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A Study on Tapping Viewed from Eco-Machining Technology

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Abstract

This study deals with machining characteristics of thread tapping (torque, tap, wear, work hardness etc.) The tapping of MMC (aluminum alloy metal matrix composite) with TiN coated forming taps under eco-machining technology operation, where chips are not produced and ejected from the tap flute, was investigated and compared with the characteristics during uncoated tapping. The following results are obtained from this study. 1) The tool life of TiN coated taps was 4 times longer than that of uncoated tap, 2) Threads formed with the TiN coated taps exhibit lower work hardening than those formed with uncoated taps.

1. Introduction

Threads form the mechanical joint of a bolt–screw connection, which is one of the most important fastening systems for mechanical components. There are many ways of thread making, especially that of tapping which has been employed as an efficient technique for the production of internal threads.

Recently, the rise of productivity has been emphasized year by year. Also it is said that the improvement of productivity is one of the most important and serious problem in today's machine shops. The improvement of hole making production (drilling/reaming and tapping) has become a serious matter. One factor limiting productivity gains has been that conventional tool materials such as HSS exhibit very short tool lives when machining an aluminum alloy metal matrix composite (MMC) due to the abrasive nature of the SiC particles. Therefore, the improvement has been obstructed by various problems as rapid tool wear and failure. As a mean of achieving the desired productivity gains, forming taps have caught the attention of machine shop engineers.

In this study, cutting characteristics of tapping (torque, taps wear, work hardness, etc.) during the tapping of MMC with forming taps, both TiN coated and uncoated was investigated.

2. Experimental Methods

2.1 Experimental Equipment

The tapping tests were conducted on a Cincinati 5'NC-MC (5HP). The (drilling and tapping) apparatus and data acquisition system are presented in Figure 2.1. The cutting forces (thrust and torque) were measured using a three component Kistler Type 9273 Piezo-electric dynamometer and the corresponding locus was amplified by a Kistler type 5007 charge amplifier. The signal obtained was then passed to a Towa A/D converter type AZI-16-12, connected to a personal computer. A schematic diagram of the cutting force measuring setup is presented in Figure 2.2.

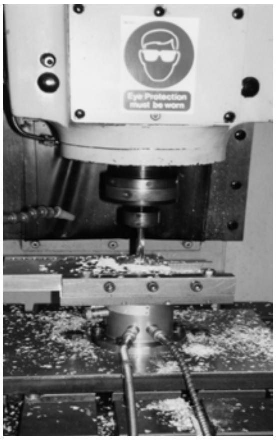

Figure 2.1: Tapping device and data acquisition apparatus.

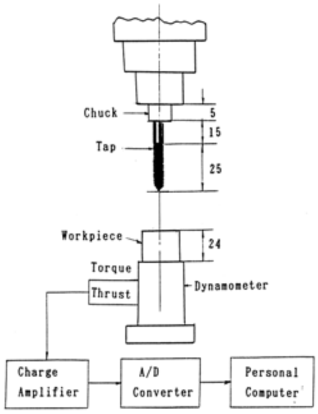

Figure 2.2: Schmatic diagram of the tapping system.

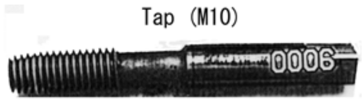

Figure 2.3: Taps used in this work.

2.2 Workpiece, Drill and Tap

The workpiece used in this experiment is aluminum alloy (2618 MMC) reinforced with 15 vol% silicon carbide (SiC) particulate. The thread forming fluteless taps were M10 as shown in Figure 2.3 and two types of taps were used during the course of the investigation.

The shape of the taps was similar to the shape of a screw (M10, Pitch:1.5), either uncoated or coated with Titanium nitride (TiN).

Pilot holes of 9.3mm diameter were used for all trials and PCD tipped drills (HSS cemented tungsten carbide and polycrystalline diamond drilling) were employed in all the tests. The shape of drill used in this test is shown in Figure 2.4.

2.3 Gauge and Inspection Method of Thread

The estimate of threads was performed with a thread gauge (Go-NoGo gauge).The results were classified as A and B quality[1]. Where, 1.4×tapped diameter is Diameter is the recommended depth of thread of hard Aluminum alloy[2].

A – quality : Gauge can be turned through the whole thread.
B – quality : Gauge can be turned in at least 15mm.

Figure 2.5 shows the appearance of gauge (M10×1.5 ISO 6H).

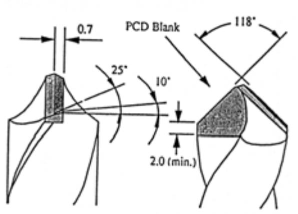

Figure 2.4: Shape of PCD Drill.

Figure 2.5: Thread gauge.

2.4 Experimental Characteristics

Tapping tests were conducted at a cutting speed (rotational speed of tap) of 215 rpm and feed rate of 0.1mm/rev (322.5mm/min). Coolant oil (Chlorine and sulphur free heat cutting oil) was supplied manually.

Table 2.1: Tapping Parameters

	Tool Material	Machine Tool	Tapping Parameters
Drilling	Pilot hole ϕ9.3 PCD Drills	Cincinnati 5' NC-MC (5HP)	N=1500rpm (f=0.10mm/rev)
Thread forming	M10×1.5 HSS TiN coated, Uncoated	Cincinnati 5' NC-MC (5HP) Oil	N=215rpm f=322.5mm/mim(1.5mm/rev)

3. Experimental Results And Discussion

3.1 Cutting Forces in Tapping (thrust, torque)

The thrust and torque signals produced in this tapping operation with a M10 tap are shown in Figure 3.1. The results show that torque increases with number of threads formed and decreases at the instant that the tap is about to break through the outlet of the hole. Whereas, little increase in thrust can be observed.

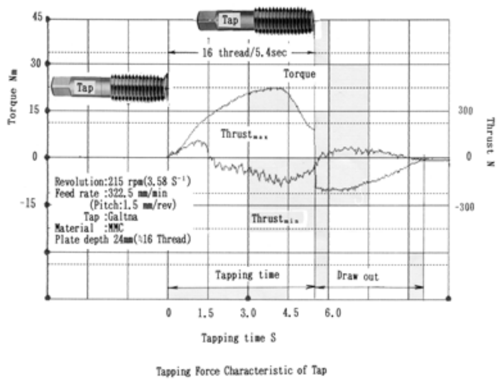

Figure 3.1: Plot of cutting force signals under the tapping test with tap.

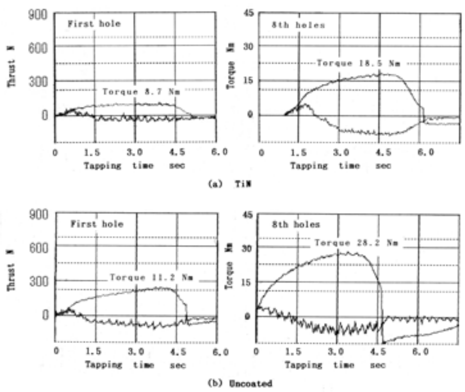

Figure 3.2: Comparison of torque signals (1st hole and 8 holes) with tap.

3.2 Comparison of Torque

Figure 3.2 shows torque signals of tap in the 1st hole and 8th holes for the TiN-coated and uncoated taps mentioned in the previous section.

At the initial stage of the tapping operation both thrust and torque show an increase in magnitude. However, when the thread forming operation enters full gear, the thrust force shows a decreasing trend accompanied with in increase in torque and as the tap retracts after breakthrough, a negative torque of 5N magnitude can be observed across a few threads at hole outlet.

The negative thrust value observed in Figure 3.1 is the outcome of the deflection of the tap from the center due to either improper workpiece, tool setup or poor finish of the pilot holes. The inconclusive results observed above led to the investigating of the factors responsible for the poor finish of the pilot holes.

The torque signals derived while threading taps for the 1st hole show tapping torque values of 8.7 Nm for the TiN coated tap and11.2 Nm for the uncoated and tap respectively. Thus, for the 1st hole, the TiN coated tap exhibits a 28% reduction in torque compared to the uncoated tap. While for the 8th hole the reduction in torque for the TiN coated tap is approximately 52% as compared to uncoated tap.

Comparison of the torque signals at the initial phase and prior to breakthrough of the taps shows that the uncoated tap exhibits a sharper decrease in torque than the TiN coated tap. It can be said that, in the case of forming taps, work is evenly distributed at the scrape point during threading. A comparison of the torque results is summarized in Figure 3.3. Results indicate that tapping torque of the TiN coated tap is generally lower than those of the un-coated tap.

3.3 Comparison of Thread Forms

The thread forms for the TiN coated and uncoated taps are shown in Figure 3.4. Magnified images of the axial cross-section of the formed threads at position No.①,②,③ and ④ in holes and 1.4 and 8 were used in the comparison.

Figure 3.4 is a model of the photographed threads at the various positions, while Figure 3.5 shows magnified images for hole No.8

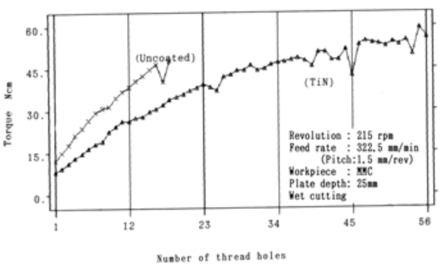

Figure 3.3: Comparison of torque signals with both type.

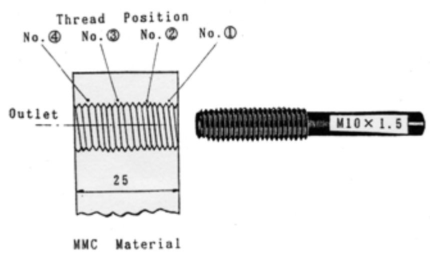

Figure 3.4: Illustrate of the axial cross-section of the formed threads.

As it can be seen from Figure 3.5, the thread profile at position No.① to ② of threads formed with the TiN coated tap show no abnormalities. On the contrary, with the uncoated taps the root shows irregularities at position No.① and ④ corresponding to the hole inlet and outlet.

In order to validate the observations mentioned above, a detailed analysis was performed on holes No.① and ②. Results are summarized in Figure 3.6. Figure 3.6(a) and (b) give results for hole No.① and 8 at thread position No.① and ② respectively. As it can be observed in Figure 3.6(a), the tooth profile of the TiN coated is far superior to the uncoated tap.

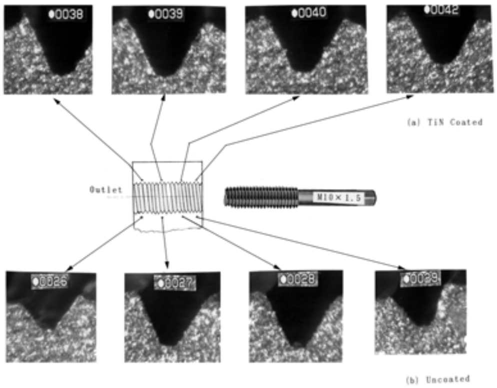

Figure 3.5: Comparison of thread forms.

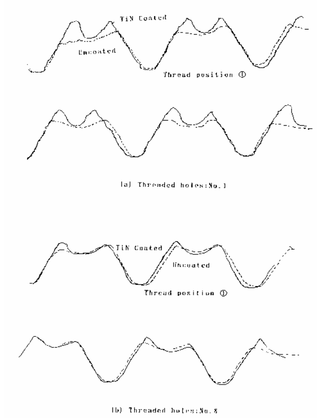

Figure 3.6: Comparison of enlarged thread forms.

3.4 Comparison of Work Hardening

A comparative study was performed to investigate the magnitude of work hardening when using the TiN coated and uncoated taps to form threads.

Results of this study are summarized in Figure 3.7. Tap No.1 of both tap types were used. Results for the TiN coated and uncoated tap are given in Figure 3.7(a) and (b) respectively. Hardness was measured on a hardness tester loaded with a 100 gw.

The results show that the hardness of the TiN coated tapping thread is lower than the uncoated tapping thread. The above results show that the TiN coated tap is superior to the uncoated tap in the following aspects, thread form and work hardening etc,.

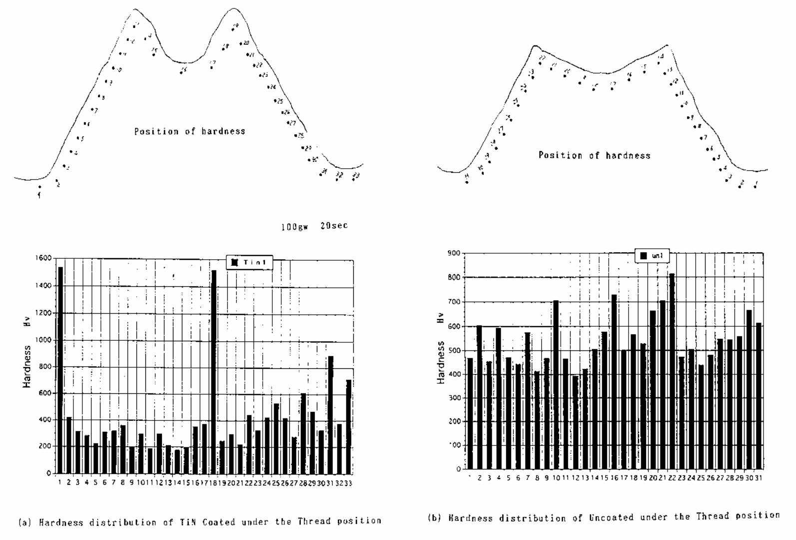

Figure 3.7: Comparison of the hardness distribution.

3.5 Comparison of Tool Life

The TiN coated and uncoated taps were used to investigate the performance level with respect to tool life of taps. Tests were repeatedly performed three times with each type of tap. The results are summarized in Figure 3.8.

Thread gauge readings were evaluated using A, B values. The results indicate that the average number of thread holes before tool life limit is reached are uncoated $\overline{X}$=13 and

TiN coated tap $\overline{X}$ =49 hole tap. The tool life of the TiN coated tap is 3.8 times longer than that of uncoated tap.

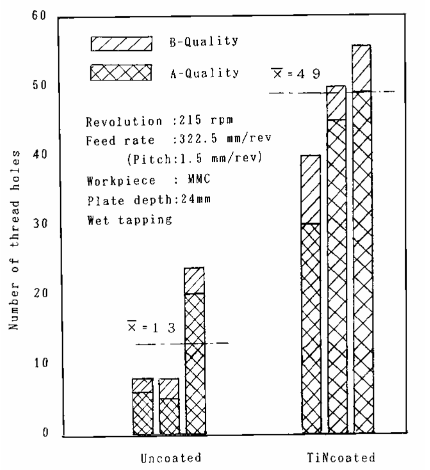

Figure 3.8: Comparison of tool life with tap.

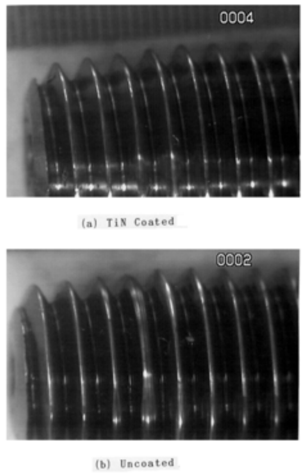

Figure 3.9: Comparison of tool wear with tap.

3.6 Comparison of Tap Wear

Figure 3.9 shows the tool wear of the various taps after threading in the experiments indicated in Figure 3.8. It should be noted that all the taps used for this comparison have already attained full tool life. TiN coated and uncoated taps are shown in Figure 3.9(a) and (b), respectively. It can be seen that the point of all the taps show tool wear. In addition, extensive wear can be observed at the boundary between the full thread form with the chamfer thread run-out of same 3～5 threads from the scrape point. A comparison of the TiN coated and the uncoated tap, as exemplified by the magnified point, shows that wear of the latter is more pronounced than the former. In the case of the TiN coated tap, an overlay of TiN coating can be observed at the tool wear zone.

4. Conclusions

(1) The tool life of the TiN coated tap was approximately 4 times longer than that of the uncoated tap.
(2) The TiN coated tap (for the 1st hole) exhibits 28% reduction in torque compared to the uncoated tap.
(3) The tooth profile of the thread produced by the TiN coated tap shows fewer irregularities than for the uncoated tap.
(4) The hardness of the TiN coated tapping thread is lower than the uncoated tapping thread.
(5) From the above results, the TiN coated tap is superior to the uncoated tap in the following aspects, tool life, thread forms and work hardening etc,.

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[2] Beitz.W : Dubbel-Taschhenbuch fuer den Maschinenbau. ISBN 3-540-52381-2, (1990), G15.