Review of: "Machinability of Ti6Al4V Alloy: Tackling Challenges in Milling Operations"

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Potential competing interests: No potential competing interests to declare.

The article titled "Machinability of Ti6Al4V Alloy: Tackling Challenges in Milling Operations," authored by Patil et al., is quite interesting and useful for both the academic and industrial communities. Titanium and its alloys are noble materials with exceptional properties, ensuring important applications, mainly in the aerospace and medical industries (prosthetics and implants), where the grade 5 alloy (Ti6Al4V) is the most popular. The article presents the main characteristics of this alloy and explains its poor machinability, offering several interesting tips related to milling Ti6Al4V.

In the discussion, the authors address important points related to cutting conditions, chip formation, the transformation of mechanical energy into heat and the resulting temperatures, cutting tools—both regarding the tool material and its geometry—and the use of lubri-cooling methods. Several nice illustrations from simulations and flowcharts are provided, as well as informative tables.

Some points, however, could be improved in this interesting article, which will be listed below. These are points that the authors should consider as constructive criticism, which, if accepted, could further improve the quality of the work.

1 – In the abstract, the authors mentioned that the machinability of the Ti6Al4V alloy is 20%. A machinability percentage index only makes sense if the reference is given. Which material would be considered 100%? It is important to mention.

2 – The authors cite four factors responsible for the poor machinability of the Ti6Al4V alloy, including the work-hardening index. Work-hardening is a bigger issue in nickel alloys and stainless steels, but in titanium alloys, this problem is similar to steels, meaning it should not be highlighted as one of the most important. On the other hand, the formation of segmented chips (due to poor thermal conductivity, which causes thermal softening rather than work-hardening) can be considered a bigger problem, causing dynamic fluctuations in forces and eventually vibrations.

3 – The authors mention that the work-hardening capability of the Ti6Al4V alloy can lead to notch wear. In practice, this type of wear is almost never seen in titanium machining, being much more common in nickel alloys. This is further evidence that work-hardening is not, in fact, a major issue. The authors should consider reviewing this point.

4 – What were the cutting conditions used to generate Figure 1? I consider the temperature values shown to be low for the Ti6Al4V alloy. The title of the figure is incorrect. It depicts a temperature distribution, not a heat distribution.

5 – Much of the article's content is more related to end milling than face milling. However, the authors do not distinguish between these two processes. This could lead to confusion when considering some of the suggestions in the paper.

6 – In the text, when the authors present Figure 3a, they indicate a cutting speed of 800 m/min. This cutting speed for machining titanium alloys is completely unrealistic, even for a simulation. No cutting tool can machine Ti6Al4V under these conditions.

7 – Below Figure 4, the authors state that at low cutting speeds and high feed rates, the production of continuous and segmented chips is observed. It is rare to observe continuous chips in titanium due to its low thermal conductivity, which almost always results in softening rather than work-hardening in the primary shear plane. Without work-hardening, continuous chips cannot form, so they are typically segmented. Continuous chips are only possible at speeds lower than 6-8 m/min (depending on the feed rate). Therefore, it would be important to mention the speed values considered.

8 – In item 2.5, the authors mentioned that Carbide PVD, CVD multilayered/nanolayered (PVD TiAlN, CVD Al2O3+TiCN, and PVD TiAlN+TiN) should be considered for machining titanium. Some tool manufacturers do indeed recommend coated tools for titanium machining. I consider this risky. The reactivity of titanium at temperatures above 500ºC is so high that no coating can offer an advantage greater than a straight grade of cemented carbide (WC+Co). Numerous studies on titanium machining prove this, unless the temperature can be reduced to values significantly lower than mentioned, which is almost impossible. PCD could be better than WC+Co, but only when used with a high-pressure fluid application (7 to 30 MPa) directed to the rake face, against the chip flow.

9 – In item 2.6, the authors comment that residual stresses can strongly affect fatigue resistance. It is necessary to emphasize that tensile residual stresses (usually of thermal origin) are negative, while compressive residual stresses (usually of mechanical origin) are positive (they increase fatigue resistance). In titanium machining, tensile residual stresses, which are negative, tend to prevail.

10 – Two classic references on this topic were not considered:

a - E.O. Ezugwu, Z.M. Wang, “Titanium alloys and their machinability: A review,” Journal of Materials Processing Technology 68 (1997) 262-274. https://doi.org/10.1016/S0924-0136(96)00030-1

b - MACHADO, A.R. and WALLBANK, J., "Machining of Titanium and Its Alloys: A Review," Proc. of the Inst. Mech. Eng., Vol 204 Part B, J. Eng. Manufacture, 1990, I. Mech. Eng., pp. 53-60. https://doi.org/10.1243/PIME_PROC_1990_204_04.

They can be used to strengthen many points covered in the paper.

11 – References [14] and [87] are the same. I have not checked the entire list. Please check.