Worn Out Value Analysis of Drill Bit and Precision in Drilling Processing

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ABSTRACT

Drilling process is a procedure to make holes by pressing a spinning drill bit into workpiece. Through the machining process, there's friction between cutting tool and workpiece that cause high temperature, which results the cutting tool to be worn out. The purpose of this research is to know the worn out value of the HSS and Co-HSS cutting tool within machining variation. Therefore it could result in knowing which various machining parameter that has biggest influence in affecting hole precision and worn out cutting tool that was resulted from drilling machining process into S50C workpiece. The machining parameters that were used for this research were feed rate and cutting speed. Both of the machining parameters were made to be varied so it can be seen which parameter has the biggest effect. After the drilling process, the resulted holes were measured to know how precise the drilling process was. The sample taken to measure the resulted holes was 10 holes in each machining variation. This research found that cutting speed was the most affecting parameter for the worn out of the cutting tool. As the cutting speed became higher, the worn out value of the cutting tool will become faster, and vice versa. The resulted holes that had been analyzed also shown to have a precise value because all of the machining variation did not go over the upper and lower class limit.

Keywords: *Drilling Process, Worn Out, HSS Cutting Tool, Co-HSS Cutting Tool, Precision*

INTRODUCTION

In a manufacturing process, making the product or machine components required to always have a workmanship that consist of good quality and exact geometric characteristics. One of the machining processes that is often used is the drilling process. The drilling process is the simplest machining process than the other machining processes, as the process of making a round hole using a twist drill.

In the machining process, chisel is tool that need a quite frequent replacement. After several times being used in the cutting process, the chisel will be worn out. Friction between the chisel with the workpiece will cause a high heat, then it will cause the tool to be worn out which results in shorter tool life. Therefore, the quality of the product will become lower. As worn out value of the chisel become greater, the chisel condition will also become more critical.

The Chisel used must have a higher hardness value than the workpiece that is going to be cut and also have mechanical properties resistance as well as worn out resistance. Moreover, the quality of the observed chisel in this study is influenced by several machining factors such as, the spindle rotation speed (n) and the feed rate (f). The parameters above also affect the chisel's worn out resistance that will occur when the chisel is used. [1].

DRILL PROCESS

The drill process is the simplest machining process among other machining processes. The process is often called the boring process. To control the drill process, description of the basic elements are needed. It can be found by using some formulas derived below [1]:

- Cutting speed:

$$v = (\pi.d.n)/\ 1000\ (m/min) \quad (1)$$

n = spindle rotating speed
d = diameter

- Feed rate for each cutting eye :

Fz =Vf / (n.z) ; z=2 (mm/r) (2)

Vf = feed rate (mm/min)
Z = numbers of cutting eye

- Cutting depth:
  a = d/2(mm) (3)

- Cutting time:
  tc = lt/Vf (min) (4)
  lt = lv + lw + ln (mm),

lv = starter length
lw = cutting workpiece length
ln = End length (d/2tan Kr) (mm)
Kr = main cut angle (°)

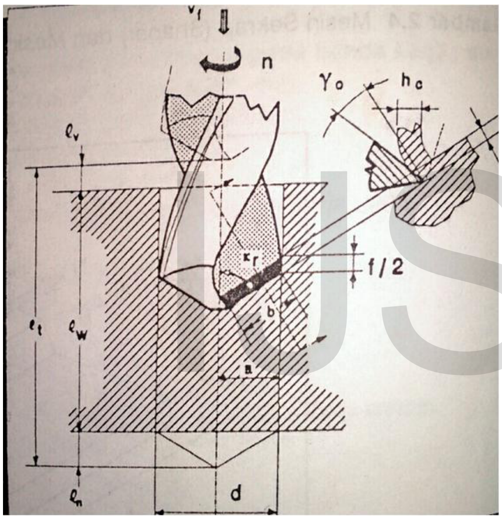

Figure 1. Drill Bit Variable [1]

CHISEL WORN OUT VALUE

The chisel worn out value will grow and expand as the cutting time become longer until at some point the chisel is considered unusable because it starts showing signs which indicates that the tool's life has expired.

The boundaries for worn out value that was used as general signs in this experiment can be seen in table 1 below.

Table 1. Critical boundaries for worn out value [2]

Chisel	Material	V_B (mm)
HSS	Metal and Iron Cast	0,3 – 0,8
Ceramic	Metal and Iron Cast	0,3

PRECISION

Precision is a measure of the proximity of the analysis results obtained from a series of repeated measurements of the same size objects. This reflects the random errors that could be occured in a method. Precision is usually measured as the coefficient of variation or relative standard deviation of the analytical results obtained from independent national quality control standards prepared.

Results of the holes that have been made and seen visually on a hole will look perfect but when we look at it using magnification tools, it will show that an imprecision is occured in that hole. Things that cause imprecision and unrounded that made in the holes are related to the manufacturing process as follows [3]:

1. The clamping chisel is not in the center
2. The vibrations caused by a great cutting force that occurs in the workpiece
3. Pressure on thin-walled workpiece

DRILL MATERIAL

Hardness and strength of the chisel must persist despite the high temperatures, this trait is called Hot Hardness. Toughness from the chisel is required, so that the chisel will not be easily damaged, especially when the cutting is performed with shock loads. Worn out resistance is needed especially for the chisel to perform cutting without getting worn out easily. Some types of cutting tool material often used in industrial machinery are listed below:

- **High Speed Steels (HSS)**
  Drill high speed steels (HSS) chisel has a range composition of 0.75% -1.5% carbon (C), 4% -4.5% chromium (Cr), 10% -20% tungsten (W) and molybdenum (Mo), 5% vanadium (V). As for the Co-HSS, the drill chisel has the same composition as HSS but it is added with more than 12% co-balt (Co) [4].

METHODOLOGY

This study is divided into three stages: the first stage is a stage to experiment with a drilling machine that aims to create a hole in the workpiece with a variety of parameters. The second stage of this study to see the worn-out value at the edge of the drill chisel after going through a drilling process. The third stage is a research on the holes from the process that was done previously to determine the precision of the drilling process towards the resulted holes. The stages of this study can be seen in the flow diagram in figure 2.

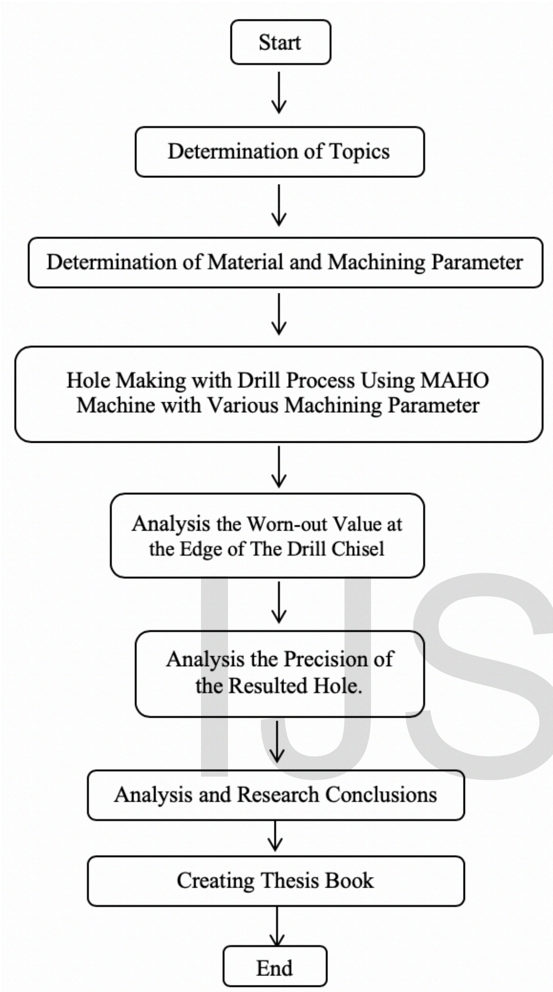

Figure 2. A flow diagram of the experiment process

TESTING TOOLS

- **CNC Machine**
  Tests using a lathe was performed at Laboratory Manufacturing Process, Atma Jaya Catholic University, BSD.

Table 2. Technical data of CNC machine

No.	Description	
1	Machine brand	MAHO
2	Type	MH600
3	Motor power	10 kW
4	Spindle Speeds	20 to 5000 (rpm)
5	Axis	3 stroke (Longitudinal (X), Transversal (Z), Veritcal (Y)

- **Drill Chisel**
  Drill chisel that was used are HSS and Co-HSS.

Table 3. Technical Data of Drill Chisel

No.	Description	
1	Material type	HSS and Co-HSS
2	Brand	Nachi
3	Diameter	7mm

TESTING PROCEDURE

- **Choosing of machining variable**
  In a study a about the creation of a hole in the S45C iron was done by varying the rotation of the machine and feed rate. Rotation of the engine chosen for HSS drill chisel is 700-1100 rpm, while the Co-HSS drill chisel is 900-1300 rpm. After creating a range from both drill chisel toward the rotation of the engine, it was chosen 3 variation of the engine spindle rotation for both of the drill spindle.
  Meanwhile, the variations of feed rate for HSS is 116-132 mm/min, and feed rate for Co-HSS is 124-140 mm/min. After creating the range from both of the drill chisel towards the feed rate, it was chosen 3 variation of feed rate for both of the drill chisel.

- **Hole making process, testing worn out value of the edge, and testing the precision of the resulted hole**
  The process of making the holes was done by twenty times holes making in the material by using a variety of different machining tools. This was done in order to determine which machining variations are the most influential in the process of drilling.
  The measuring process of the chisel life or usage was obtained by measuring the worn-out value at the edge of the drill chisel just using micro microscope. This was done twice because the drill chisel has two drill bit. Then the magnification and focus was operated so that the worn out value at the edge of VB can be seen.

- **Precision testing at the resulted hole on the workpiece**
  Data retrieval process of the hole precision on the workpiece after drilling process was taken using a stereo microscope, by looking at the midpoint of the results of drill holes, then the radius line was drawn from the center point of the hole to the end of the farthest and nearest hole (opposite). After that, the differences from the radius of the hole can be seen. This process is done by taking a sample of ten holes in a workpiece.

ANALYSIS

Within each trial, the machining process vary in spindle rotation and feed rate (table 4).

Table 4. Experiment result of worn out level of the edge (VB)

Type	n (rpm)	f (mm/rev)	VB1 (mm)	VB2 (mm)
CO-HSS	900	124	0.13	0.15
	900	132	0.176	0.175
	1100	124	0.211	0.217
	1100	132	0.252	0.255
	1100	140	0.29	0.31
	1300	132	0.31	0.3
HSS	700	124	0.27	0.276
	900	116	0.33	0.345
	900	124	0.44	0.45
	900	132	0.52	0.52
	1100	124	0.551	0.546
	1100	132	0.58	0.58

Data Processing of Worn Out Level at the Edge of the Drill Bit

Results obtained between Co-HSS and HSS drill has sufficiently different value. Co-HSS drill has gone over the boundaries for worn out level of the edge, meanwhile the worn out level of HSS drill has more diverse variation of worn out level and still in range with the boundaries (table 4). At the same feed rate, worn out level on the edge of the drill will rise as the rotation speed become higher.

This was because in all metal operation, the energy generated in the drilling operation was converted into heat, which in turn would raise the temperature in the drilling area. Thus, the higher the rotational speed of spindle drilling machine the chips would be hotter.

The Effect on Rotating Speed Towards the Worn Out Level of the Drill

Increased of the tool's worn out level could be seen visually with charts that shows the influence of spindle rotation speed towards the worn out value on the edge of the drill bit. The test results of experiments on Co-HSS drill bits with the first spindle rotation speed variation, the smallest one which was 900 rpm, has a worn out value of 0.176 mm and 0.175 mm. The next test with a spindle rotation speed of 1100 rpm, had a value of 0.252 mm for both the 1st and 2nd edge of the drill. In the last experiment, using the greatest spindle rotation speed, which was 1300 rpm, results the worn out value of 0.31 mm and 0.3 mm in all spindle rotation speed. Comparison of percentage tool life of 900 rpm to 700 rpm with fixed feed rate of 132 mm/min was 19.4%. While the spindle rotation speed of 700 rpm to 1300 was 37.4%

For HSS drill, which used constant feed rate that is equal to 124 mm/min by varying the spindle rotational speed of 700 rpm, it resulted the worn out value of 0.27 mm. For speed of 900 rpm, the worn out value is 0.44 mm. As for the greatest spindle rotation speed at 1100 rpm, it resulted the worn out value of 0.551 mm. Comparison percentage of the worn out value at the edge between the spindle rotation speed of 700 rpm to 900 rpm was 62.9%, while the percentage of worn out value at the edge between the spindle rotation speed of 700 rpm to 1100 rpm had the greatest value.

The graph below (figure 3) is made by combining both the drill bit in a graph with the variation of rotation speed machining and constant feed rate, so that it can be seen which drill edges was the fastest and most easily to be worn out. Seen from the graph in figure 3, the HSS drill bit has faster pace to be worn out than the Co-HSS workpiece.

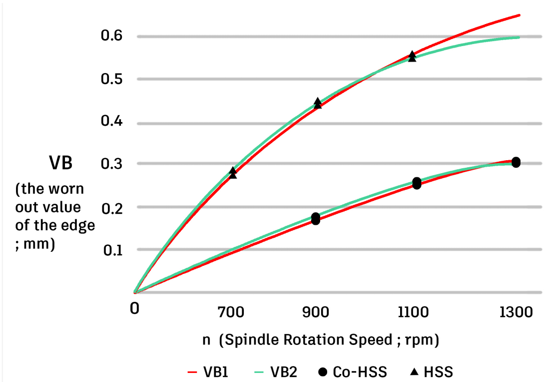

Figure 3. Graph of spindle rotating speed towards worn out value of the edges with constant feed rate (Co-HSS 132 mm/rev ; HSS 124 mm/rev)

Effect of Feed Rate Towards Worn Out Value of the Drill Edges

The graph below was made by varying the feed rate against a constant spindle rotation speed. For Co-HSS drill bits, smallest experimental variation of feed rate was 124 mm/min which resulted a worn out value of 0.211 mm and 0.217 mm. In the experiment where the feed rate was at 132 mm/min, it resulted the worn out value of 0.252 mm and 0.255 mm. Furthermore, the biggest feed rate, at 140 mm/min had a worn out value of of 0.29 mm and 0.31 mm. The experimental results for the percentage of wear edge motion eat 140 mm/min to 124 mm/min had a difference of 37.4%, while the percentage for feed rate of 132 mm/min to 124 mm/min was 19.4%.

For HSS drill, spindle rotation speed of 900 rpm were used. The smallest feed rate was at 116 mm/min which had a worn out value of 0.33 mm and 0.34 mm. When the feed rate was at 124 mm/min, the worn out value was 0.44 mm and 0.45 mm. Meanwhile as for the greatest feed rate at 132 mm/min, it resulted the worn out value of 0.52 mm. Comparison percentage between the feed rate at 132 mm/min to 116 mm/min was 57.6%, while the percentage of worn out value of the edge between the spindle rotation speed of 132 mm/min to 116 mm/min had the greatest value which was 33.3 %.

The graph in figure 4 was also created by combining the two drills on the feed rate variation with constant spindle rotation speed. It can be seen that worn out value at the edge of HSS drill bits also experienced faster increase rate than the Co-HSS drill bits.

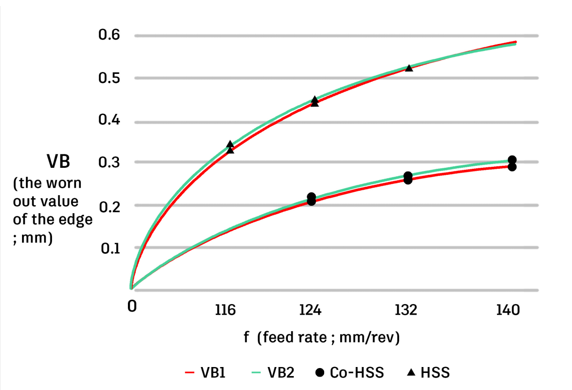

Figure 4. Graphic of feed rate towards worn out value of the edges with constant spindle rotation speed (Co-HSS 1100 rpm ; HSS 900 rpm)

The Co-HSS drill bit is more resistant because the Co-HSS drill is consisted of some mixture of Cobalt which made the drill to be heat-resistant and not easily worn out eventhough it was put under high temperature heat [5].

From the results of experiments that have been performed (figure 3 and figure 4.), it shows the greatest effect of worn out edges (VB) occured when the spindle rotation speed was varied with constant feed rate, rather than when feed rate was varied with a constant spindle rotation speed. Common mechanisms that usually occur were the process of diffusion, oxidation and plastic deformation. Therefore, the rotation speed of the spindle is machining parameters that has the most influence on the worn out values of the edge.

Data Processing of the Resulted Holes Precision After Drilling Process

The resulted holes were measured using a stereo microscope to determine the precision value from the hole towards the center point of the drill hole. Once measured, the results of all the machining variations on all of the drill can be seen in table 5 and table 6.

After that, the 10 samples were taken randomly out of 20 holes and it resulted in a statistical analysis to see the boundary of the upper class limit (UCL) and lower class limit (LCL) of each of the machining variations. Upper Class Limit is the maximum boundary for the distance from the holes edge towards the center to be considered as precise. Meanwhile Lower Class Limit is the minimum boundary for the distance value. Distance value which is larger than UCL and smaller than LCL will be considered as imprecise. While distance value which is in range between UCL and LCL will be considered as precise. Before, the average and standard deviation of each machining variations were calculated (table 7). The equation that was used to calculate the average ($\bar{x}$) and standard deviation (s) are described as follows [6] :

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \quad \ldots (5)$$

$$s = \sqrt{n\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_1\right)^2} \quad \ldots (6)$$

The formula for this UCL and LCL is shown below [6]:

$$UCL = \bar{x} + (3\ x\ Std.deviation) \ \ldots (7)$$
$$LCL = \bar{x} - (3\ x\ Std.deviation) \ \ldots (8)$$

After obtaining the average, standard deviation, as well as upper and lower class limit for each machining variations (figure 5 to figure 10) can be seen in every machining variation, the hole still considered as precise, if it is still within the limits of precision or considered as imprecise, if it is outside the limits of precision.

Table 5. Data of the Radius in the Resulted Holes at the Drill Bit with Types of Machining Variations (Variation 1-6)

Sample	Machining Parameter (number of variation)											
	1 (CO-HSS; n=900; f=124)		2 (CO-HSS; n=900; f=132)		3 (CO-HSS; n=1100; f=124)		4 (CO-HSS; n=1100; f=132)		5 (CO-HSS; n=1100; f=140)		6 (CO-HSS; n=1300; f=132)	
	r1 (mm)	r2 (mm)	r1 (mm)	r2 (mm)	r1 (mm)	r2 (mm)	r1 (mm)	r2 (mm)	r1 (mm)	r2 (mm)	r1 (mm)	r2 (mm)
1	3,520	3,447	3,451	3,336	3,520	3,455	3,452	3,449	3,452	3,451	3,448	3,450
2	3,382	3,448	3,452	3,474	3,380	3,446	3,450	3,447	3,450	3,450	3,449	3,450
3	3,453	3,452	3,461	3,446	3,447	3,450	3,351	3,453	3,453	3,448	3,400	3,450
4	3,450	3,380	3,440	3,451	3,449	3,450	3,552	3,451	3,442	3,464	3,500	3,450
5	3,449	3,449	3,443	3,450	3,451	3,454	3,380	3,452	3,448	3,453	3,530	3,447
6	3,453	3,448	3,451	3,450	3,452	3,449	3,517	3,452	3,451	3,449	3,350	3,451
7	3,451	3,450	3,573	3,453	3,450	3,448	3,344	3,451	3,460	3,451	3,452	3,451
8	3,453	3,450	3,336	3,388	3,452	3,450	3,560	3,447	3,440	3,450	3,449	3,448
9	3,460	3,447	3,455	3,451	3,570	3,447	3,448	3,450	3,453	3,454	3,449	3,447
10	3,440	3,451	3,452	3,450	3,330	3,451	3,454	3,450	3,447	3,395	3,452	3,451

Table 6. Data of the Radius in the Resulted Holes at the Drill Bit with Types of Machining Variations (Variation 7-12)

Sample	Machining Parameter (number of variation)											
	7 (HSS ; n=700 ; f=124)		8 (HSS; n=900; f=116)		9 (HSS; n=900; f=124)		10 (HSS; n=900; f=132)		11 (HSS; n =1100; f=124)		12 (HSS; n=1100; f=132)	
	r1 (mm)	r2 (mm)	r1 (mm)	r2 (mm)	r1 (mm)	r2 (mm)	r1 (mm)	r2 (mm)	r1 (mm)	r2 (mm)	r1 (mm)	r2 (mm)
1	3,520	3,453	3,405	3,447	3,535	3,450	3,449	3,456	3,530	3,449	3,452	3,450
2	3,380	3,504	3,446	3,449	3,350	3,452	3,452	3,450	3,360	3,451	3,449	3,448
3	3,520	3,441	3,452	3,366	3,533	3,451	3,520	3,450	3,454	3,451	3,448	3,447
4	3,380	3,445	3,451	3,521	3,362	3,452	3,380	3,450	3,451	3,450	3,450	3,451
5	3,447	3,450	3,449	3,445	3,450	3,448	3,377	3,450	3,400	3,447	3,522	3,454
6	3,450	3,451	3,450	3,512	3,447	3,449	3,531	3,450	3,500	3,448	3,381	3,453
7	3,533	3,448	3,452	3,450	3,449	3,445	3,350	3,454	3,450	3,451	3,373	3,449
8	3,362	3,450	3,452	3,450	3,450	3,450	3,448	3,447	3,449	3,450	3,530	3,445
9	3,415	3,513	3,521	3,450	3,454	3,452	3,447	3,453	3,520	3,451	3,450	3,448
10	3,520	3,414	3,380	3,450	3,451	3,448	3,450	3,451	3,380	3,452	3,452	3,451

Table 7. Result of the Calculated Average, Standard Deviation, Upper Limit and Lower Limit

Variation	Average (mm)	Standard Deviation	Upper Class Limit (mm)	Lower Class Limit (mm)
1	3,4467	0,0276	3,5294	3,3639
2	3,4432	0,0486	3,5890	3,2973
3	3,4501	0,0451	3,5854	3,3147
4	3,4505	0,0528	3,6089	3,2921
5	3,4468	0,0185	3,5022	3,3913
6	3,4487	0,0336	3,5494	3,3480
7	3,4548	0,0504	3,6059	3,3037
8	3,4499	0,0384	3,5650	3,3348
9	3,4489	0,0410	3,5718	3,3260
10	3,4458	0,0407	3,5677	3,3238
11	3,4497	0,0393	3,5676	3,3318
12	3,4502	0,0343	3,5531	3,3472

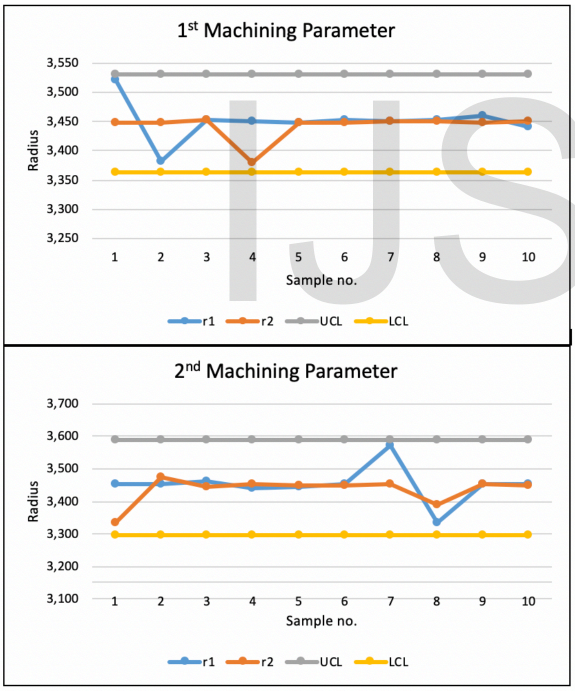

Figure 5. Measurement Graphic of Precision on 1st and 2nd Machining Parameter

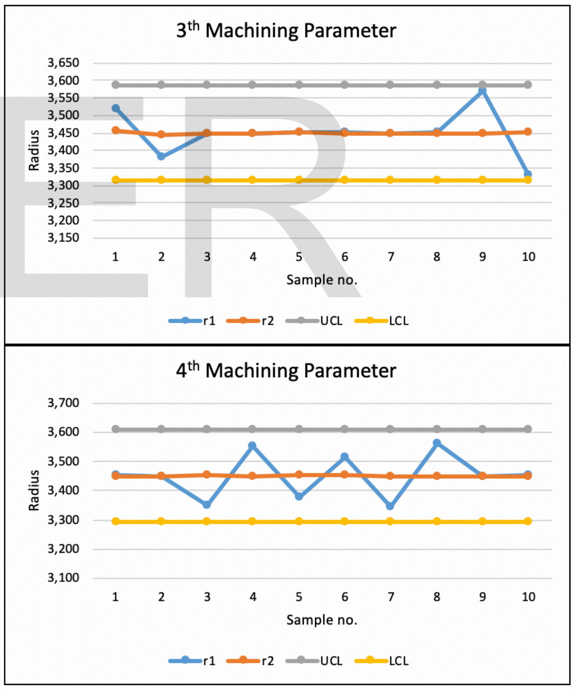

Figure 6. Measurement Graphic of Precision on 3rd and 4th Machining Variation

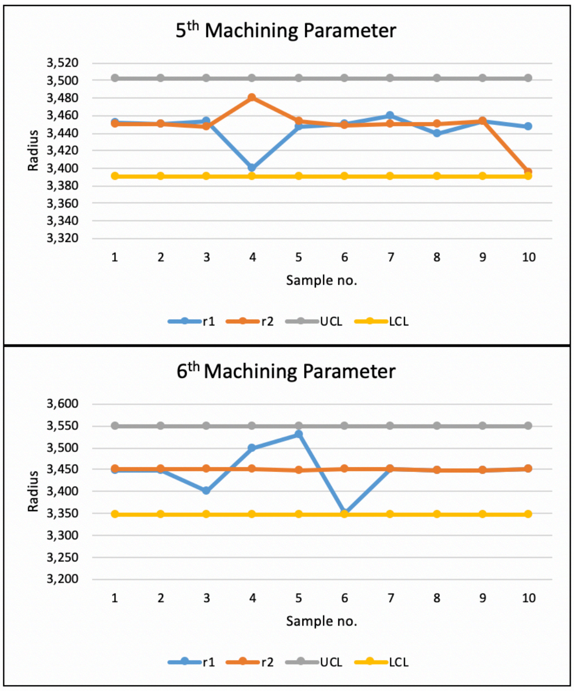

Figure 7. Measurement Graphic of Precision on 5th and 6th Machining Variation

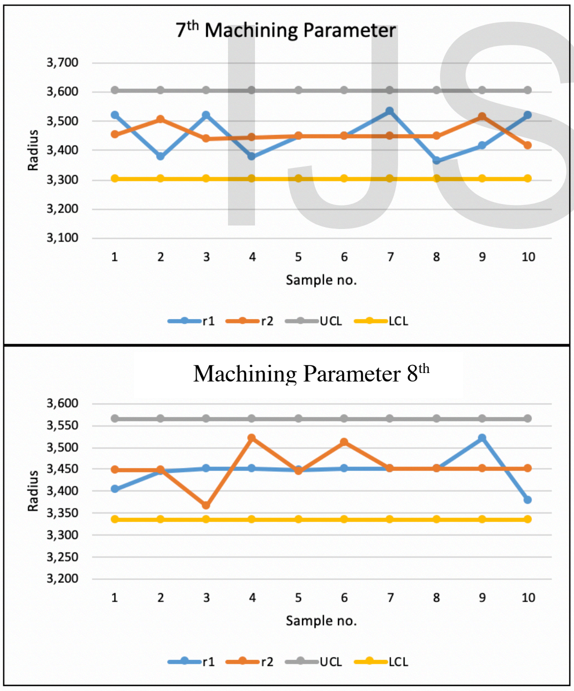

Figure 8. Measurement Graphic of Precision on 7th and 8th Machining Variation

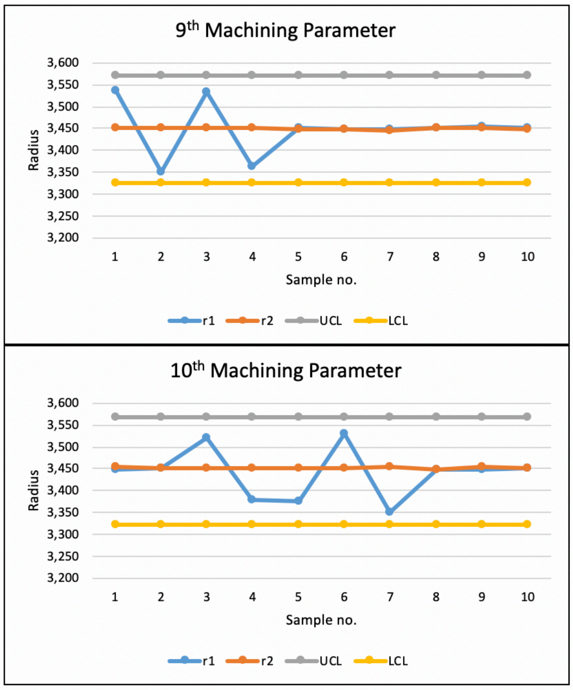

Figure 9. Measurement Graphic of Precision on 9th and 10th Machining Variation

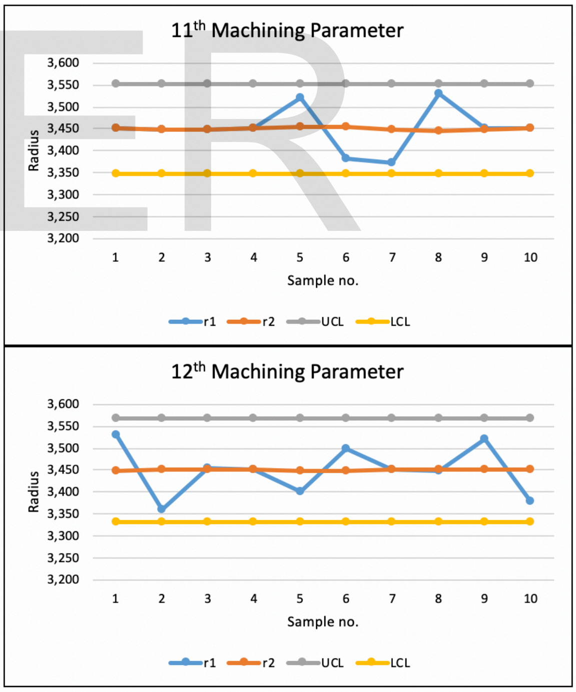

Figure 10. Measurement Graphic of Precision on 11th and 12th Machining Variation

From the graphics above, it can be analyzed that all 10 randomly taken samples taken with each machining variation still get inside the range of the boundaries of the upper class limit and lower classper limit. Therefore, all of the holes that were analyzed at each machining variation pemesian still can be considered as precise.

CONCLUSIONS

1. The edges of the drill are more easily to be worn out in HSS drill compared to Co-HSS drill
2. The most influencing machining parameter in the drilling proses is the spindle rotating speed compared to the feed rate.
3. From the graphic, it can be seen that as the spindle rotating speed become higher, the worn out value of the edge will also be greater, and vice versa. As the spindle rotating speed become lower, the worn out value of the edge will become smaller and the drill life will become longer.
4. At high speed of rotating spindle, it will cause diffusion mechanism, oxidation, dan plastic deformation.
5. The holes had been resulted from all variations, and it can be considered that all holes have precision values because after some calculations, it was found that all holes were still inside the range of the boundaries of the upper and lower class limit.

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