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Analysis of form threads using fluteless taps in cast magnesium alloy (AM60)

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ABSTRACT

Threads are used in the most assemblies of industrial products. Commonly, mechanical components need to have threaded parts allowing fast and accurate assemblies and disassemblies. Internal tapping is one of the most demanded machining operations, and threads obtained by forming have been a good alternative. This work investigates the effect of the factors the hole diameter, the forming speed and types of tool on the responses: torque, hardness, fill rate, and thrust force of the form tapping process. The experiments were carried out with three diameters, three forming speeds, and two coatings. The material used was the AM60 alloy due to its high ductility and wide application as head engine. The results revealed torque is more affected by the hole diameter than thrust force, and little hardening occurred using high forming speed with a small diameter. The fill rate of the thread profile was not significantly affected by the intermediate and large diameters. Finally, it can be stated that the recommended hole diameter provided by the tool's supplier can be modified to achieve more accurate thread profiles.

1. Introduction

The assemblies provided by screws have been widely used in every industrial sector. Generally, tapping is the last stage of manufacturing process, consequently good accuracy and surface finishing must be reached for a perfect assembly with not air-gaps. The Al–Si alloys are the most widely material used in the automotive industry, mainly for engine head and gearbox (Bhowmicka et al., 2010). Several tap geometries with different coatings can be used for machining of metals, as well as non-ferrous and non-metallic materials. The most industrial processes produce internal threads using cutting taps. According to Fromentin et al. (2010) the form tapping has increased in industrial applications in the last years due to the environmental requirements, such as the waste generation by the chip formation. Ivanov and Kirov (1997) stated the efficiency of fluteless taps on the shop floor is not satisfactory because of basic issues which are associated with the physical phenomenon of the cutting taps. Despite the tapping process has been widely applied in industry, there is a relevant gap between the researches and the practical cases.

Although the form tapping process has existed for decades, very few studies have been published due to the poor interest by the industry (Gontarz et al., 2004). Screws are usually manufactured by forming process due to the amount of parts produced by hours and the strength necessary to join different parts. Generally, forming threads support higher mechanical efforts than cutting threads. In particular, the automotive industry has great interest in this process due to the possibility of eliminating steps to remove chips from internal threads (Stephan et al., 2011).

In addition, the great advantage of form tapping is linked to the characteristics of the screw thread. The thread is formed by the plastic deformation of the worked material, providing a perfect screw thread with no waste material. In the automotive industry, for example, the engine heads are manufactured with non-ferrous materials which have a superior capacity to deform and maintain an acceptable mechanical strength. Baldo et al. (2010) have investigated the form tapping process in Aluminum alloy 7055 determining the tensile strength of internal threads. The results demonstrated that the formed threads exhibited the same mechanical strength of machined threads considering similar parameters of production, pitch and hole diameter.

Magnesium and aluminum alloys are non-ferrous materials applied frequently in the automotive industry due to their low weight, ease of work and the possibility of recycling (Chowdhary et al., 2002). The aluminum alloys have great potential in the Brazilian industry corresponding to 95 wt% of recycling. According to Agapiou (1994), smaller hole diameter provides higher fill screw thread, however, the process needs high level of torque, and the operation must be monitored to avoid tool breakage. The threads produced by fluteless taps have some peculiarities, such as the appearance of a split crest on the top of the thread.

According to Fromentin et al. (2002) the rate of crest formation depends directly on the initial hole diameter because smaller diameters provide a smaller split crest on the top of the screw thread

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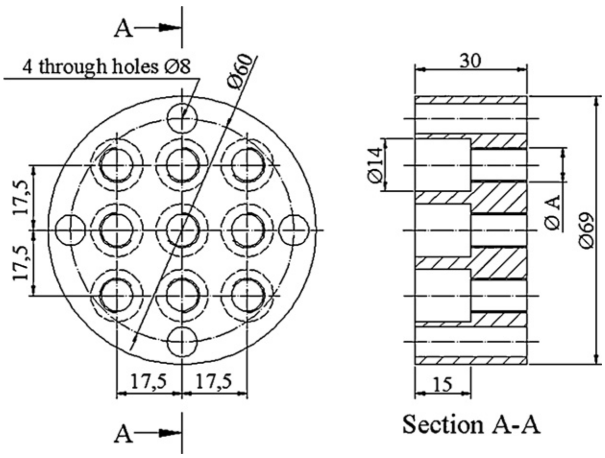

Fig. 1. Work piece dimensions and experimental setup.

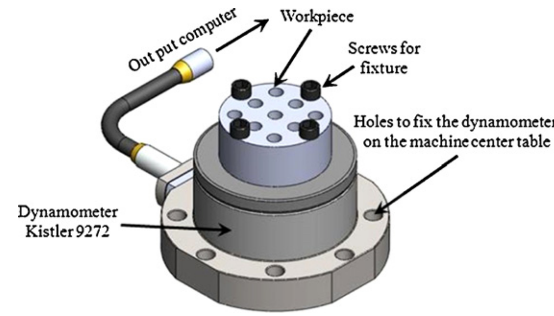

Fig. 3. Assembly of the experimental test setup.

Table 1
Factors and levels of the experiment.

Input factors	Levels		
	−1	0	+1
Diameter (mm)	9.1	9.3	9.5
Forming speed (m/min)	60	80	100
Tool	Coated		Uncoated

after form tapping. Small diameters, however, increase the torque values. Based on this statement, form tapping is suitable for high ductile and metallic materials, mainly for internal threads, which are used to bear high load and perfect fixture. The experimental and numerical researches have been carried out to determine the load level which provides the best surface finishing in thread forming process (Mathurin et al., 2009). The finite element technique has been used to preview the load in the machining process; however the results must be compared with the experimental data.

Finally, the selection of the initial diameter must be set for each material as a function of the torque, the split crest formation, and the surface hardness values. A design of experiment (DOE) was conducted to identify the effect of the factors, tool coating, hole diameter and forming speed on the responses torque, thrust force, hardness, and fill rate for form tapping process. The optical and scanning electron microscopes were used to analyze the topography of the forming thread's profiles.

2. Methodology

A machining center, ROMI Discovery 560, with 10,000 rpm and 15 kW of main power was used to perform the experimental tests. A rigid tapping system consisted of a BT-40 tool holder and mechanical collet. The axial and rotational movement synchronization was based on the SINUMERIC 840D CNC software. A start distance of 10 mm was set from the work piece to ensure the full acceleration of the tool holder. All experimental tests were carried out under emulsion coolant with 6% of concentration at a flow rate of 20 l/min. Specimens of magnesium cast alloy, AM60 grade, with dimensions 69 mm of diameter and 30 mm of height were manufactured as illustrated in Fig. 1. A relief hole with 14 mm of diameter and 15 mm of height was set at the bottom to allow the output of the tap. The diameter indicated as "A" in Fig. 1 corresponds to the diameter variation for the initial holes used in the tests, and the holes with 8 mm of diameter were used to assemble the work piece on the dynamometer. In order to run the experiments, nine form tapping setup were randomly machined for each work piece.

The hardness was measured in three random regions of the work piece, ranging from 65 to 74 HB. The taps, model M10 6HX Druck-S, manufactured by Emuge-Franken were used in the experiment. The taps are manufactured according to the DIN-13-1 and ISO-68 standards for metric threads. Uncoated and TiN coated HSSE taps were used with polygonal geometry and a lead taper of 2–3.5 threads, according to Fig. 2(a) and (b) (DIN 2175, 2008). However, the coated taps provided five slots for lubrication, as shown in Fig. 2(b).

The assembly of the work pieces on the dynamometer was performed to avoid interference between the fixture and intermediate devices. The work pieces were fixed directly upon the dynamometer as shown in Fig. 3. Tests of microhardness Vickers were carried out using a MVK-G1 Mitutoyo^{TM} hardness tester with 50 grf of load and 20 s of pre load time. The distance between the micro indentations of the thread's border were set based on three times of the indentation size avoiding the displacement of material at the border and consequently, influencing the results.

Table 1 shows the evaluated factors and levels investigated in the experiment. The zero level for diameter (9.3 ± 0.2 mm) and forming speed (80 m/min) were set based on the results of Baldo et al. (2010) which investigated aluminum alloy. These levels were also checked on Emuge-Franken (2010) for non-ferrous materials. The diameter dimension was verified at both sides of the hole

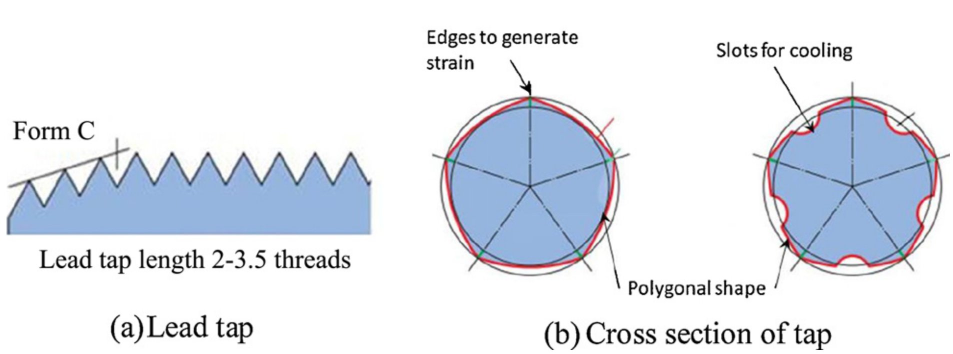

Fig. 2. Design of the taps (Emuge-Franken, 2010).