EFFECT OF HSS AND WC DRILL BITS ON FORM AND HOLE PRECISION IN Ti-6AL-4V DRILLING OPERATIONS

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Abstract

In many manufacturing applications, the form and hole precision of a product can directly affect its functionality. High form and hole precision are key indicators of product quality. If a product is manufactured with low precision, it can lead to defects, errors, and a reduction in overall product performance. Manufacturing with high precision can help reduce waste and improve efficiency. By minimizing errors and producing high-quality products consistently, manufacturers can increase their throughput, reduce costs, and ultimately improve their bottom line. The aim of this study is to evaluate the differences in vibrations and form that are induced by using HSS and WC drill bits to perform drilling operations on Ti-6AL-4V work material. In the current study, measurements of form error in the work piece as well as vibrations of the tool that is being used throughout the drilling process are obtained. The diameter of the drill bits that were taken is 10 millimetres. The increasing frequency and vibration amplitude both lead to an increase in the amount of form error in the work material, as well as a displacement of the hole centre and a movement of the tool position away from its centre. Form error, such as the measurement of roundness is taken into consideration.

Keywords: Drilling; Roundness; Vibrations; CMM; Form measurement

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1. INTRODUCTION

Drilling is the most significant step involved in machining. Chatter is caused by vibrations, which are produced throughout any machining operation. Chatter may be heard. The machining parameters such as speed, feed, and depth of cut, among others, all have an effect on the vibrations that are created. The frequency and amplitude of vibrations that are created and induced during the drilling of the work piece [1] are monitored and taken into consideration in order to obtain results that are close to null or to prevent form defects. Additionally investigated is how the assisted vibrations have an effect on the drill quality of the machined hole. The examination of these vibrations throughout the drilling process demonstrates how they impact the task of preserving the work piece's quality. The spindle speed and the drill diameter both have an effect on the magnitude of the vibrations that are produced during the drilling process [2].Form defects, including roundness, cylindricity, and others, may be discovered as a result of the influence that vibration has on drilling. The movement of the spindle shaft during rotation away from its axis point, which results in an inaccuracy in roundness [3].The dynamic cutting forces excite the shaft, which causes it to deflect or vibrate, which in turn generates inaccuracy in the form of things like hole tolerances and roundness [4]. During the machining process, the vibrations that are created may be recognised using acoustic emission monitoring. This allows one to see and compute the deflection of the tool from its axis, which is referred to as displacement [5]. The cutting parameters used in the drilling of the work piece are the primary cause of the form, which has an effect on the hole quality. During the drilling of super alloys with coated and uncoated carbide drills, the influence of cutting parameters on hole quality, including circularity, hole diameter, and tool wear, was investigated [6].In recent years, a great number of research studies on measuring forms via contact and non-contact types including techniques of measurement have been done in order to assess roughness and roundness in machined parts [7]. There are many different approaches to measuring roundness, many of which use the peak and valley of the roundness profile, and they have been developed and applied in a variety of measuring equipment. MZC, which stands for "Maximum Zone Circle," MIC, which stands for "Maximum Inscribed Circle," MCC, which stands for "Minimum Circumscribed Circle," and LSC, which stands for "Least Square Circle," are the approaches. However, the LSC method is used in the majority of cases. Errors in roundness have the most significant impact on the form of machined components, particularly those involved in the rotational motion movement of the parts. It has been given a lot of thought to assess the roundness measurement approach by employing a coordinate measuring machine (CMM), [8] which has been done extensively. CMM is used to measure the variation in roundness at four or more probing locations, depending on the level of precision and accuracy that is desired. The thorough accuracy of the nearer to neared point profile analysis is provided by the multiple probing points that are measured along the whole hole diameter. CMM has been explored [9] in which the measurement is based on measuring points of the interior and exterior holes in drilled machine components. This CMM involves difficult characteristics of roundness, cylindricity, and surface roughness. The tolerance that is assessed is determined by the number of points that need to be measured throughout the whole of the region that is being used to measure form [10]. [11] Research has been done on a developing pattern in the design of instruments for measurements of roundness and cylindricity. This pattern incorporates software that is interlined with the measuring machine and involves magnification and viewing of the form data in a way that is both clearly clear and accurate.

2. METHODOLOGY

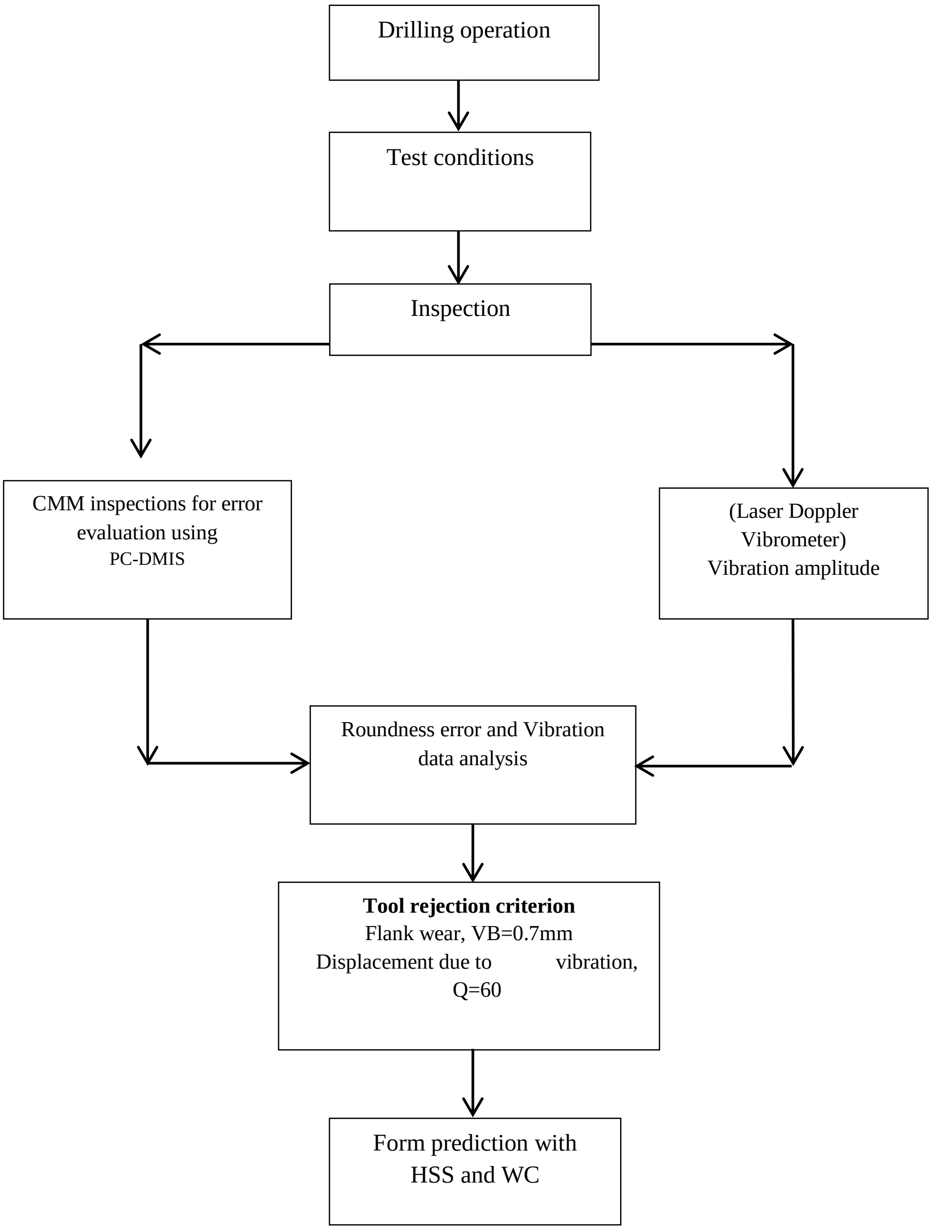

Figure 1: Schematic overview of the methodology

Experimentation and Methodology:

When it comes to defining and negotiating the cutting parameters that are included in the machining of work materials, the measurement adaptive CNC control equipment that have been technically in hand in the present day have been essential. Drilling of Ti-6AL-4V, technically being employed in the ongoing research testing at the using CNC adaptive control drilling maching. Drilling of this material is essential for the various aerospace applications that call for great precision and accuracy. The drilling process is performed in Ti-6AL-4V using High-Speed Steel (HSS) and Tungsten Carbide (WC) drill bits, respectively.

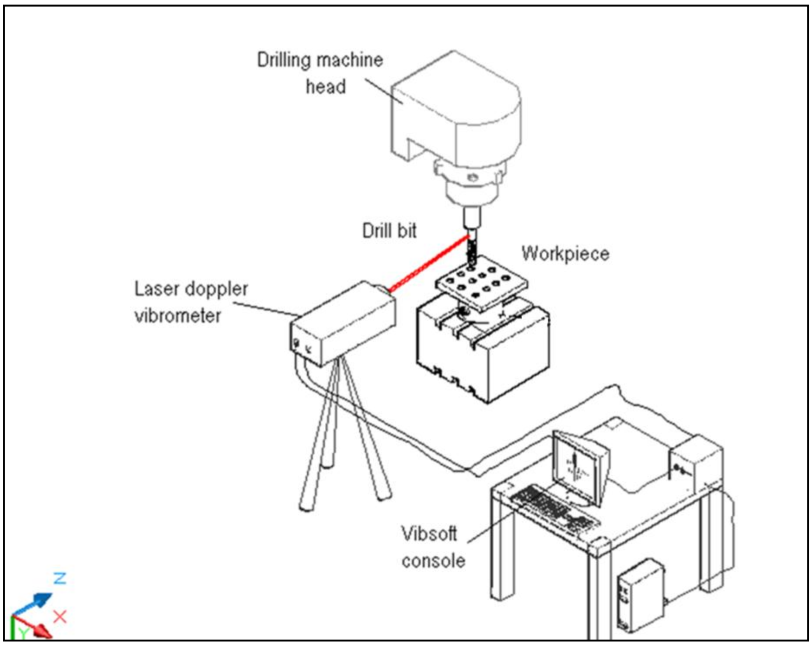

Figure 1. Schematic diagram of experimental setup

Drilling operation is carried out in dry conditions. Experimental setup is shown in the figure1. Ti-6Al-4V is drilled with HSS and WC drill bit combinations which is as shown in the table (1). The experiment of drilling Ti-6AL-4V work material is carried under test conditions from the table (2) considering cutting parameters of Speed (N), Feed (f) and depth of cut (d) during drilling operation.

Table 1: Tool and work piece combinations.

S.No	Workpiece material	Tool bit material
1	Ti-6AL-4V	HSS
2	Ti-6AL-4V	WC

Table 1 lists two combinations of workpiece material and tool bit material that will be used in experiments. In both combinations, the workpiece material is Ti-6AL-4V, which is a commonly used titanium alloy in industries such as aerospace, medical, and automotive due to its high strength-to-weight ratio, corrosion resistance, and biocompatibility. The first combination uses a tool bit made of High-Speed Steel (HSS), which is a type of tool steel commonly used in machining applications due to its ability to retain its hardness at high temperatures. The second combination uses a tool bit made of Tungsten Carbide (WC), which is a hard and wear-resistant material commonly used in cutting tools. The experiments will likely involve machining the Ti-6AL-4V workpiece using both HSS and WC tool bits under controlled conditions such as cutting speed, feed rate, and depth of cut. The goal of the experiments will be to compare the performance of the two tool bit materials in terms of factors such as cutting force, surface roughness, tool wear, and machining accuracy.

Table 2: Test conditions during drilling operation.

CUTTING SPEED (rpm)	**FEED RATE (mm/min)**	**DEPTH OF CUT (mm)**
465	18 26	8
795	18 26	8
1250	18 26	8

1980	18 26	8
Work piece Materials	Ti-6Al-4V(150mmX150mmX10mm)	
Drilling Tools	Carbide Tip (Ø 10mm) HSS (Ø 10mm)	

Table 2, the cutting conditions for a 10mm hole drilled using a Carbide Tip tool and a High-Speed Steel (HSS) tool into a Ti-6Al-4V workpiece are listed below. Cutting conditions are specified in terms of rotations per minute (rpm), millimetres per minute (mm/min), and millimetres (mm) of depth of cut, and tests will be conducted for four distinct rpm ranges (465, 625, 725, and 1980). Drilling tools with carbide inserts, noted for their hardness, wear resilience, and ability to maintain a sharp cutting edge even when subjected to high temperatures, are known as Carbide Tip tools. High-speed steel (HSS) is used to make the HSS tool, which is noted for its toughness, longevity, and ability to retain its hardness at high temperatures. The Ti-6Al-4V workpiece will likely be drilled using Carbide Tip and HSS tools at varying cutting speeds, feed rates, and depths of cut for the tests. The trials will examine cutting force, surface quality, tool wear, and machining precision to determine which tool is superior. The experimental process is used to enhance the efficiency and effectiveness of the drilling procedures used by manufacturers.

Signal processing involving vibration data acquisition during drilling of work material is obtained using Laser Doppler Vibrometer (PloyTech 100V) is positioned 15feet from the drilling tool and the laser is projected onto the drill bit and Vibration amplitude data is obtained using Vibsoft console of online PC. Data acquired is of Time domain analysis (waveform graph), involving Fast Fourier Transforms (FFT) Frequency domain analysis (spectrograph) plots are obtained at various parameters of speed, feed, depth of cut. The raw waveform graphs are converted to spectrograph through FFT analyser in which the data obtained in spectrograph give much more information than waveform. The analysed vibration signal in frequency domain is displacement of the tool. The tool is monitored using LDV as shown in the Figure 2.

Laser Doppler Vibrometer:

Laser Doppler Vibrometer (PloyTech 100V system) is based on the principle of acquiring the Doppler shift in the frequency of coherent light scattered by a moving target from which a time resolved measurement of a target velocity is obtained.

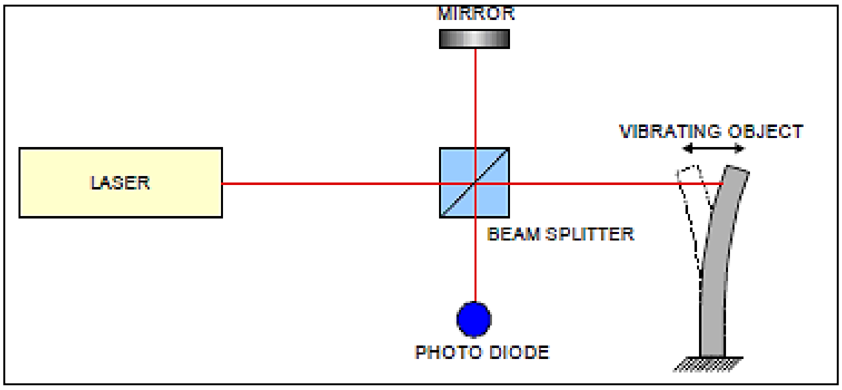

Figure 2. Schematic diagram of a Laser Doppler Vibrometer

The Displacement is calculated using Laser Doppler Vibrometer (LDV) online monitoring method of focusing laser onto the tool during drilling process through flank wear criteria by measuring the flank wear reaches greater than 0.3mm measuring tool displacement. Consideration of machining time is also precisely calculated.

a. Time domain Analysis (waveform):

A non-contact acousto optic emission method has been used; both the actuation and the data acquisition are performed using a laser Doppler Vibrometer (LDV) coupled with pre amplifier and on board FFT analyser and a desktop PC running Vibsoft 4.0 as a virtual controller. The change in phase of acousto optic emission signal varies according to progression in flank wear value. This phase shift occurs when flank wear crosses its rejection value ($VB \geq 0.3mm$). Time domain graph plotted using LDV at speed 465 rpm, feed 18mm and depth of cut 8mm drilled with HSS tool as shown in the Figure 3.

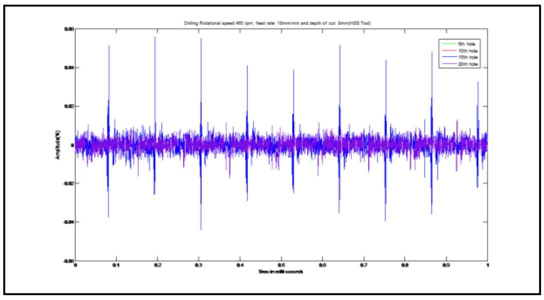

Figure 3. Time domain (Waveform graph)

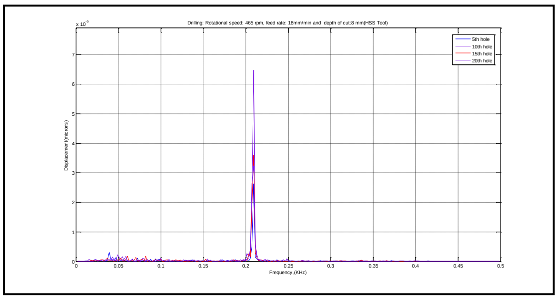

Figure 4. Frequency domain (spectrograph)

Dynamic Frequency response (spectrograph):

Direct time series information is highly incapable of direct time-series analysis is normally incapable of isolating defect-scattered information exactly from noise in different frequency bands. Therefore, signal which is taken as benchmark is essential for comparison. It is more usual to examine a dynamic signal in the frequency domain via Fourier transform (FT). The frequency domain analysis (spectrograph) plot is as shown in the Figure 4.

Form error measurement through CMM in Ti-6AL-4V:

The work piece of Ti-6Al-4V drilled with HSS and WC combinations under test conditions which are discussed earlier are inspected so as to measure the form prevailed in the drilled hole using coordinate measuring machine (CMM) named DEA 070705 as shown in Figure 5. CMM which is connected to the PC-DMIS (Dimension measurement Instrumentation Standard) software pre-linked to the measuring equipment. The drilled hole is measured with probe in four hits of each hole and the profile obtained which is as shown in Figure 6.

Figure 5. Form measurement using DEA 070705 CMM

The form is measured in either pattern of holes drilled with HSS and Ti-6Al-4V. The results obtained informed an interesting fact of data shown in results and discussion. The PC-DMIS console interlinked to the movement of the CMM probe resulted in the form measurement in deviation of the round out total measurement as show in the Figure 6.

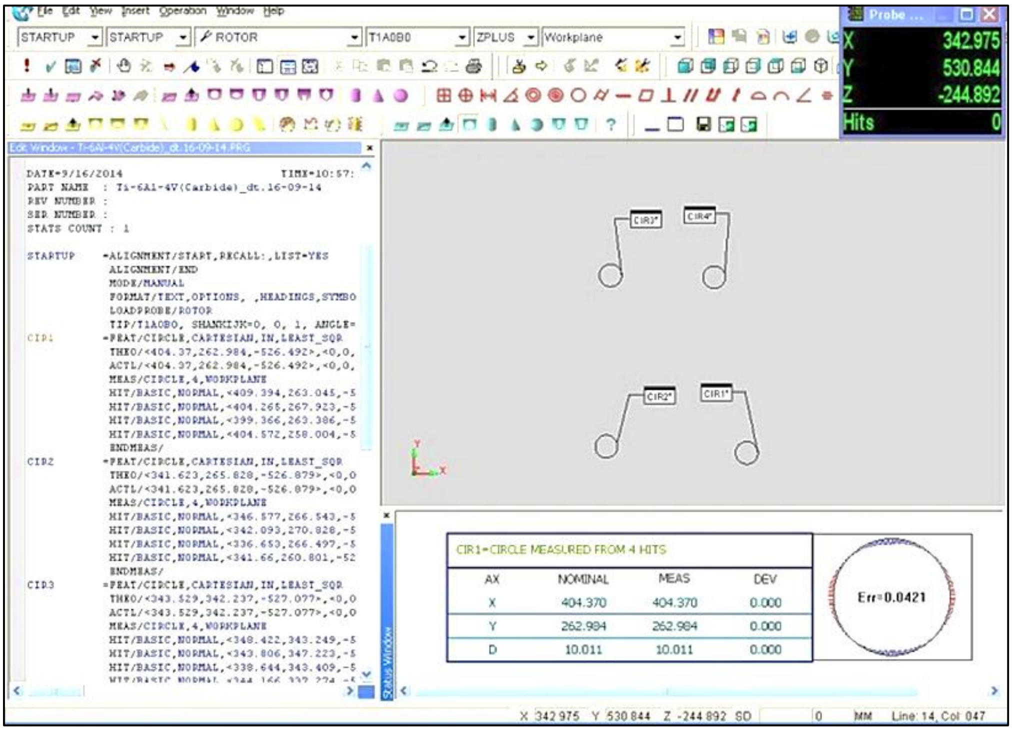

Figure 6. The measured outlet of holes in CMM using PC-DMIS for Ti-6AL-4V (WC)

3. RESULTS AND DISCUSSIONS:

The results obtained showed an interesting fact that the HSS drilled holes and carbide drilled holes showed higher variations in tolerances and form caused during cutting operation.

Table 3: Ti-6Al-4V drilled with HSS tool

Test condition	Displacement (µm)	Flank wear (mm)	Machining time (sec)	Roundness (mm)
TC-11	42.289	0.298	189.66	0.008
TC-12	53.071	0.373	131.66	0.037
TC-13	54.225	0.399	236.66	0.042
TC-14	56.331	0.351	201.66	0.051

Table 3 shows the results of a machining experiment performed under different test conditions, where the displacement in micrometres, flank wear in millimetres, machining time in seconds, and CMM measurement in millimetres are recorded. As it is observed from the Table 3, the displacement increased from 42.289 µm at test condition 1 to 56.331 at test condition 4 as a result, the flank wear increased from 0.298 mm to 0.351 mm. as the criteria for the flank wear taken according to Vb>0.3 it is termed as tool wear failure. This indicated the tool failure occurs with increased displacement thereby resulting in roundness measure which increased from 0.008 mm at test condition 1, to 0.051 mm at test condition 4 when drilled with HSS. From the results, it is clearly observed that the roundness increased with increase in vibrations which caused displacement and increased flank wear along with machining time. Therefore, the values in the Table 3, indicate that as the displacement increases, the flank wear also increases, indicating a higher level of tool wear. Additionally, the machining time is seen to increase with increasing displacement, indicating that it takes longer to complete the machining process. The CMM measurement column shows the resulting form error or deviation from the desired shape of the workpiece, with lower values indicating better accuracy. Therefore the relationship between various parameters and their impact on the machining process are analysed with the goal of optimizing the conditions for the best results.

Table 4: Ti-6Al-4V drilled with WC tool

Test condition	Displacement (µm)	Flank wear (mm)	Machining time (sec)	Roundness (mm)
TC-21	9.073	0.086	175.66	0.002
TC-22	20.322	0.149	118.33	0.008
TC-23	23.803	0.159	133	0.010
TC-24	32.410	1.255	28.33	0.015

Table 4 shows the results of a machining experiment conducted under different test conditions using carbide tool, where the displacement in micrometres, flank wear in millimetres, machining time in seconds, and roundness error in millimetres are recorded.

The displacement, which is recorded and observed in Table 4, increased from 3.073 µm to 32.410 µm which is the lowest compared to the HSS tool. Similarly, flank wear in using the carbide tool is 0.086 mm to 1.255 mm which is observed from Table 4, where the flank wear increased, but when compared to HSS, WC performed better, generating lesser flank wear and displacement. Upon investigation, the roundness is observed to be 0.002 mm at test condition 21, which increased to 0.015 at TC-24. The values from Table 4 indicate that as the displacement increases, the flank wear also increases, indicating a higher level of tool wear. Moreover, as the flank wear increases, the roundness error also increases, indicating a decrease in the accuracy of the workpiece. The machining time column shows the time taken to complete the machining process, with lower values indicating better efficiency. The table provides insights into the relationship between various parameters and their impact on the machining process, with the goal of identifying the optimal conditions to achieve the best results in terms of accuracy, efficiency, and tool wear. The variance observed from the experiment details obtained showed the higher form is observed in HSS drilled holes in Ti-6AL-4V. The strength of the HSS drill tool is less when compared to carbide drill bit, when drilled with HSS, the drill bit tend to produce higher form when machining twice harder material i.e., Ti-6AL-4V.

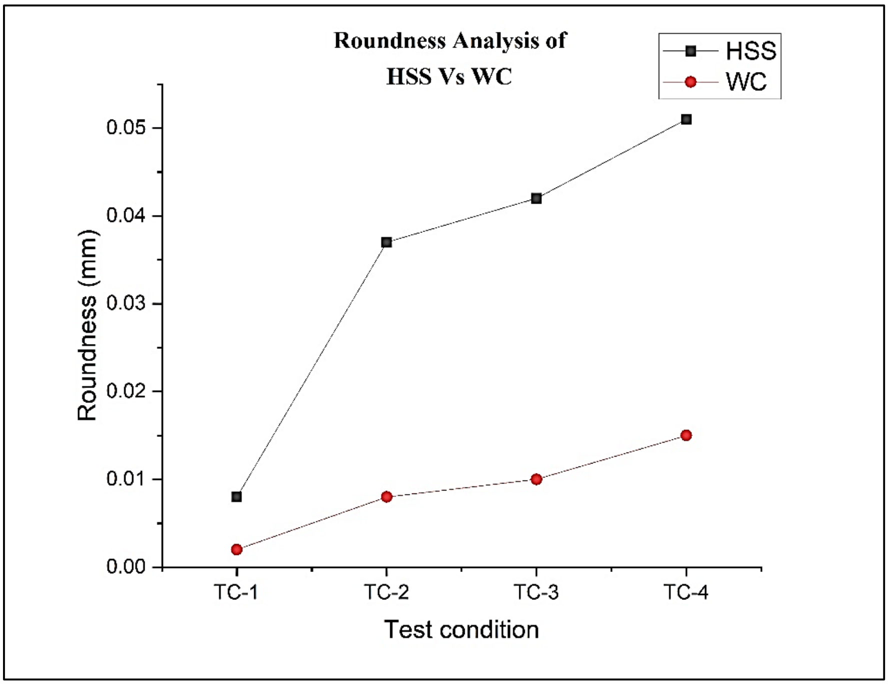

Figure 7. Roundness in HSS and Wc

Figure 7, obtained from Tables 3 and 4 show the outcomes of drilling Ti-6Al-4V with HSS and WC tools. When looking at tool wear, displacement, and roundness error, the WC tool is clearly superior than the HSS tool which is observed from the Figure 7. Drilling using a WC tool resulted in reduced distortion of the workpiece compared to drilling with an HSS tool, as measured by the displacement values. In addition, the WC tool's flank wear values were lower than those of the HSS tool, suggesting a longer tool life for the WC tool. As a result, the WC tool consistently produced more precise holes than the HSS tool, as measured by roundness error values, which were consistently lower for the WC tool. However, in some cases the machining time values for the WC tool were greater than those for the HSS tool, suggesting that the WC tool may require more time to complete the drilling process.

4. CONCLUSIONS

The drilling process with HSS generated larger from when compared to WC due to less strength of the drill tool than the Ti-6Al-4V work material.
The use of Carbide drill tools are rear due to cost effective, but HSS drill tool causes form which reduces the precision and tolerance degradable to the quality of the machined work piece. The experiment proved that highest form is obtained when drilled with HSS when compared to holes drilled with Tungsten Carbide drill tools. From the results the following conclusions can be drawn:

1. The WC tool outperformed the HSS tool in terms of tool wear, displacement, and roundness error when drilling Ti-6Al-4V.
2. The displacement values for the WC tool were consistently lower than those for the HSS tool, indicating that the WC tool produced less deformation of the workpiece during drilling.
3. The flank wear values for the WC tool were also lower than those for the HSS tool, indicating that the WC tool had a longer tool life.
4. The roundness error values for the WC tool were consistently lower than those for the HSS tool, indicating that the WC tool produced more accurate holes.
5. However, the machining time values for the WC tool were higher than those for the HSS tool in some cases, indicating that the WC tool may take longer to complete the drilling process.

Therefore, the results suggest that the WC tool is more effective than the HSS tool for drilling Ti-6Al 4V due to its superior performance regarding tool wear, displacement, and roundness error.

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