Adoption of the Omative system in Inconel 718 turbine blade machining

Zastosowanie systemu Omative w obróbce łopatki turbiny ze stopu Inconel 718

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This paper presents a research focusing on adopting adapting control system Omative for tool condition monitoring during milling of Inconel 718 turbine blade.
KEYWORDS: milling, turbine blade, adaptive control, Inconel 718

The modern aviation industry is increasingly demanding its components, while striving for maximum efficiency and maximum profit. New construction solutions make it necessary to use special materials such as heat-resistant super alloys. These are alloys based on nickel, cobalt or iron. Of these, one of the best properties is Inconel 718 [1, 2].

The advantages of this alloy are particularly important in those engine points that are subjected to the largest loads. The turbine blades work in the most difficult temperature and load conditions. The blade end speed reaches 390 m/s, the gas temperature is even 1200 °C and their speed is 600 m/s. The turbine blade material, in addition to high strength, must be characterized by high heat resistance, high temperature creep resistance, corrosion and oxidation resistance and high hardness. Density of the alloy, which affects the weight of the engine, is also important in generating centrifugal forces [3, 4].

Inconel 718 is one of the hardest materials to work on. Blade locks are currently being successfully developed in the Creep-Feed Grinding (CFG) process. This method allows for efficient machining of elements made of super alloys and other hard-working materials. It allows the parts to be polished after heat treatment and ensures high surface quality [5]. On the other hand, in the case of free surfaces of the blades, the method of their execution is simultaneous process of five-axes milling. Due to the complexity of this machining, the presence of high milling strength components and the high cost of the workpiece and tooling, it is legitimate to use a system that monitors the correctness of the cutting process. They are based on the measurement of selected physical quantities, such as: cutting force, vibration, power and engine torque, sound emission or coolant flow. Measured signals (after processing) serve to obtain process measures that enable application of adaptive AC control and detection of tool contact with workpiece, alarm condition or tool wear [6, 7].

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Test conditions

The purpose of the study was to use Omative system to monitor tool status while milling the Inconel 718 alloy. This system is based on recording the I_w current signal or the linear axis motors of the machine - on this basis level of the tool wear in real time can be determined. Experiments were carried out at a research station based on the DMU 100 monoblock machining center by DMG (Fig. 1).

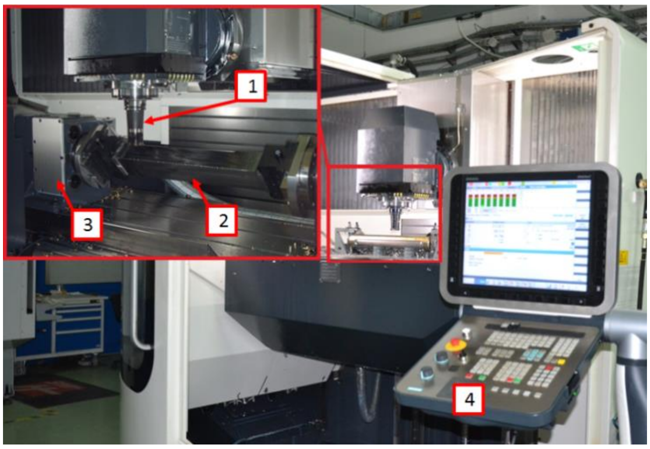

Fig. 1. Test stand: 1 - toroidal cutter, 2 - workpiece, 3 - divider, 4 - control system with Omative system

The research was carried out during the milling of the turbine blade made of Inconel 718 alloy using toroid 5-blade cutter of d = 50 mm from Sandvik Coromant. The cutting parameters were: cutting speed v_c = 40 m/min, cutting depth a_p = 1.15 mm, cutting width a_e = 30 mm, feedrate per blade f_z = 0.15 mm/blade. The workpiece was fastened in a divider using pre-tensioning. The machining program was done in the NX10 system.

Test results

The test was started from milling of the workpiece in the teaching mode of the Omative system. For this purpose, a number of parameters should be determined, including: tool and workpiece parameters, load limits, type of monitoring strategy and machining conditions. Then, the tool was milled with a new tool until it was worn. As a result, the so-called load-learning curve was recorded, which is the basis for using the system to monitor the tool wear. Next, the type of strategy should be determined – Maximum Load Monitoring or Load Band Monitoring. In the case of the former strategy during machining, the system compares the currently measured spindle load with the maximum load recorded in the learning mode (every 100 ms). On the other hand, the latter strategy enables the real-time comparisons of the measured load with that recorded in the learning curve (Fig. 2).

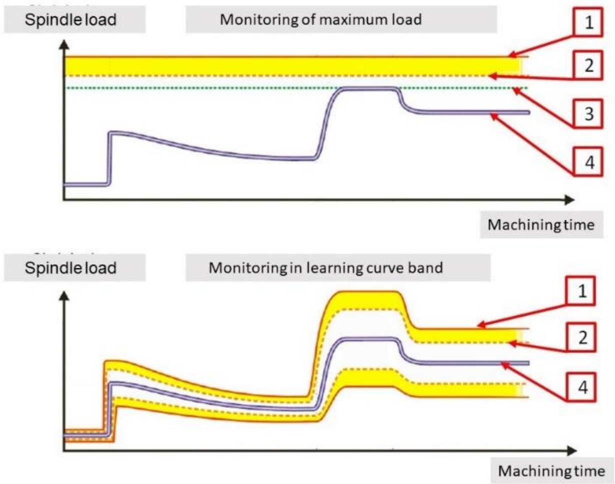

Fig. 2. Comparison of tool status monitoring strategies: 1 - alarm level, 2 - warning level, 3 - maximum recorded load, 4 - learning curve

After the learning mode execution, a monitoring strategy in the learning curve was adopted to the study. After entering the appropriate commands of Omative system into the NC software and specifying the learning curve bandwidth, that must be greater than the spindle load at the preset speed without machining, milling was started with the active tool status monitoring mode (Fig. 3).

a) *b)*

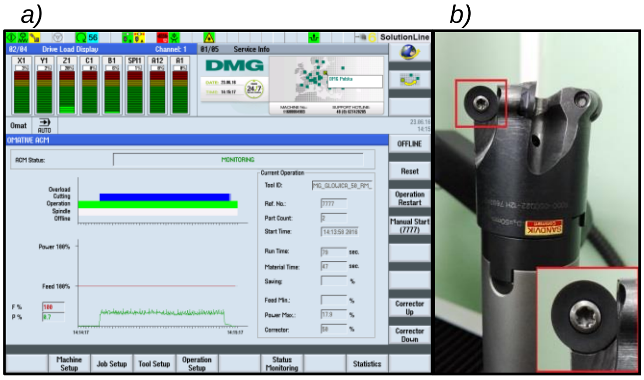

Figure 3. Omative monitoring window during milling *(a)* and new toroid milling view *(b)*

Tool status monitoring with the Omative system allows to detect: tool wear, excessive milling load (caused by e.g. oversize or local material hardness), tool failure or fracture. In addition, there is the possibility of early detection of programming errors or workpiece setting and, consequently, damage to the tool or machine. During coarse milling of the blade, 60 cutting edges were used. The warning level has been reached ten times, which means that the system has detected tool wear, but allowed the program to complete the machining course - stopping to change the milling cutter occurred when it was outside the material (Fig. 4). The alarm level was reached twice, which resulted in the immediate machine stopping and a tool change message was displayed. The average working time of the cutter was similar to that declared by the manufacturer and amounted to approximately 42 min.

a) *b)*

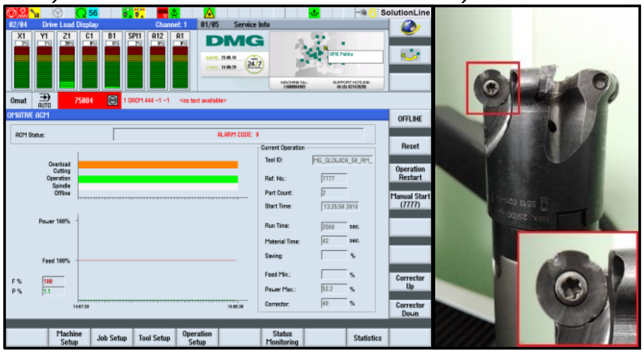

Fig. 4. Omative monitoring window after detecting tool wear (a) and view of worn toroid milling cutter (b)

Conclusions

The use of the Omative system can improve the cutting performance by adjusting the tool running time to actual machining conditions and thus prolonging its service life as compared to the manufacturer's recommended fixed working time. In addition, this system, by constantly monitoring the spindle load, in some cases is able to protect the tool and machine from damage. Due to the use of the spindle current signal for load monitoring, it is not necessary to install additional sensors in the working space of the machine, which are often expensive and inconvenient for assembly.

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