus, it is neccessary to search cutting tools life improvement conditions.

Research lines developed for that purpose involve tool wear minimizing and/or process based tool redesign (Sebastian & Faura, 1997). Design changes can be seen from two viewpoints: on the one hand, tool geometrical modifications; on the other hand, modifications of the core and/or covering cutting tool material.

The production requirementes and other factors, such as the initial cost of design modifications to be made by the cutting tool manufacturer, and the results obtained in a previous analysis of the cutting tool wear in the HSM of Al alloys (Cano et Al., 2007), give rise to proposal a cutting tool material modification, executable in the same plant where the machining processes are being carried out.

In this context, this paper shows the benefits of heat treatments on the tool life improvement, for tungsten carbide end milling tools applied in the HSM of one of the most used alloys in the aerospace industry, the UNS A92024-T3.

2. EXPERIMENTAL

The HSM tests were in profile contouring processes. In these tests, sets of large UNS A92024-T3 overlapped sheets, with total thickness under 10 mm, were contour machined by making use of a 3 axis CNC machine-tool, with a spindle speed of 19,800 rpm, feedrate of 1,440 mm/min, and cutting depth of 10 mm, using an MQL cooling system, in order to reduce the environmental impact and to improve by this other way the economic performance (Kelly & Cotterell, 2002).

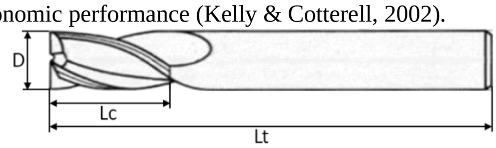

Fig. 1. Milling tool geometry (D=10mm, Lc=16 mm, Lt=60 mm, Helix angle= 30º)

Milling tools used were uncoated WC-10%Co with MG10 grain size (K30-K40). Mill geometry has been plotted in the previous Figure 1.

In a first step, tools were tested in 0 to 10 hours machining tests, in order both to verify that the secondary adhesion mechanism, based on the development of Built Up Edge (BUE) and Built Up Layer (BUL), was the predominant wear mechanism (Yousefi & Ichida, 2000), and to evaluate the cutting tool life. After testing, milling tools were analysed by combining Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS) techniques, Figure 2.

In a second step, and in order to change the core material properties, the tools were subjected to tempered heat treatments between 550 and 900 K, for intervals between 5 and 15 minutes, making use of the same industrial furnace used to change the thermal state of the aluminium alloys in the factory, having so an immediate access, avoiding the intermediation of the cutting tool manufacturer, as was discussed previously.

After the thermal treatment, the cutting tools were tested in the HSM process until the life end, and after this tests, they were analyzed again with SEM/EDS equipments.

3. RESULTS AND DISCUSSION

The results obtained in the first step have showed that the maximum tool life is about 4,5 hours of machining, from which the cutting-tool degradation (Figure 2) causes the apparition of several burrs. This short tool life is caused by a weakening of the cutting edge, due to a non-homogeneous Cobalt distribution in this zone, possibly due to the negative thermal effects of the grinding process in the cutting-tool manufacturing, and favoured by the formation, development and detachment of the BUE, Fig. 3.

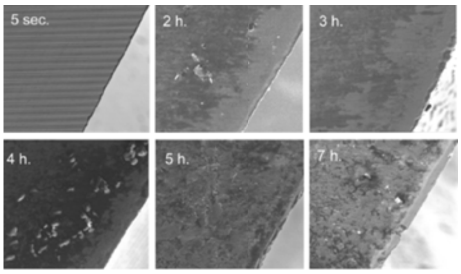

Fig. 2. SEM micrographies of cutting tools tested as a function of cutting time

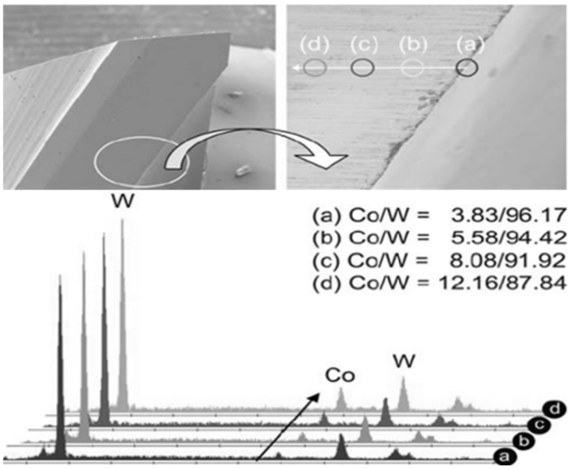

Fig. 3. SEM images and EDS spectra showing irregular distributions of Co in the zone closer to the cutting edge

After the tests developed in the second step, with cutting tools thermal treated, the best results are obtained for treatments at a temperature of 725 K for 15 minutes, reaching levels of improvement in the order of 450%, which involves multiplying the tool life by almost a factor 6, taking the original average life of 4 hours 30 minutes. This fact supposes the overcoming of 24 hours of continuous work on plant, without needing a tool change.This fact is an additional advantage directly associated with the improvement of the economic performance.

Figure 4 includes a SEM image of a tungsten carbide milling tool, treated for 15 minutes at 725 K after more than 20 hours of contour milling operation at 19,800 rpm. As it can be observed, there is not a special damage in the cutting edge, except the appearance of adhered material. This fact has previously been found in other studies developed on this and other aerospace aluminum alloys (Batista et Al., 2009).

Associated EDS profiles included in Figure 4 show that there is not an appreciable loss of Cobalt. Furthermore, the ratio of peak intensities for W/Co evaluated from the EDS spectra remains approximately constant. Thus, it can be concluded that thermal treatment leads to reduce the loss of Cobalt in the milling tool cutting area. On the other hand the edge weakness is avoided.

On the other hand, thermal treatments have showed a high improvement in the tool surface hardness. This can be related to the formation of some complex compounds, such as W_2C, Co_6W_6C or Co_3W_3C, according to (Thakur, et Al., 2008).

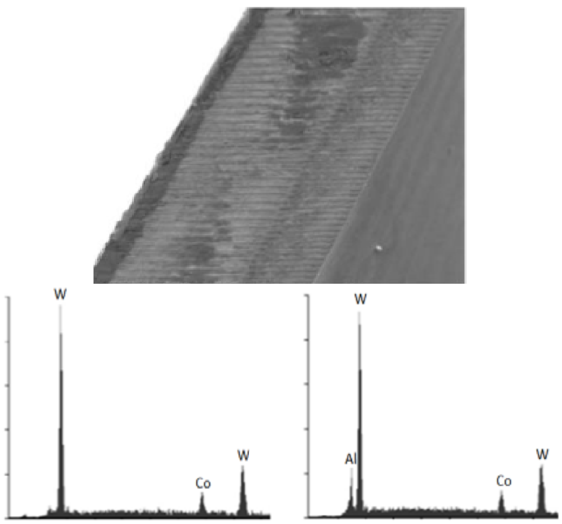

Fig. 4. SEM of the 725 K and 15 min. treated cutting tool and EDS spectra in the edge and in the zone close to the edge

4. CONCLUSIONS

One of the causes of the wear of a WC-Co cutting tool is the weakening of the cutting edge, apparently due to a non-homogeneous Cobalt distribution. This fact comes favoured by the formation, development and detachment of the BUE in the HSM of aluminium alloys.

This work shows the influence of heat treatment on the improvement of the performance in the HSM process of the UNS A92024-T3 (Al-Cu) alloy, in terms of tool life increase.

The thermal treatments developed have allowed improving the performance of the process, achieving increased tool life. The best conditions have been obtained for 15 minutes tempered thermal treatments at 725 K. This treatment has improved cutting tools life by factor close to 6, being this improvement associated to an homogeneous redistribution of Co in the milling tool. This fact carries on an increase of the tool hardness values, associated to the formation of complex carbides Co_XW_YC.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Arnone, M. (1998). *High Performance Machining*, Hanser Gardner Publications, 1-56990-246-1, Cincinatti (USA)

Batista, M.; Sanchez-Carrilero, M.; Rubio, EM. & Marcos M. (2009). Cutting Speed and Feed Based Analysis of Chip Arrangement in the Dry Horizontal Turning of UNS A92024 Alloy, *Proceedings of the 20th International DAAAM Symposium*, B. Katalinic (Ed.), pp 967-968, 1726-9679, Vienna, November 2009.

Cano, MJ.; Salguero, J.; Batista, M.; Álvarez, M.; Carrilero, MS. & Marcos, M. (2007). SEM/EDS Analysis of the Compositional and Morphological Changes of the Cutting Tool in the HSM of Al-Cu Alloys, *Proceedings of the II Manufacturing Engineering Society International Conference*, Sebastian, MA. (Ed.), pp 1-7, 978-84-611-8001-1, Madrid, July 2007

Kelly, JF. & Cotterell, MG. (2002). Minimal Lubrication Machining of Aluminium Alloys. *Journal of Materials Processing Technology*, Vol. 120, No. 1-3, (Jan. 2002) (327-334), 0924-0136

Salguero, J.; González, JM.; Carrilero, MS.; Gerez, J.; Batista, M. & Marcos, M. (2007). Study of the Finishing Surface Quality in the HSM of Al-Cu Alloys, *Proceedings of the II Manufacturing Engineering Society International Conference*, Sebastian, MA. (Ed.), pp 1-7, 978-84-611-8001-1, Madrid, July 2007.

Sebastian, M.A. & Faura, F. (1997). Analisys of the Cutting Tool Wear Models in Machining Proceses. *Iberoamerican Journal of Mechanical Engineering*, Vol.1, No.1, (Apr. 1997) (81-93), 1137-2729

Spitler, D; Lantrip, J.; Nee, JG. & Smith, D. (2003). *Fundamentals of Tool Design (5th edition)*, Society of Manufacturing Engineers, 0-87263-650-X, Michigan (USA)

Thakur, D.; Ramamoorthy, B. & Vijayaraghavan, L. Influence of Different Post Treatments on Tungsten Carbide–Cobalt Inserts. *Materials Letters*, Vol. 62, No. 1, (Jul. 2008) (4403-4406), 0167-577X

Yousefi, R. & Ichida, Y. (2000). A Study on Ultra-High Speed Cutting of Aluminium Alloy. *Journal of the International Society for Precision Engineering and Nanotechnology*, Vol. 24, No. 4, (May. 2000) (371-376), 0141-6359