A Review on Thread Tapping Operation and Parametric Study

Hardik J. Patel*, Bhaveshkumar P. Patel, Prof. S. M. Patel*****

*(M. Tech. student-AMT, Mechanical Engineering Department, U. V. Patel College of Engineering, Ganpat University, Kherva- 384012, Dist. Mehsana, Gujarat, India)

** (Assistant Professor, Mechanical Engineering Department, U. V. Patel College of Engineering, Ganpat University, Kherva- 384012, Dist. Mehsana, Gujarat, India)

** (Professor, H.O.D., Mechanical Engineering Department, U. V. Patel College of Engineering, Ganpat University, Kherva- 384012, Dist. Mehsana, Gujarat, India)

ABSTRACT

Now days, there is a tremendous development in the production industry and their relevant machinery to improve the productivity. But still, in small, medium and some large scale industries uses the conventional methods in some of the operations. Thread tapping is one of them. Tapping is the method to produce the fine thread inside the drilled hole on the plate. Most of the industries uses the conventional method says hand tapping. This conventional method is very time consuming process, less accurate and includes higher labour cost, and ultimately less productivity. So there is a scope to develop the machine for tapping operation. This paper focuses on the review of the tapping operation and its parametric study carried out by other researchers in the same field.

Keywords - **Machine tapping, Pneumatic, tap size**

I. INTRODUCTION

There is a tremendous technological development in the manufacturing industry and manufacturing industries are making large amount of effort for their mass production with best quality products having higher reliability and economical in cost. Now days the hand operated machines are replaced with the application of automation in automatic or semi automatic machines which utilized to improve the productivity. Tapping may either be achieved by hand tapping by using a set of taps first tap, second tap & final (finish) tap or using a machine to do the tapping, such as a lathe, radial drilling machine, bench type drill machine, pillar type drill machine, vertical milling machines, HMCs, VMCs. Machine tapping is a process to produce the female threads inside the drilled hole. Machine tapping is faster and generally more accurate because human error is eliminated. Final tapping is achieved with single tap. Although in general machine tapping is more accurate, tapping operations have traditionally been verytricky to execute due to frequent tap breakage and inconsistent quality of tapping. Machine tapping can be performed by electric drives and the problems concerned with the machine tapping can be eliminated with the application of pneumatic tapping machine.

II. FORMULATION OF PROBLEM

A tap cuts a thread on the inside surface of a hole, creating a female surface which functions like a nut. During operation, it is necessary with a hand tap to periodically reverse rotation to break the chip formed during the cutting process, thus preventing an effect called "crowding" that may cause breakage. Periodic reversing is usually not practical when power tapping is involved, and thus has led to the development of taps suitable for continuous rotation in the cutting direction.

Taps and machine tapping operation for internal threads are amongst the most complex and least understood cutting tools and cutting processes used in practice. Tapping of a screw thread is one of the very common machine operations used in manufacturing industry and is frequently among the last operations performed on a component so that the added value of the component is close to its peak when tapping is performed. But tap breakage may either ruin the almost finished work piece, or create a large down time to remove the broken tap from the work piece. Other problems associated with the tapping process include thread dimensional accuracy, thread form error, and surface roughness of thread form. For several decades, it remains troublesome and costly due to various process failures such as tap breakage, over- and under-sized threads, and burrs at the entry and exit of threaded holes. These failures are usually caused by certain process faults that often exeunt in production. Small, medium and some large scale industries still uses the conventional methods to perform the tapping operation and faces the above mentioned problems. As the industry strives for higher productivity and better quality, this is a need for the tapping process to operate without error or human intervention. So here there is a chance to develop an air tapping machine which can reduce or eliminate the above mentioned problems associated with tapping process and study can be conducted for affecting parameters responsible for better quality and improvement in productivity and economy.

III. LITERATURE REVIEW

For the development of the new technique, operation, process or methodology it is very important to make detail study on the existing techniques, operation, process or methodology and to understand the same for elimination of problems concerned with them. This section covers the literature review for tapping operation and its parametric study carried out by other researchers in the same field. This study can be helpful for improving the quality of tapping, dimensional accuracy, and productivity, also reduced in operational timing, tool breakages, and human errors.

In 1973, E. D. Doyle and S. K. Dean have designed tapping attachment to reduce the axial forces generated during the tapping operation. When tapping threads on a machine tool, such as a drilling machine, axial forces on the tap can be generated by the cutting action of the tap, by the operator and by the machine, and they can cause dimensional inaccuracies in the thread. Oversize threads and poor thread forms produced on a radial drill were found to be caused by axial forces generated by the machine. These defects were eliminated by using a tapping attachment specifically designed to reduce axial forces. A device for reducing the axial force was developed and its use enables the cutting of accurate thread forms [1]. G. Lorenz, in 1980, has studied on tapping torque and tap geometry. Vibrations in tap geometry are reflected in the measurements of the tapping torque. The effects of cutting speed, thread relief, chamfer and rake angle on torque have been investigated in a statistically designed experiment when using 7/16 – 20 UNF bottoming taps and zp-oil on a pitch gear controlled tapping machine. The analysis of the experimental data showed that the higher order interactions of the variables, in particular those of speed and chamfer relief, significantly affect the torque. The thread relief and the chamfer relief must be selected for the tapping speed used in production, if the torque is to be reduced. At fast speeds only a combined increase of thread relief and rake angle is expected to yield a substantial reduction in torque, which in turn will reduce the enlargement cut by the tap. The experiments also showed little change in tapping torque around a rake angle of $\gamma = 7^{o}$, when tapping CS 1114 free machining steel. Furthermore, the results suggest that tapping torque measurements should be carried out at three speed levels when the ratings of cutting fluids have to be established [2].

In 1987, S. S. Patil, S . S. Pande and S. Somasundaram have reported the results of an experimental program to study the influence of torsional vibrations on tapping process. An attachment has been designed and developed to produce controlled torsional vibration on the tap while tapping. Investigations have been carried out to study the influence of different process conditions, such as tap size, work material, vibration amplitude and frequency, etc. on the tapping torque and thrust during machining. Optimal process conditions which enhance the tap life are reported. The optimal frequency of vibration corresponding to the maximum reduction in tapping torque and thrust is different under different operating conditions. The optimal process conditions observed for vibratory tapping process on cast iron and aluminum. The optimal cutting conditions give about 8% reduction in tapping torque and about 16 % reduction in thrust while tapping cast iron. For tapping in aluminum reduction in tapping torque and thrust was about 14% and 56% respectively. A critical uncut chip thickness value is seen to exit below which only the reduction in tapping torques and thrust is possible. The critical uncut chip thickness is found to increase with the decrease in the hardness of the work material. The optimal value of the frequency increases with the decrease in uncut chip thickness. The optimal value of amplitude, for a given size of tap or uncut chip thickness, depends upon the hardness of the work material. Thus, it is seen that the vibratory tapping process is suitable under particular operating conditions [3].

De-Yuan Zhang and Ding Chang Chen, in 1998, have a one of the key problem in the tapping process to cut materials such as titanium alloys is difficult in which the relief-face friction of the tap is very large. The vibration tapping process in which the spring back of the machined surface can be removed, has been analyzed with elasto-plastically. Thus the reason why vibration tapping can reduce the tapping torque has been explained qualitatively, and a theoretically basics for choosing reasonable values for the cutting parameter for vibration tapping has been provided. The theoretically analysis shows good agreement with the experimental results obtained when tapping a titanium alloy [4]. E. J. A Armarego and Marilyn N. P. Chen, in 2001, have developed cutting models for the forces and torque in machine tapping operations with straight flute taps is outlined. The models, based on the "unified- Generalized Mechanics of Cutting Approach" allow for the many tap and cut geometrical variables. The models have been verified by extensive computer simulation studies as well as comprehensive experimental testing programmers. This investigation has provided a deeper understanding of the basic cutting action as well as predictive force models of tapping, renowned as "one of the most neglected operation in machining research. Although this work has shown that both thrust and torque can now be predicted, further research is required to improve the unbalanced side force prediction and to allow for variables such as the tap helix angle and possible eccentricity in the axis of rotation [5].

Synchronizing error between the spindle motor and the z- axis motor directly influence the cutting characteristics in tapping, because the tapping processes is accomplished by synchronizing the movement of the z-axis with the revolutionary spindle motion. The excessive synchronizing error can cause tap breakage due to the abrupt increases of cutting torque or damage the thread accuracy by overcutting the already cut threads. This paper describes the affects of the synchronizing error on the cutting performance in the ultra high speed tapping and presents a minimum level of synchronizing errors necessary to maintain the quality of the cut thread presented by J. h. Ahn, D. J. Lee, S. H. Kim, H. Y. Kim and K. K. Cha, in 2002. They have concluded that the tapping torque pattern experimentally obtained with a near zero synchronizing error is well matched with the simulated one based on the proposed theoretical model. Synchronizing errors greatly vary according to the change of feed forward gain as well as cutting speed. In the case of large synchronizing errors, the tapping torque and thrust increase and the cut threads are damaged while retreating. Synchronizing errors should be controlled less than 0.04 mm, 8% of the pitch of the M3 tap, to meet the level of JIS class 2 in the ultra- high speed tapping [6].

Tengyun Cao and John W. Sutherland in 2002, a mechanistic model for the prediction of tapping torque and axial force is developed. The model is capable of predicting tapping torque and axial force resulting from chip formation and tool flank work piece friction under various machining conditions including dry tapping and tapping with different cutting fluids. Extensive tests on tapping torque and axial force measurements are conducted to verify the predictive model. Characteristics of the measured tapping loads are studied. It is found the total tapping load consists of a base load and a chip packing load. The base load results from chip formation and tool/work piece friction. The predicted tapping load is found to be in good agreement with measured base load. The chip packing load is the result of chip clogging in the flute, and is random in nature. The chip packing load may be as large as five times that of the base load depending on tap geometries and the machining conditions. Factor causing severs chip clogging and excessive torques leading to tap breakage is also reported. Tap breakage was observed to be torsional fracture resulting from excessive tapping torque; particularly the random load from chip clogging chip clogging may be reduced through optimized design in tap geometry with improved chip accommodation and chip evacuation. The coefficient of friction between tool material and work piece material was change with lubricating conditions. The coefficient for dry sliding is about 4 times that with cutting fluid lubrication. The coefficient of friction change with sliding speed, usually decreasing as speed increases. There are only slight differences between the friction coefficients measured with different cutting fluids. Application of cutting fluids reduces the base tapping load, but has little effect on the peak load, and therefore is not a critical determinate in terms of tap breakage [7].

In 2002, Oleg A. Mezentsev, Rixin Zhu, Richard E. DeVor, Shiv G. Kapoor, and William A. Kline have developed a model based method for fault detection in tapping based on torque and radial forces. The method allows the identification of faults typical of a tapping operation including axial misalignment, tap run-out, and tooth breakage both singly and together. The validation experiments have been run on aluminum 356 work pieces for different combinations of process faults. Results have shown that the model predictions are in good agreement with the experimental radial force and torque signals under various fault conditions. A mechanistic model for the tap tapping process has been enhanced to study the effects of different tapping process faults on the force signals: torque and radial forces. Enhancement includes the occurrence of runout axis misalignment and tooth breakage. The fault identification strategy focuses on torque and redials forces and is based on comparing experimental signals obtained during cutting with those based on the model in the presence of various faults, namely tap axis misalignment, tap runout, tooth breakage and their various combinations. Results of validation experiments show excellent agreement between model simulations and experiments. The average prediction error of the magnitude of torque and radial forces is less than 10%. The error in predicting the mean of radial forces for the studies cases is less than 15% [8].

W. Li, D. Li and J. Ni have presented a two stage pair wise feature selection and classification method to diagnose the tapping process using the electrical current signal of the spindle motor in the year 2003. The motor current is measured with a non intrusive Hall Effect sensor. The diagnostics process is divided into two stages. The final diagnostic decision is made based on a statistical voting procedure. The proposed method has been demonstrated with experimental data. On average a 93% success rate has been achieved [9]. In 2003, Bi Zhang, Fulun Yang and Jiexin Wang, have carried out a study on fundamental aspects in vibration-assisted tapping. A although tapping has been widely used for thread fabrication, it is often a time consuming process causing a delay on an automated production line. This study investigates the fundamental aspects in vibration-assisted taping. It addresses two major mechanisms that are responsible for torque reduction during vibration-assisted tapping, i.e. friction torque reduction and material property change at an enhanced strain rate. Theoretical analyses are conducted to account for the effect of vibration on tapping torque reduction, and the verified by the tapping experiments with and without vibration assistance. Taps of three different sizes and vibration of two different waveforms are used in the tapping experiments. The theoretical results are applicable to vibration-assisted tapping and other machining processes. For a given frequency of vibration, there exists an optimum amplitude at which the minimum tapping torque is obtained. More reduction in tapping torque is obtained when a smaller size tap is used, and vice versa. A torque reduction is always obtainable with vibration assistance in tapping. Vibration waveforms have influence on the tapping torque reduction. Square waves have a better effect than sine waves [10].

J. D. Adams, L. Manning, B. Rogers, M. Jones and S. C. Minne, in 2005 have demonstrate self sensing tapping mode using commercially available, low- stress, piezoelectric cantilevers with sharp design integrated, silicon tips. Previous work has been limited by stress in the cantilever, thickness and size of the cantilevers, un-optimized electrical trace design and/or a lack of a probing tip. Tests indicate amplitude resolution with self-sensing to be as good or better than optical detection, and sensitivities up to twice as good, with the same type cantilever. A tapping mode image of an evaporated gold film and force curves that compare optical and self-sensing detection methods are presented [11]. A tapping operation having a problem, as high-speed steel tap is incapable of tapping small hole (M3) in hardened steel (50HRC). Theoretical analysis with fracture mechanics indicates that the impact effect of the tap on the work piece results in increased H-type stress intensity factor and extended micro cracks, leading to lower plastic deformation, reduced cutting forces and a much lower tapping torque and the torsional rigidity of the tap is enhanced in vibration tapping as proved using dynamic analysis by Baolin Yin and Rongdi Han in 2006. The experimental results show that well chosen amplitude tapping torque decreases as vibration frequency increases, and tapping torque increases as net cutting time ratio increases, where net cutting time ratio influences the tapping more significantly. Vibration tapping is then proved to be a practical solution to the problem of small hole tapping in hardened steel [12].

Kei-Lin Kuo, in 2007, has studed a vibration assistance tapping for fabricating internal thread for titanium metal. High frequency imposed on the work piece, was generated by a piezoelectric actuator. The axial thrust force and the tapping torque were respectively plotted against the tap's traveled distance relative to the work piece. Each of the plots demonstrated that the entire tapping process could be divided into six characteristics stages. The implication associated with each characteristics stage was discussed for each plot. The stages where there was maximum thrust force and maximum torque located were indentified. For smaller size tapping of pure titanium metal, imposing an ultrasonic vibration can beneficially affect the tapping process in terms of reducing the tapping torque, and thereby decreasing the likelihood of the tap breakage. Within the adjustable range of the ultrasonic vibration generator, it was verified that vibration assisted tapping performed at the resonance frequency would have the lowest tapping torque generated. Introducing of cutting fluid during tapping had a beneficial effect in terms of reducing the tapping torque, though the degree of reduction was less than that realizing by vibration. The smaller the tap size was, the greater the degree of the tapping torque reduction could be. No adverse effect on the profile of the internal threads was noted when vibration-assisted tapping was employed [13]. S. Bhowmick, M. J. Lukitsch, A. T. Alaps, in 2010, have made study on the deep hole drilling and tapping of automotive power train components made on of hypoeutectic Ai-Si alloys and having considerable importance. This work investigates the dry and minimum quantity lubricated (MQL) tapping of AI-6.5% Si (319) alloy as alternative to conventional flooded tapping. Two types of tests were done in comparison with flooded tapping. In the first set dry tapping experiments were performed using diamond like carbon (DLC) coated and uncoated HSS taps. The second set of tapping experiments used MQL and only uncoated HSS taps. The mechanicals properties of the material adjacent to tapped holes, evaluated using hardness measurements, revealed a notable softening in the case of HSS-dry tapping, but not for MQL tapping. The presence of sulphur and phosphorus based additives in MQL fluids proved beneficial in preventing aluminum adhesion [14].

In 2010, G. Fromentin, A. Bierla, C. Minfray and G. Poulachon have presented the results of a study of lubrication in form tapping and aims a better understanding of its effect. It appears that lubrication is of paramount importance. Oil with efficient high pressure additives can reduce considerably the torque necessary to form the thread. Lubricants reduce the tool/work material friction during the forming process and as a consequence. This investigation includes an analysis on the effect of additives in lubricants on the temperature during tapping, enabling correlation with the appearance of chemical elements of the oil which react with the thread material and contribute to lubrication. The present study evaluated the ability of 9 oil and 2 water based emulsions to reduce friction in form of tapping. From this study, important differences are shown to exit between these lubricants, and consequently the choice of suitable oils for form tapping is necessary to obtain success with this process. Thus, the key to performance of a given lubricant in form tapping is surely determined by the molecular structure of the sulphur additive and its thermal behavior [15].

IV. CONCLUSION

The tapping operation is normally performed as end operation and very important for fastening purpose. There are so many work carried out by the researchers on tapping operation which includes the quality of tapped hole, accuracy in dimensions, alignment of tapping tool with center of drilled hole, vibration assisted tapping, machine tapping, tapping tool breakages, application of different lubricants and its effect on quality, and parametric study and its analysis. Still there is a scope to work on tapping operation with pneumatic application and can be perform parametric study on it. This study can helpful for better quality of tapped hole and improvement in productivity as well as to reduce the problems concerned with hand tapping and machine tool tapping which can eliminate major problem of tapping tool breakage.

REFERENCES

[1] E. D. Doyle and S. K. Dean, Effect of axial forces on dimensional accuracy during tapping, *International Journal of Machine Tool Design and Research, Pergamon press, Vol. 14,* 1974, 325-333.

[2] G. Lorenz, "on tapping torque and tap geometry", Division of manufacturing technology, Annals of the CIRP, CSIRO, Melbourne, Australia, 1980, pp. 1-4.

[3] S. S. Patil, S. S. Pande and S. Somasundaram, Some investigations on vibratory tapping process, *International Journal of Machine Tools Manufacture, 27(.3)*, 1987, 343-350.

[4] De-Yuan Zhang and Ding Chang Chen, Relief face friction in vibration tapping, *International Journal of Mechanical sciences, 40, (12)*, 1998, 1209-1222.

[5] E. J. A Armarego and Marilyn N. P. Chen, Predictive cutting models for the forces and torque in machine tapping with straight flute taps, Department of mechanical engineering, The university of Melbourne, Australia, 2001.

[6] J. h. Ahn, D. J. Lee, S. H. Kim, H. Y. Kim and K. K. Cha, Effects of synchronizing errors on cutting performance in the ultra high speed tapping, School of mechanical engineering, Pusan National University and ERC-NSDM, pusan, korea, 2002.

[7] Tengyun Cao and John W. Sutherland, investigation of thread tapping load characteristics through mechanistic modeling and experimentation, *International Journal of Machine tools & Manufacturing, ELSEVIER, 42*, 2002, 1527- 1538.

[8] Oleg A. Mezentsev, Rixin Zhu, Richard E. DeVor, Shiv G. Kapoor, and William A. Kline, Use of radial forces for fault detection in tapping, *International Journal of Machine tools & Manufacturing, ELSEVIER, 42*, 2002, 479-488.

[9] W. Li, D. Li and J. Ni, Diagnosis of tapping process using spindle motor current, *International Journal of machine Tools & Manufacturing, ELSEVIER, 43*, 2003, 73-79.

[10] Bi Zhang, Fulun Yang and Jiexin Wang, Fundamental aspects in vibration assisted tapping, *Journal of Material Processing Technology, ELSEVIER, 132*, 2003, 345-352.

[11] J. D. Adams, L. Manning, B. Rogers, M. Jones and S. C. Minne, Self sensing mode atomic forces microscopy, *Sensors and Actuators A, ELSEVIER, 121*, 2005, 262-266.

[12] Baolin Yin and Rongdi Han, Investigation of the torque characteristics in vibration tapping of hardened steel, *International Journal of Machine Tools & Manufacture, ELSEVIER, 46*, 2006, 623-630.

[13] Kei-Lin Kuo, Experimental investigation of ultrasonic vibration assisted tapping, *Journal of Material Processing Technology, ELSEVIER, 192-193*, 2007, 306 -311.

[14] S. Bhowmick, M. J. Lukitsch, A. T. Alaps, Tapping of Al–Si alloys with diamond-like carbon coated tools and minimum quantity lubrication, *Journal of Materials Processing Technology, ELSEVIER, 210*, 2010, 2142-2123.

[15] G. Fromentin, A. Bierla, C. Minfray and G. Poulachon, Tribology international, *Teratology International, ELSEVIER, 43*, 2010, 1726-1734.