A Technical Review on the Wear Rate of Deep-Hole Drilling Process Based on BTA (Boring and Trepanning Association) Technique

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A Technical Review on the Wear Rate of Deep-Hole Drilling Process Based on BTA (Boring and Trepanning Association) Technique

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Abstract
Deep-hole drilling of hard materials like carbon steel and super alloys like Inconel-718 is a very complicated process as the wear rate of BTA inserts is quite high as compared to other materials. In this review paper author aims to study the various factors affecting the wear rate and the type of wear occurring in different inserts used for deep-hole drilling of the above mentioned materials. It also emphasizes on studying the various defects like spiralling and chatter occurring commonly in the process and to find out the reasons for the same. The cutting parameters used have a significant influence on the type and rate of wear occurring in the BTA deep-hole drilling inserts.

Keywords: *BTA deep-hole drilling, Inconel-718, wear rate, spiralling*

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INTRODUCTION
Deep hole drilling is defined as the process of drilling a hole whose depth is at least 10 times larger than its diameter i.e., the ratio of depth to diameter of the hole is 10:1. There are basically two types of DHD (deep hole drilling) processes: BTA drilling and Gun drilling. BTA drilling usually uses metal cutting inserts attached to drilling tubes. The wear rate of BTA inserts is a major concern in the recent times. The rate and type of wear changes according to the metal being drilled and the cutting parameters selected. Some of the parameters affecting the wear in inserts are cutting speed, feed rate, coolant flow, chip removal, etc.

LITERATURE REVIEW
Zhang et al. [1] determined the relation between process parameters of deep hole drilling process and the quality of surface generated by using these parameters. It emphasizes on studying the effect of different combinations of parameters on the microstructure and surface roughness of the cast iron samples created. It was found that the guide pads used left a burnished texture on the sample surface. Also there is a specific combination of feed rate and cutting speed which provides a great surface finish by combined drilling and burnishing effects of the inserts and guide pads, respectively.

Dong et al. [2] focused on simulating the static characteristics of BTA deep hole drilling to examine the wear condition of the inserts of the drill tube. Nowadays, meeting the surface quality requirements of deep hole drilling process is a major concern. In this, firstly, a 3-dimensional model of the drill tube was created and analysed with the help of Ansys software. These results were then compared with the experimental results on carbon steel sample work pieces. It concluded that the calculated feed rate and cutting speed had much more effect on the central inserts during experimentation as compared to simulation data. This was because Ansys only took into account the average load and not variable load. Therefore, further study needs consideration of regional differences in load.

Murugabalaji et al. [3] attempted to optimise surface roughness and metal removal rate of an Aluminium casting machined by BTA deep hole drilling process. The optimisation was carried out by using Response Surface Methodology and the results were analysed by ANOVA technique. The analysis output indicated that use of process parameters like high speed, high feed and high depth of cut resulted in an increase in the Metal Removal Rate while low speed, low feed and low depth of cut resulted in a better surface finish due to lower surface roughness.

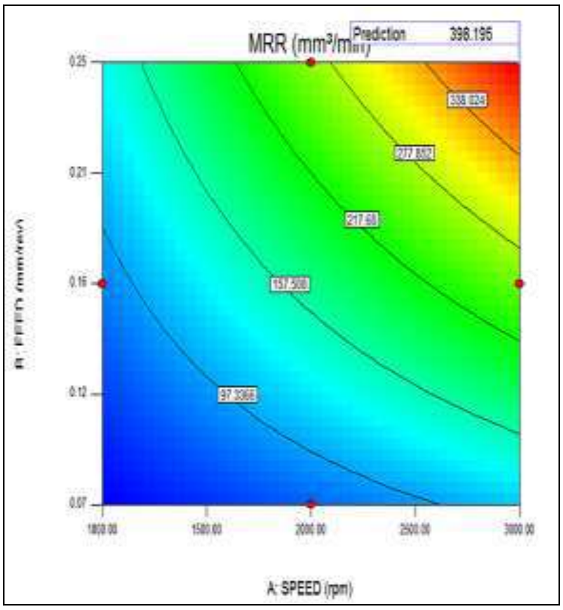

Fig. 1: *High MRR at Optimum Parameters [3].*

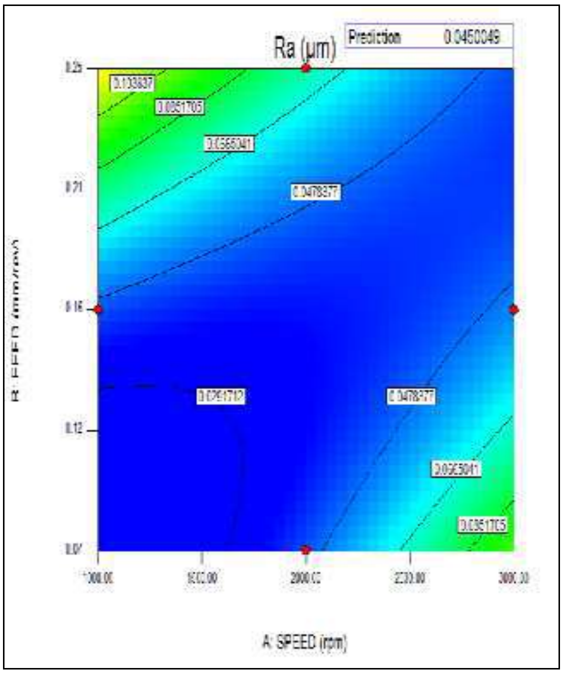

Fig. 2: *Low R_a at Optimum Parameters [3].*

Figure 1 shows the increasing effect of using the optimum machining parameters on the metal removal rate (MRR) while machining Aluminium specimens. Figure 2 depicts the reducing effect of machining parameters on the surface roughness of the Aluminium specimens. These figures show how the optimum parameters affect both MRR and surface roughness differently.

Gao et al. [4] focused on investigation of chip deformation and drilling forces associated with it. The author carries out a computer-based approach to the formulation and testing of machining mechanisms or models created in BTA deep hole drilling processes. Primarily, data related to deep hole drilling process is acquired and a machining model is generated on the computer. The cutting force data are acquired with the help of an optical fibre force sensor in order to find out the condition of wear in the inserts. It was found that the inner insert generates the largest chip deformation. This study is important for developing an online monitoring and control system for BTA deep hole drilling processes.

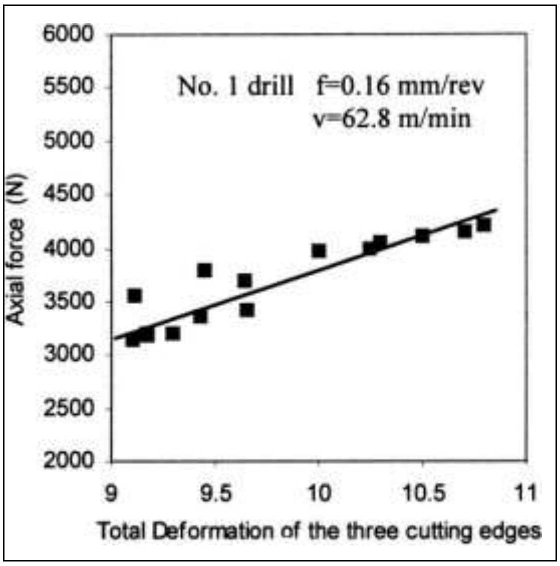

Fig. 3: *Deformation of the Three Cutting Edges [4].*

Figure 3 shows the total deformation occurring in all the three cutting edges after machining. It clearly shows that the deformation is almost precisely placed near the constant deformation line.

Matsukazi et al. [5] focused on finding out the generating mechanism of rifling mark in BTA deep hole drilling process and to create a countermeasure to prevent that. The rifling mark is generated due to chatter vibration occurring sometimes in the deep hole drilling tool. The authors tried to study the generating mechanism with the help of an analytical model and found that the drill tool used to vibrate in different in different portions of the hole drilled. This mainly depended on the depth of the hole to be drilled. The solution was to provide the drill tool with an extra guide pad to prevent the excessive vibrations, thereby reducing rifling marks.

Yang et al. [6] worked towards a novel experiment method used to evaluate the tool geometry of BTA deep hole drilling system. It mainly consists of turning inserts being used instead of BTA inserts in the drill tool and a turning test to simulate the drilling process. A three level and three factor Taguchi method is applied to implement this method with three different angles of BTA inserts. This is mainly to establish the effect of the three angles: edge inclination, flank angle and edge declination on cutting force, chip patterns and chip curl radius. The future work on this would be experimental evaluation on other parameters.

Huang et al. [7] analysed the structural features of BTA tool and to find out the forms of wear that could occur in BTA inserts. The authors aimed to investigate a way of reducing abnormal wear in inserts, which would in turn increase machining accuracy and reduce processing costs. The experiments were carried out on specimens made of TC11 titanium alloy and after machining, the inserts were analysed for wear. The authors found that as the speeds of all the inserts are different, the wear forms in them are also different. They also concluded that as the coating on the work piece changes, the wear rate of the inserts also changes.

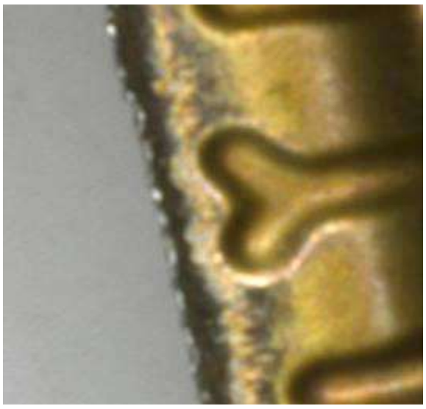

Fig. 4: *Wear form of Intermediate Insert [7].*

Figures 4, 5 and 6 show the respective deformations occurring in the intermediate, peripheral and central inserts of a BTA drill. It clearly shows that as the cutting speed of all three inserts are different, the wear type and wear rate of all three inserts is different.

Ueda et al. [8] carried out the study and development of a new method for the purpose of machining deep holes in a tube sheet to be used for steam generators. Since the thickness of tube sheet is large and has more than 10000 holes to be drilled, the alignment of holes throughout the thickness of tube sheet was a major concern with the conventional tool. The authors decided to conduct a feasibility test on the process using BTA (Boring and Trepanning Association) tools and to monitor the process parameters concerned with the accuracy of holes. They made use of a CNC machine for deep whole drilling and prepared a program covering all aspects of machining from the tool setup and movement to the cutting parameters for the same. They concluded that the CNC machine was much more efficient and highly reliable than the conventional machine tool.

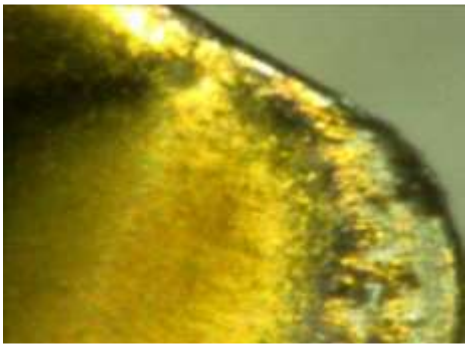

Fig. 5: *Wear form of Peripheral Insert [7].*

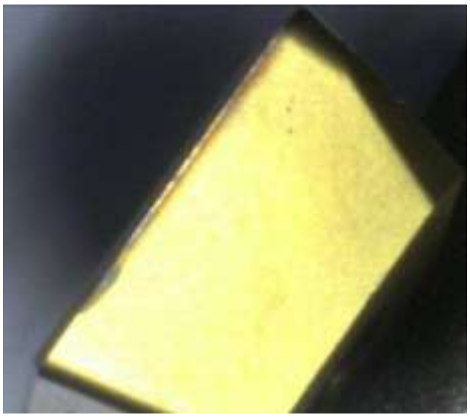

Fig. 6: *Wear form of Central Insert [7].*

Yu et al. [9] found that novel guidance principle has been a newly accepted concept in the field of deep hole drilling tools after the existence guidance principle became obsolete. This principle works on the basis of "fluid-wedge effect". It makes use of a wedge shaped body attached to the drill tool with an attempt to make four wedge shaped spaces between the tool and work piece surface. As a result, the oil coming out from the tool is distributed into four oil films thereby forcing the tool from all directions due to oil pressure. The tool remains aligned with the axis of hole and the straightness of the hole was improved in comparison to the conventional tool. The angle of the wedge shaped body plays an important role in the force applied on the alignment of tool due to oil pressure. Therefore, the correct angle of the body is inevitable.

Biermann et al. [10] studied many mechanical methods and non-mechanical methods that have been used up till now for deep hole drilling operations. But the main concern at this point of time is the machining of aerospace components. Because of the importance of safety in aerospace industries, the above methods have not been very successful due to reasons like poor surface finish, increased tool wear due to high hardness of materials, low thermal conductivity of nickel-based alloys, etc. Such a concern also lies with the machining of super alloy Inconel 718 which is very hard by using standard tool geometries. So, this paper focuses on making a change in the tool tip used to machine Inconel 718 which in turn stopped the generation of undesirable chip and also reduced the rate of wear of the tool tip. It further requires a study of the effect of different lubricants on the same process.

Sasahara et al. [11] identified that in order to obtain the required surface texture and finish, it is important to identify the correct cutting conditions that can fulfil these requirements. This paper emphasizes on the determination of correct cutting parameters for obtaining the required surface finish and life of a product. The author tries different combinations of cutting parameters to achieve the desired fatigue life as well as surface finish on a work piece made of 0.45% C steel. He found that at a lower feed rate, the fatigue life of the machined components was much longer. He also found that by using a sharp tool rather than a chamfered tool, the surface finish was much better.

Sharman et al. [12] mainly focused on the issues of drilling operation on such nickel-based super alloys. The authors here examined various types of different drilling tools available in the market to find out the one suitable for such alloys. They found that the quality obtained by these commercially available tools was not satisfying when tried on Inconel 718. They concluded that a more sophisticated tool was required to machine the alloy in order to get a desired surface.

Biermann et al. [13] observed that during the drilling of ductile materials, the chips produced are long and therefore, the removal of these chips is a big concern as it might hinder the tool while machining. While deep hole drilling, the volume of the cooling lubricant was not enough to remove the chips away from the tool. Therefore, the authors suggested a change in the structural design of the deep hole drilling tool. They first carried out a mechanical analysis to find out the load acting on the tool with the existing design. Based on the results, they underwent with an FEM analysis to find the stresses induced because of the loads. Finally, they conducted structural topology optimisation to change the design of the tool to enable more coolant flow rate. They concluded that the changed design had a higher amount of coolant flowing through which helped in better removal of chips.

Biermann et al. [14] found that deep hole drilling process comes with a lot of issues like spiralling and chatter. These problems mainly happen because of the dynamic disturbances occurring in the tool during machining. However, the exact reasons for spiralling had not been identified. So, this work mainly focuses on the modelling and analysis of the existing tool to find out the exact reasons for spiralling and chatter. Some simulations were run during the working condition of the tool and the results showed that the rotational speed of the tool was a reason behind the spiralling or chatter occurring during machining. This speed can be controlled to reduce the chatter in the tool. But the simulation under different conditions is yet to be done.

Kong et al. [15] has found vibration to be one of the most prevailing issues in the process of deep hole drilling. The main aim of this work is to suppress this effect through variable damping technique under the novel approach. For that, a Magneto-Rheological fluid damper is used on different locations in the deep hole drilling setup in order to fully or partially damp the vibrational effect. A series of experiments on the BTA drilling setup showed that at different locations, the damping effect is different but achievable. It showed that it is possible to reduce the vibrations to a level that is less harmful to the setup.

Woon et al. [16] found that Inconel 718 is one of the most difficult materials to machine when it comes to deep hole drilling. The main hindrance in this process is the straightness of the hole. In this work, the main aim is to investigate the wear taking place in the inserts and the guide pads while machining Inconel 718 and its consequences on the straightness of the hole. Studies carried out in this paper have shown that the wear severely occurs on the sides of the inserts and on the guide pads due to irregular wear rates on the inner and outer sides of the inserts, as a result of which the straightness of hole is adversely affected.

Malarvizhi et al. [17] carried out a study that aerospace and oil industries mainly rely on Inconel 718 to prepare most of the components used. The deep hole drilling of Inconel 718 is a big concern for such industries due to poor quality of surface finish. The above article is based on the use of single-lip deep hole drilling tool to machine this alloy due to its combined drilling and burnishing effect. But the results have shown that the burnishing effect of the bearing pad is diminished during machining as a result of the hot hardness and abrasive nature of Inconel 718. The surface quality of the hole is also dependent on the axial interference occurring due to tilting of the drill head.

Jindal et al. [18] identified that temperature rise is a very prominent effect occurring during any machining process. It can affect the accuracy and precision of the process. Especially for deep hole drilling, the cylindricity and accuracy of the hole is very important. The author here has tried to find out the effect of using a high pressure coolant (HPC) during the drilling process. Firstly, the specimens of CS were machined using HSS drill bits and after some cycles, the drill bit was examined under the scanning electron microscope (SEM). It was found that as compared to dry drilling, the tool wear rate is much lesser when a high pressure coolant is used.

OVERVIEW OF PREVIOUS WORK

From the above studied literature review, it can be concluded that:

(1) The rate and type of wear occurring in BTA drill inserts while machining hard materials like carbon steel are yet to be studied. Different materials have different process parameters to be used for machining and therefore, the type and rate of wear in the tool is different for every material.
(2) As BTA deep hole drilling process uses three different drill inserts, the wear rate of all three inserts are different. Therefore, to find out the rate of wear of the process, wear type and wear rates occurring in all three inserts have to be taken into account.
(3) An appropriate coolant flow rate and proper chip removal system also have to be considered for obtaining accurate holes.

CONCLUSION

The deep hole drilling of hard materials like carbon steel and super alloys like Inconel are difficult to machine and in order to obtain accurate holes, appropriate process parameters have to be selected. The wear rate and type of wear occurring in the drill inserts can be identified through various methods and different wear rates of inserts occur under different working conditions. Coolant flow and chip removal are also important factors for obtaining accuracy and precision in deep hole drilling process.

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