TAPPING TOOL LIFE WHEN MACHINING INCONEL 718

Milan Daňa , Miroslav Zetek, Václav Schorník

*Regional Technological Institute, University of West Bohemia – Faculty of Mechanical Engineering,
Univerzitní 8, Pilsen 306 14*

Abstract

This work deals with the issue of tapping Inconel 718 alloy. This material is known for its unique properties of high strength at high temperatures, corrosion resistance, high hardness, work hardening and low thermal conductivity. This paper deals with creating internal threads by using monoliths taps. The taps are made of powder metallurgy high speed steel. Preparation of the hole for the thread has a huge impact on the cutting tool life. If the preparation is poor the inner face of the hole will be work hardened. This makes the cutting tool life far shorter. For the test, taps with different threads per chamfer were used. The second part of the paper is focused on the experiment where cutting tool life was monitored.

Keywords: Tapping tool; Thread; Cutting tool life; Tool wear; Inconel 718

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1. Introduction

There are many different possibilities for producing threads, but this paper deals with only one standard technology which is called thread tapping. Internal threads are most frequently used in parts used in the automotive and aerospace industries. This method is used for different types of materials and is suitable for almost all types of threads. The tools for the tapping must have properties different from tools for milling or turning. Tool hardness is not too great a priority because it would be brittle. The tool must have adequate toughness. If the hardness outweighs toughness it can lead to destruction of the tools. These demands limit the choice of the cutting materials. The materials suitable for tapping are high speed steel and cemented carbide. A coating is preferably used for both these materials. Threading of Inconel 718 is very hard, because this material belongs to a group of difficult to machine materials. Materials such as Inconel 718 have high strength, high hardness, low heat conductivity, corrosion resistance, high strength at high temperature and many other unique properties. The high speed steel produced by the method of powder metallurgy is the most suitable for tapping difficult to machine materials. This material achieves better results than conventionally processed high speed steel.

Reference [1] provides in depth information about Inconel 718. Reference [9] is a very substantial paper containing an extensive description of cutting edges for tools which are suitable for Inconel 718. This paper provides a lot of information about the material, the cutting tool and cutting tool edge. Reference [10] is also focused on the cutting taps. The authors of this reference conducted a very interesting experiment which compares threads made using cutting and forming. Reference [11] gives information about the machinability of Inconel 718 and its material properties which are essential for productive machining.

2. Material properties

Inconel 718 is known thanks to the company Special Metals Corporation which supplies specialist materials to the world market. Inconel is a very frequently used material from this group. We can find this material under the designation UNS N07718, W.Nr. 2.4668, but most often under its tradename. This alloy belongs to the nickel based alloys, which are characterised by their high content of nickel - about 50%. Inconel 718 has special properties which common materials cannot achieve. The special properties are, for example, strength at high temperature and strength at low temperature. It can withstand temperatures from -250°C up to $+700^{\circ}\text{C}$. Another unique property is corrosion resistance at high temperature. A surface layer of oxide is created during heating up to high temperature on the surface of a part. This surface layer of oxide protects the component against hostile influences. The hardness of this material is dependent on the heat treatment. The hardness can be 20 - 25 HRC in annealed condition, but the hardness can be 36 - 44 HRC after hardening. Ultimate tensile strength reaches values up to 1300 MPa. [1],[2],[10],[12]

3. Machinability of Inconel 718

The machinability of Inconel 718 is very hard and cutting tool wear is high. It is one material in a group which is the most difficult for machining. The materials from this group are for example Rene, Waspaloy, Nimonic and so on. These alloys are very difficult to machine due to their excellent mechanical properties. Inconel 718 has a basic property during the machining and this is hardening. The mechanical hardening is created during the contact of the cutting tool with the machined part. Machining must be limited to the smallest possible number of operating cycles. It is recommended to set the cutting edge of the tool deeper than the thickness of the hardened layer. During the machining of this alloy a large amount of heat is generated due to poor thermal conductivity. This means it is advisable to use cooling. The cooling ensures better heat dissipation from the cutting area. The cooling is carried out using a high pressure and high volume of coolant. [1],[3]

Fig. 1. Machinability of Inconel 718 [5].

4. Thread tapping

The tap must be prepared for any problems which may occur in the material during tapping. The main problems could be high strength, bad thermal conductivity, hardening and especially constriction of this material. The tool has to withstand all influences which act on the tool during cutting of Inconel 718. Therefore the tools have to be strong enough, especially tenacious, have a negative rake angle, a very positive flank angle and so on. It is appropriate to use coatings. The coating must have high hardness, excellent adhesion and good friction properties. [3],[4],[6],[7]

5. Preparation of hole for thread

It is extremely important to concentrate on the preparation of the hole for the thread. Holes for the threads are mostly prepared using drilling. It is a standard process, but the drilling has an enormous impact on the next operation which is tapping. The preparation of the hole greatly affects the cutting tool life of the taps. If the hole is badly prepared, the cutting tool life may be up to several times worse. The drill and the tap must be taken together due to the cutting tool life. The walls of the hole are mechanically and thermally stressed during the process of drilling. This leads to hardening of the walls because Inconel 718 has a tendency to hardening. The depth of the hardened surface of the hole increases if the drill is too worn. The wear of the drill is accompanied by an increase in temperature and mechanical stress. The hardening of the walls must be limited and in the best case eliminated. It is necessary to set the limit of the wear of the drill to a suitable value. The hardened surface of a hole can be seen in the following figure. The circularity and cylindricity of the hole may also affect the process of tapping. It is required to keep the cylindricity and circularity within the specified tolerances. The corners of the hole must be chamfered due to the right introduction of the tap in to the hole. The depth of the hole must be selected correctly as in Fig. 3. [4],[6],[8],[13]

Fig. 2. Hardened layer [6]

Fig. 3. Hole for thread [6]

6. Experiment

A metric thread was selected for this experiment. The size of thread chosen was M14 x 2, because this size is the most widely used. The diameter of the hole was selected according to standards. The drill diameter is $d = 12\text{mm}$. The wear of the taps was monitored during the process. The cutting condition was set by the manufacturer's recommendations and catalogue values. The cutting conditions were constant throughout the experiment. The cutting conditions are: cutting speed $v_c = 5\text{ m/min}$ and feed per rotation $f_{ot} = 2\text{ mm}$. Thread cutting paste ensured lubrication during tapping. Two types of taps were tested. All samples had the same material and mechanical properties. The material and mechanical properties are listed in the following Tables 1 and 2. The chemical composition is given for individual elements in percent. Criteria value of experimental machining was set on $150\mu\text{m}$ of tool wear.

Ni	Cr	Fe	Nb (+Ta)	Mo	Ti	Al	Co	Mg	Si	Cu	C	P	S	B
53.15	18.5	18.53	4.936	2.84	1.06	0.49	0.02	0.08	0.14	0.02	0.024	0.009	0.001	0.0028

Table 1. Material composition.

Yield strength Rp0,2 in MPa	Strength Rm in MPa	Ductility A4 in %	Contraction Z in %	Hardness HB	in	Deformation work in J	Heat conductivity in W/mK
938	1227	27	4.936	355		1.06	11

Table 2. Material properties

7. Results

This section is focused on evaluation of the cutting tool life. The length of the thread was selected as the criterion for cutting tool life. The taps from series C were tested first. Tap C1 created only one piece with a thread. One piece equals 20 mm. This tap seized up in the second piece. Tap C1 created approximately 25 mm of thread. The confirmation tap C2 seized up in the first piece. This tap confirms the very short cutting tool life of this series. One tap from series D created a thread in 12 pieces then the test was stopped. The tap was not at the end of the cutting tool life, but the drill was. Tap D1 showed no signs of wear after 240 mm. The confirmation tap D2 created 180 mm of thread. The test with tap D2 was stopped due to the drill again. This tap confirms the excellent cutting tool life of this series. The results were plotted in a simple graph (Fig. 5), which shows cutting tool life.

Fig. 5. Cutting tool life

It was necessary to thoroughly analyse the influences which could cause the failure of the taps. Bad chip flow was a reason which was critical for the taps. The chip flow collided with the cutting edge and after this, the tap seized up in the hole. The chip flow collided with the cutting edge creating enormous stress. Then the tap seized up in the hole. The following figure shows the situation in detail.

8. Conclusion

The article presents the results of experimental study of cutting tool life of aged Inconel 718 during its tapping with coated tools. The experiment when Inconel 718 was machined with a tap was carried out. The cutting tool life of individual series was diametrically different. The taps from series D achieved more than ten times longer cutting tool life

than the taps from series C. The tap from series D was not at the end of the cutting tool life, but the drill was. This tap created threads in 12 pieces, equal to 240 mm. The taps from series D showed no signs of wear after stopping the test.

The taps from series C seized up in the first few pieces. The cutting tool life of series C was different compared to cutting tool life presented by the manufacturer. The reason for seizure was determined. The seizure was caused by bad chip flow. The recommendation for avoiding seizure is to interrupt the cutting process after 0.5 D.

The tapping of Inconel 718 is a very demanding technological operation, therefore it is necessary to carry out further research in the field. The obtained results are clear proof.

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