Performance Evaluation of Machine Tap for tapping Al6061-T6 Aluminium Alloy

Narayanan S[1], Nagaraja[2], Raviraja Adhikari[3]

***Abstract*—**The present study deals with tapping of Al6061-T6 alloy specimen in dry condition. The study aims at determining the progressive wear of M8 HSS machine tap dueto machining. The charecterisation of the specimen was done by conducting hardness and tensile test. The tappingtool experiments wereconducted on a radial drilling machine using an automatic tapping attachment. Kistler drilling tool dynamometer was used to record the thrust and torque during tapping. The progressive wear of the tool was evaluated by weight loss method. From the experimental study it was observed that wear in the tap was considerably less due to soft nature of the work piece material Al6061 T6 alloy. During tapping operation, the thrust force and torque found to increase with tool wear due to progressive wear of machine tap.

***Keywords*—** Spindle Speed, Feed rate, Toolwear, Al6061-T6 aluminium alloy.

I. Introduction

A tap is simply a hardened tool steel screw with lengthwise grooves, called flutes, milled or ground across the threads. In machine tap, flutes form a series of teeth and provide chip room along the entire length of the threaded portion of the tap. When a tap is turned into a hole of proper diameter, the teeth cut into the wall of the hole and remove material to form threads of same pitch as the threads of the tap. The majority of tapping process is done by the teeth on the chamfer portion and the first full following thread.The common failures of tapping are tap breakage and poor thread quality. Chen *et al.* [1] showed that from the metallurgical point of view, the shape of a tap causes very high surface stress concentrations, as it is subjected to both torsional and bending loads. Generally, tap breakage may be caused by overload, material fatigue, inadequate heat treatment etc. The quality of the thread is decided by the size and surface finish. The threaded hole may be undersized or oversized. In a threading operation, surface finish is usually not crucial, if the thread is to be used for a fastener. But, the burr on the entry or exit of the hole can cause a significant problem. The major causes of above symptoms are tap wear, error in size of hole, misalignment, and poor lubrication. Information available on the tapping of metal matrix composite is very rare and incomplete.Dogra *et al.* [2] used a mechanistic approach for modeling the tapping process. The mechanics of cutting for tapping is analysed, considering it as an oblique cutting phenomenon. The effects of tap geometry (tap diameter, thread pitch, number of flutes, flute helix angle, tooth rake angle and thread type), work piece geometry (hole diameter and hole depth), process parameters (spindle speed and tap penetration depth) and process faults (tap runout, axis misalignment and drilled hole geometry) were incorporated in the model. Patil *et al.* [3] designed and developed an attachment for tapping to produce controlled torsional vibrations on the tap and to study the effect of vibration frequency, amplitude, tap size, properties of work material etc. on the tapping torque and thrust while tapping cast iron and aluminum. The study has reported the reduction in tapping torque and thrust required under torsional vibration conditions. Koelsch[4] studied the overall performance of machine taps and concluded that tapping wear means tight, unacceptable threads. To solve this problem, it was recommended to use two flutes instead of three/four fluted taps on soft/work hardenable materials. But, on harder or abrasive materials, three or four fluted taps might last longer than two-fluted taps. To overcome the severe tap wear, it is recommended to reduce cutting speed if possible, or to use harder tool materials, Chen *et al*. developed a method for the diagnosis of the tapping process using the information measured and multiple probability voting scheme. A set of indices based on the time-domain statistical analysis has been done. The following conclusions have been drawn from the evaluation of indices: Cutting torque contains most information about the tapping process. The tap wear condition will dominate the variation of cutting torque. Thrust force contains least information about the tapping process. Misalignment condition will be more sensitive to the value of torque in retraction stroke phase because there is no cutting force involved. Lorenz [5] studied the effect of variation of tap geometry and its implications on tapping torque required. The effects of thread relief, chamfer relief and rake angle on toque had been investigated in a statistically designed experiment.. Patil *etal*.[6] studied on the torsional behavior of straight fluted machine taps for the stress distributions in different non-circular cross sections of taps using Finite Element method. The influence of tap geometrical parameters like core diameter, land length, number of flutes on torsional stiffness and stress concentration in tap cross sections were studied. Based on these studies, a procedure for the design of optimal machine tap cross sections has been reported. The study has reported the reduction in tapping torque and thrust required under torsional vibration conditions.

The review of literature has revealed that researchers have mainly focused their attention on ferrous materials for evaluating the performance of machine taps.Therefore, the present study deals with tapping of Al6061-T6 alloy specimen in dry condition. The study aims at determining the progressive wear of M8 HSS machine tap during to machining.

[1,2,3] Department of Mechanical and Manufacturing Engineering, Manipal Institute of Technology, Manipal University, Manipal, India

https://doi.org/10.17758/EAP.U0317109

II. Methodology

The methodology adapted for estimating the progressive wear of taps is given below.

- Characterization of Al6061-T6 alloy Test specimen
- Measurement of thrust force (Fz) and torque (Mz) during taping using a Radial Drilling machine.
- Measurement of tool wear

A. Experimental Study

Characterization of Al6061-T6 alloy Test specimen
Composition of Al6061-T6 Alloy

The composition of Al6061–T6 alloy,as provided by the supplier [M/s HINDALCO India Ltd.] is given in table 1

TABLE I
Material Composition Of Al6061-T6 Alloy

Component	Amount(wt.%)
Aluminium	Balance
Crabon	2.9
Megnisium	1.2
Silicon	0.6
Iron	0 .2
Copper	0.4
Zinc	0 .01
Titanium	0.03
Manganese	0.4

A Hardness Test

The hardness value of the test specimen was determined by using Brinell hardness testing machine (Avery make), using ball indenter. Three samples and five readings on each sample were taken and the average of these readings was considered as the representative hardness of the material.. The hardness value of Al6061-T6 alloy specimen was found to be 93 BHN.

B Tensile Test

The tensile test of the Al 6061 alloy was tested using Electronic Tensometer TMER3(Khudal Instruments, Pune make),shown in the figure 1. The size of the test specimen is shown in figure 2. The average of tensile test values ofthree samples were determined to estimate the representative tensile strength of the material. Thetensile strength of the Al6061-T6 specimen as obtained, was found to be 791.7 N/mm^2.

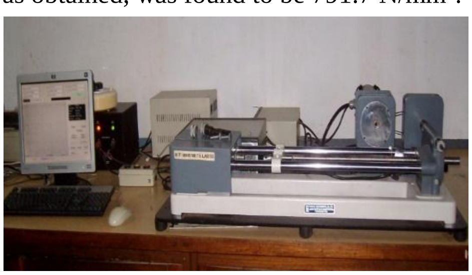

Fig.1: Electronic Tensometer TMER3

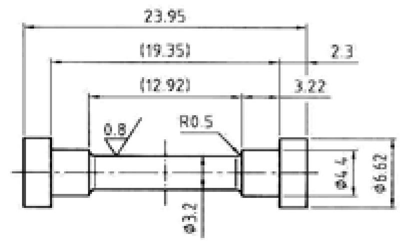

Fig.2: Tensile test specimen

Tapping Experiments

The Al6061-T6 alloy bar of Ø 20 mm was machined to 15 mmlength. Holewas tapped in the specimen in dry condition by using HSS M8x1.25 straight, three fluted spiral point taps shown in fig. 3 and 4, with 9° chamfer angle, 6.25mm chamfer and 22 mm flute length (*l*) were used. The specification of the machine tap is given in the table 2. The specimen was clamped on the top of piezoelectric based 4 component Drill tool dynamometer 9272A (Kistler make) which was used for measuring thrust and torque during tapping. The tapping experiments were conducted on a radial drilling machine at constant feed rate with cutting speed of 16 m/minas the cutting speed recommended for tapping aluminium is in the range of 14-18 m/min[7]. The setup used during the machining operation is as shown in the figure 5.

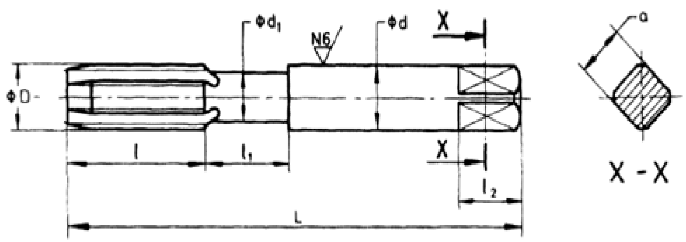

Fig.3. HSS M8x1.25 straight fluted spiral point tap [8]

Fig.4. Photograph of HSS straight, three fluted spiral point tap, M8x1.25

Table.II. Specification of Machine Tap M8 X 1.25

Parameter	l	L	d1	l_1	a	l2
Value (mm)	22	72	6	13	6.3	9

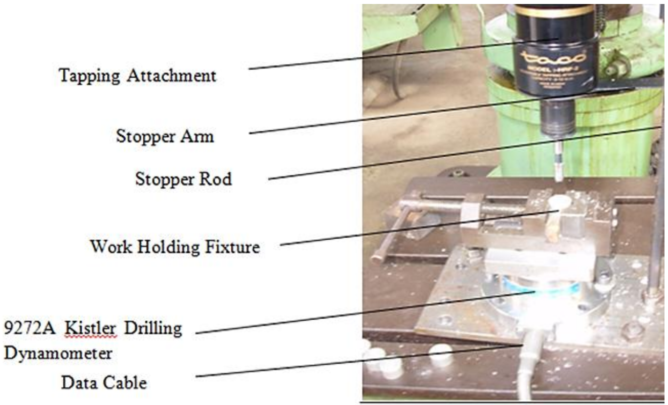

Fig. 5 Tapping attachment and dynamometer setup

A Thrust And Torque

The typical plot of thrust and torque captured in the Dynowaresoftware (Kistler make) during tapping is shown in fig. 6. It is observed that the torque increase steadily from initial tap engagement to its maximum value when the chamfer is fully engaged and the full thread is formed. The torque remains fairly constant while the full thread is being formed followed by steady reduction in the torque as the chamfered end of the tap begins to exit the hole, reaching zero value when the chamfered end is fully disengaged from the threaded hole. This trend matches very well with the pattern of variation of torque already reported [9].The torque required and thrust developed during tapping were noted at regular interval of 50 holes and are given in table III. The plot of torque and thrust while tapping different interval of holesis shown in fig. 7. It was observed that thrust and torque increased with the number of holes tapped.

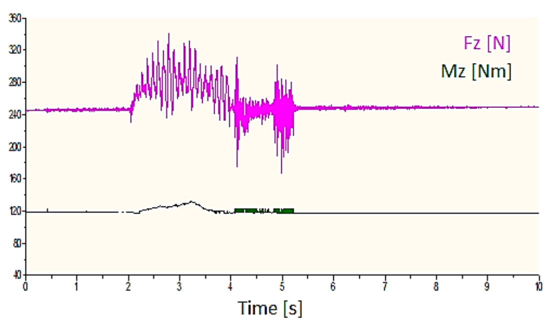

Fig.6 Sample plot for thrust force and torque variation during tapping

TABLE III - THRUST FORCE AND TORQUE AT DIFFERENT NUMBER OF HOLES TAPPED

Hole No.	Fz (N)	Mz (Nm)
1	26	6
50	34	7
100	49	15
150	65.4	18.4
200	76.8	23.8
250	94.2	28.6
300	114.6	32.2
350	128.6	36.3
400	136.4	40.4
450	146.2	45.3

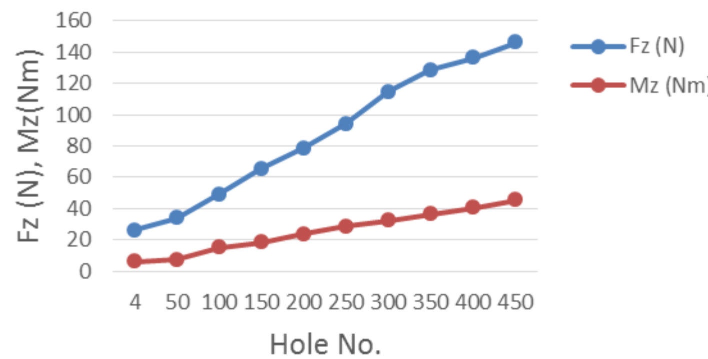

Fig.7 Variation of thrust and torque

B Tap Wear

The wear of tap was estimated by two methods viz. by estimating the flank wear using a profile projector and weight loss method.

I. By Using Profile Projector: The wear pattern of the machine tap was measured using a profile projector (METZER, India make) as shown in fig.8. The profile measurement was done at magnification of 20X. The profile of the teeth in the chamfer portion of the tap was traced from the display in the profile projector, before the start of tapping as shown in fig. 9. Subsequently the same procedure is repeated after tapping at every interval of 50 holes, up to 450 holes. During this, the reference axis of the tap is made to coincide with cross wire in the display of profile projector, to avoid positioning error. All the cutting edges in the chamfer portion including the first full depth thread at the end of chamfer section undergo progressive wear with increase in number of holes tapped. In addition to this, the first full depth thread is responsible for cutting the thread to the desired size as it is the last thread in the cutting section of machine tap. Therefore, progressive wear of other cutting edges in the chamfer portion causes additional burden or load on the full depth thread to perform the task. Hence the cutting edges of the first full depth thread is taken as reference for estimating the progressive flank wear of machine tap.

The reduction in the height of cutting tooth (h) in the chamfer section is measured as shown in fig. 10. The flank wear was estimated at every interval of 50 holes, up to 450 holes. The progressive flank wear (h_f) is obtained by marking the successive reduction in height of the teeth in the chamfer portion of tap on its original profile. The progressive reduction in height of the tooth was marked as a point on rake face in each case. The horizontal lines were drawn from these points to intersect the flank surface. The progressive flank wear was estimated by measuring the length of each line. The procedure adapted is shown in fig. 11. The flank wear with the number of holes tapped is shown in table IV and figure 12.

Fig.8. Machine Tap positioned in the Profile Projector for Wear measurement

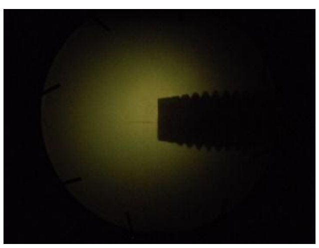

Fig. 9. Display of tap profile in the profile projector

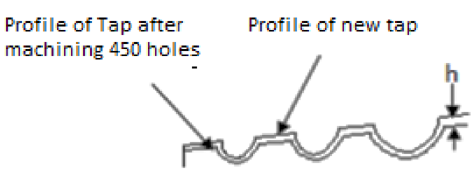

Fig. 10 Profile of the chamfer portion of tap

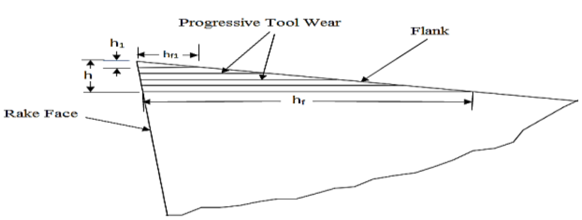

Fig.11 Flank Wear (h_f) derived from reduction in height of the tooth (h)

TABLE IV

FLANK WEAR (HF) ON THE CUTTING EDGE OF THE TAP

Hole Number	50	100	150	200	250	300	350	400	450
Flank wear (h_f) in mm	0.03	0.08	0.15	0.18	0.24	0.31	0.39	0.48	0.56

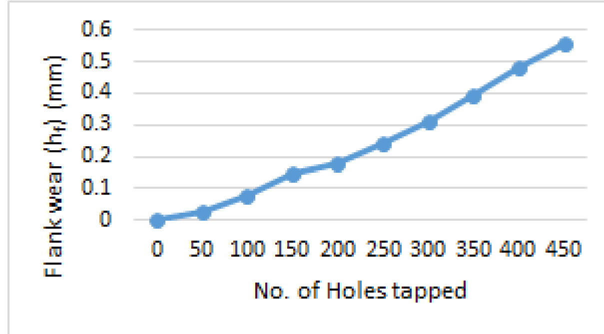

Fig.12 Plot of flank wear after machining at interval of 50 holes

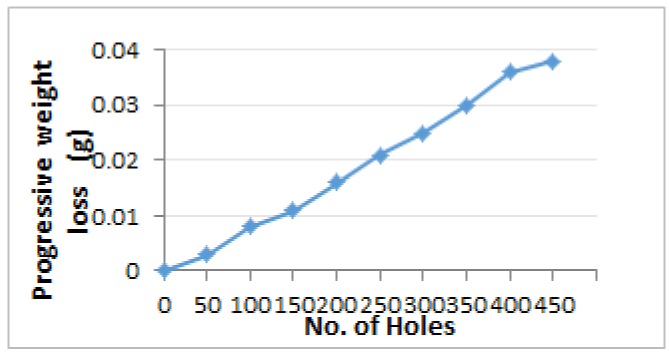

Fig. 13 Variation of progressive weight loss of tap with number of holes tapped

It is observed that the flank wear has increased with the number of holes tapped. It is also noted that the flank wear increases uniformly with the increase in number of holes, indicating that the tool is in uniform wear phase. Further, flank wear width (h_f) at the end of tapping 450 holes is 0.56 mm at one of the cutting teeth. With the maximum limit for flank wear width being 0.3mm for HSS too ls [10],it could be understood that the tool is still having significant service life.

II. By Weight Loss Method: The reduction in the weight of the tap due to wear was found at intervals of tapping 50 holes, using an electronic balance with three decimal places of accuracy. The progressive wear of tap in terms of weight loss at different interval of tapped holes in the specimens are givenin thetable V and figure 13. It was observed that progressive wear increased with the number of holes tapped. The trend of progressive loss of weight of the tool closely matches with that of progressive flank wear of the tool.

TABLE V:

PROGRESSIVE WEAR OF TAP WITH NUMBER OF HOLES TAPPED

No. of holes tapped	50	100	150	200	250	300	350	400	450
Weight loss of tap(g)	0.003	0.008	0.011	0.016	0.021	0.025	0.03	0.036	0.038

III. Conclusions

It was observed that wear in the tap was considerably less due to soft nature of the work piece material Al6061 T6 alloy.During tapping operation, the cutting force (F_Z) and thrust (M_Z) found to increase with progressive tool wear. It was observed that the tool is in the uniform wear phase and still having significant service life.

References

[1] Y B Chen, J.L.Sha, S.M.Wu, "Diagnosis of the tapping process by information measure and probability voting approach", *Trans ASME – Journal of Engineering for Industry* vol.112, pp. 319-325, 1990 https://doi.org/10.1115/1.2899594.

[2] Ajit Pal S.Dogra, Shiv G.Kapoor and Richard E.DeVor , "Mechanistic Model for Tapping Process with Emphasis on Process Faults and Hole Geometry", *Transactions of ASME*, pp. 18-25,2002.

[3] S.S. Patil , "Some investigations on vibratory tapping process" *International Journal of Machine tool and Manufacture*,vol. 27, pp.343-350, 1987.

[4] James R Koelsch, "All tapped out", *Manufacturing Engineering*,pp.49 – 52, 1990.

[5] G.Lorenz, "A study on the Effect of Tap Geometry", *Mechanical Engineering Transactions*,pp.1-4, 1980.

[6] S.S.Patil, S.S.Pande and S.Somasundaram,,"Torsional analysis of taps using finite element method",12th AIMTDR conference,, IIT Delhi, Tata McGraw Hill Pub. Co. Ltd., New Delhi 1986,

[7] CMTI,"*Machine Tool Design Hand Book*", Tata McGraw Hill, New Delhi, 2001, ch. 3, pp. 656 Indian standard screwing Taps, IS:6175 (Part 2):1992.

[8] E.J.A. Armarego, M.N.P.Chen, 2002,"Predictive Cutting Models for the forces and torque in machine tapping with straight flute taps", *Annals of the CIRP*, v51/1.

[9] A.K.Dutta, A.B.Chattopadhyaya, K.K.Ray, Progressive flank wear and machining performance of silver toughened alumina cutting tool inserts, *Wear*, vol. 261, pp. 885–895,2006 https://doi.org/10.1016/j.wear.2006.01.038