IOP Conf. Series: Materials Science and Engineering **403** (2018) 012094 doi:10.1088/1757-899X/403/1/012094

Application of cold dry cutting and coated carbide tool on high speed turning process against tool wear and surface roughness of Brass MS58

T Sugiarto[1a], B Sugiantoro[1b], N Supriyana[1], K Setyawan[1] and Y Praharto[2]

[1]Mechanical Engineering Department, [2]Electical Engineering Department
STT Wiworotomo Purwokerto,
Semingkir 1[ist] Street, Purwokerto, Central Java, Indonesia, 53352

[a)]trismesinsttw@gmail.com,[b)]biotech.machining@gmail.com

Abstract. The development of cooling process its necessary to aim develop green machining requirement because it still contains subtances that being harmful for the operator and environmental effect. In this study, high speed turning process is done by using insert chisel and cold air (dry cutting) and Cubic Boron Nitride (CBN) with insert tool on Brass Type MS58. The research method refers to Taguchi methods that using four factors (spindle speed, depth of cuth, feed rate and cold dry cutting with defferen pressure). From the test results to get the optimization of machinery Turning on Brass with cooling dry with cold air using Taguchi methods can be assumme that the cooling process that has the most effect on brass surface roughness level is on cutting condition at 50 Psi (pressure), 10 ^{o}C (air jet temperature). The most optimum roughness in brass that the cutting conditions used are at spindle speed at 790 Rpm, feed rate 0.0034 mm /min, depth of cut 1.5 mm and good cutting condition at 50 Psi pressure. The highest level of sculptural wear on the brass turning process at the edges and the carving crater. The research results prove that the cooling with cold air can be an option for sustain machining process.

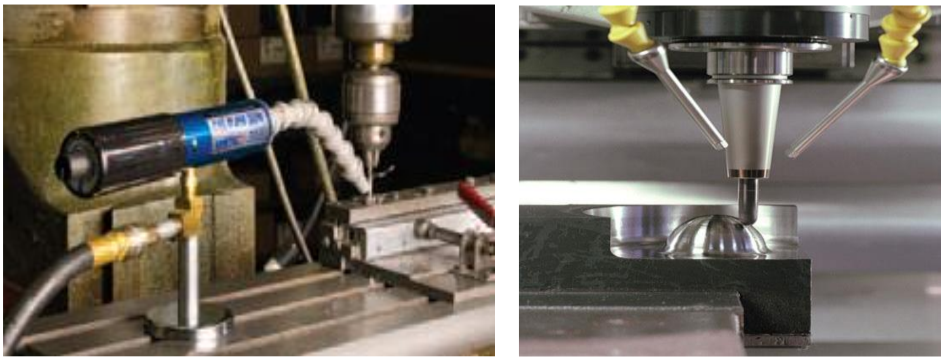
1. Introduction

The development of machining process according to green machining target is to use environmentally friendly material, easy to decompose, safe for operator, and economical, as green machining goal [1, 2]. The target of machining cooling according to an environmentally friendly process as well as cost considerations that must be economical [3]. The development of pressurized air use as coolant has been carried out by various positions of jet cooling improve surface roughness [4]. The usage vortex tube to decrease air temperature [5]. The use of air as an environmentally friendly machining targets encourages process innovation and a cooling air cooler model.

In the machining process the main indicator is seen from surface roughness of workpiece [6]. Pressurized air or Air Jet cooling has the advantage of being one of the cooling mediums in the machining process but still has not produced good surface roughness and the wear is still high, proved the lowest surface roughness palm kernel oil still better than dry cutting [7]. The resulting surface roughness in the dry cutting process is still lower than the use of oil cooling, but high economic value and potential to develop [8]. Temperatures affect the cooling performance, air jet cooling with an

IOP Conf. Series: Materials Science and Engineering **403** (2018) 012094 doi:10.1088/1757-899X/403/1/012094

uncooled compressor pressure having an average temperature of 28-32°C, to improve performance of air cooling in dry cutting need innovation to decrease temperature cooling under 15ºC. With these conditions still need to be developed air brealing technology that is able to produce the output temperature adjusted constant at (10ºC). The technology of dry cutting has developed from vortex tube to cold dry cutting, limitations of vortex tube is low reduction of air/gas temperature, set up can be seen at figure 1.



(a) **(b)**

Figure.1. Dry cooling process with (a) vortex tube (b) dry cutting (air jet cooling).

According to the previous research, to decrease air temperature obtained from heat exchanger by utilizing refrigeration process to reduce significant air temperature from compressor. The temperature drop depends on the cross-sectional area of the spiral pipe on the evaporative pipe. To set the air temperature used micro control for air has constant pressure and temperature required during the machining process.

The requirement of industrial machinery demands a fast process with high quality, so that machining process is directed to be executed at high speed machining process. According to industry quality constraint (ASME standard), HSM process range in figure 2.

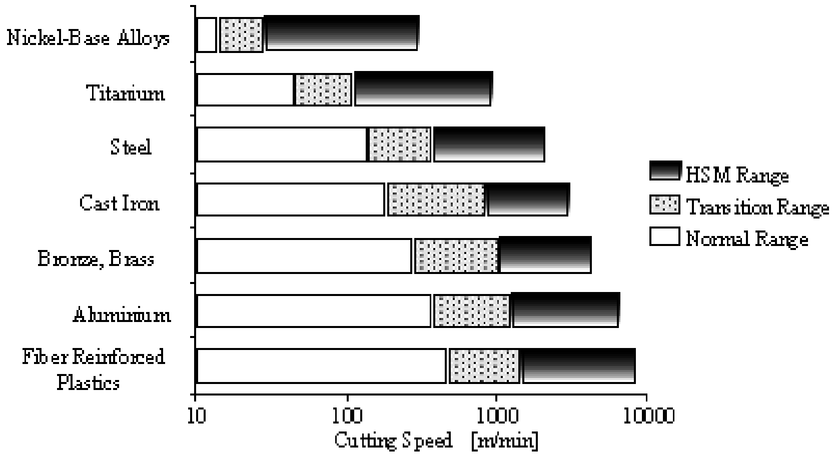


Figure 2. Comparison of cutting speed of material on high speed machining [9].

The choice of feed rate is very important, as it affects material deformation [10]. Pressure influenced residul stress of material. The choice of pressure on dry cutting is essential to prevent increasing temperature and stress in the material and chisels [11]. Parameters affect to the forces and surface roughness [12]. The effect of the feed rate, the spindle speed on the machining process influences the surface roughness of workpiece quality [13]. Cooling with cold air at temperatures below 15ºC becomes the dominant factor against temperature and surface roughness [14].

Utilization of high performance refrigeration system becomes an option and not yet used commercially in ASME industry. Performance of cold dry cuttings is measured by looking at the turning machinery process conditions, including temperature process, engine power, tool wear, engine vibration. The lowest roughness condition will be the reference according to industry grouping.

2. **Metodology**

2.1. Materials

Material used in this research is Brass type (MS58, Code DIN CW614N), good machinability. The result of hardness testing can be seen at table 1. Tools used in this research is CBN Insert (Coated Carbide tool material). The use of chisel with carbide coating improves process speed and tool life and improves the quality of machining surfaces [15, 16]. Cooler air adjustment uses output air temperature, constant at 10^{o}C.

Table 1. The result of hardness testing of Brass type (MS58).

No	Hardness Number (HRB)					Means (HRB)	Hardness HRC	Standart of deviation
1	84.1	87.1	87.5	92.2	91.9	88.65	7.42	3.320

Type of hardness testing: Rockwell Hardness (HRB),
Load: 100 N,
Penetrator: Ball

2.2. Taguchi methods

In this work, parameters are based on the most optimum results, the Taguchi methods used to design efficient experiments and is used to analyze experimental data. Ortogonal arrays $L_9(3)^4$ Desain of experiment can be seen at table 2.

Table 2. Planning of Taguchi experimental on HSM turning on Brass (MS58).

Parameters	Factor	Level Desain Variations		
		1	2	3
Spindle Speed (rpm)	A	790	950	1300
Feed Rate (mm/rev)	B	0.0034	0.0069	0.0137
Depth Of Cut (mm)	C	1	1,5	2
Cutting Condition (cold air injections (psi, ^{o}C)	D	P Compresor = 30 Psi, T ; 10 ^{o}C	P Compresor = 40 Psi, T ; 10 ^{o}C	P Compresor = 50 Psi, T ; 10 ^{o}C

Whereas: P: pressure adjustment air cooling, using constant temperature at 10^{o}C, obtained at 15 minute operations of refrigeration process.

2.3. The cooling working principle

The cooling working principle of the cooling process uses compressed air, which requires only the compressor as a pressurized air-generator, effect of evaporation usage to lowering the air temperature. The Pressure Gauge as a valve to adjust the nozzle output air pressure, and the nozzle as the air spray guide. The cooling process is carried out through refrigeration use cooper pipe (diameter 8 mm), using placed on the round of evaporator. The heat exchange fluid aim to reduce air at a temperature of 10^{o}C. Principle of temperature reducer with counter flow as shown figure 3.

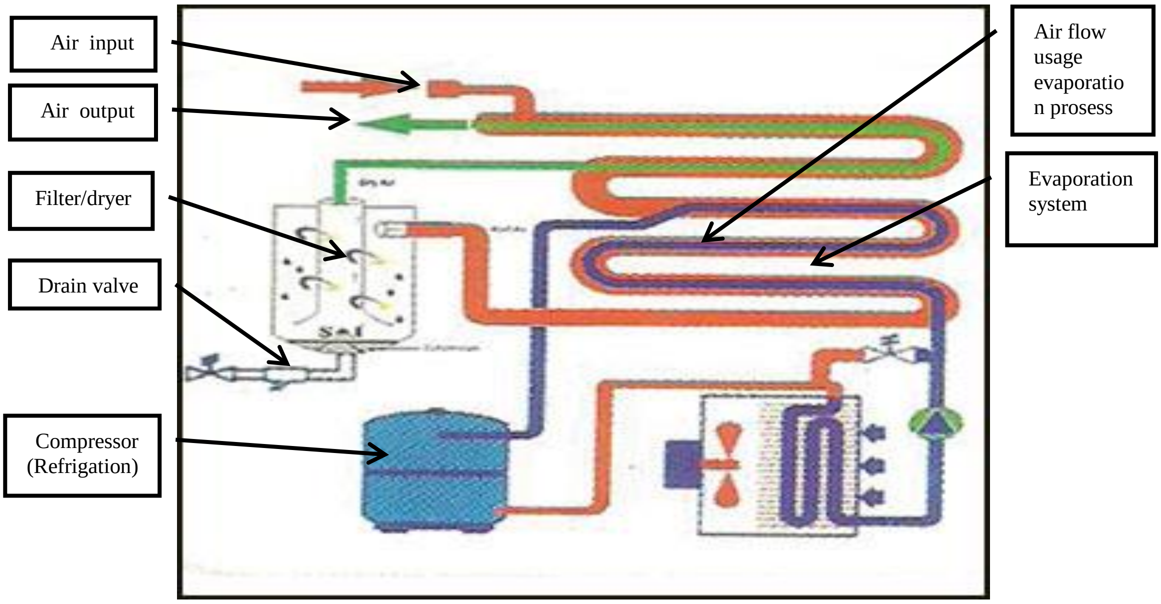


Figure 3. Principle of heat excange to obtained cold air cooling by usage refrigeration process.

2.4. Set-up experimental (turning process using cold dry cutting)

The data collection of turning machine with dry cooling at high speed turning is done with the set up of machining according to figure 4.

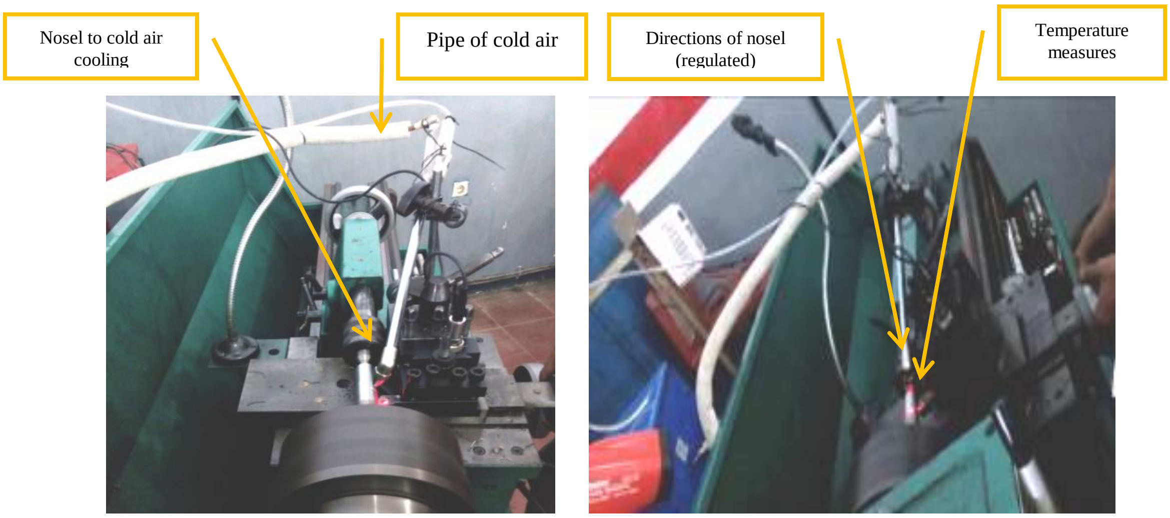


Figure 4. Set-up of experimental cold dry cutting on brass MS58.

2.5. Interpretation of experimental results

Measures for interpreting experimental results using the Taguchi Methods can be done by determining percent contributions, which is a significant portion of each factor interaction to the total observed variation. Quality characteristics used are Smaller-the-Better (STB). Characteristic quality where the lower the value, the better quality, as the equation (1) [17].

$$S/N_{STB} = -10 \log \left[1/n \sum_{i=n}^{n} y^2 \right] \quad (1)$$

Vibration in the machining process is very influential on the results, the smaller the vibration indicates engine rigidity and chisel, a small frictional force. Chatter conditions occur because of small stiffness, for that vibration quantity is measured to be able to detect the forces that occur in the machining process. Achievement of process optimization will be known from motor power, vibration, temperature of air cooling pressure, chisel temperature, chip type. To know the phenomenon and condition of data process measured with (clam ampere), vibrationmeter, infrared / thermocouple sensor, pressure gauge. Lowest power, lowest temperature, smallest vibration and best roughness target as target of optimum condition determination.

3. Results and discussion

Roughness test results of the workpiece surface, measured using surface roughness type Surfcorder SE300. The result of measurement of surface roughness of MS58 brass can be seen in table 3.

Table 3. The result of surface roughness of brass (MS58).

Experiments	Specimen	Roughness	means	S/N
	Specimen 1	5.2910		
1	Specimen 2	5.4710	5.3810	-14.6181
	Specimen 3	5.3810		
	Specimen 1	7.5530		
2	Specimen 2	7.8340	7.6440	-17.6678
	Specimen 3	7.5450		
	Specimen 1	5.7930		
3	Specimen 2	5.8730	5.7840	-15.2453
	Specimen 3	5.6860		
	Specimen 1	1.9780		
4	Specimen 2	1.9540	1.9553	-5.8248
	Specimen 3	1.9340		
	Specimen 1	11.1730		
5	Specimen 2	11.1820	11.1730	-20.9634
	Specimen 3	11.1640		
	Specimen 1	28.5920		
6	Specimen 2	28.8910	28.7910	-29.1852
	Specimen 3	28.8900		
	Specimen 1	2.3910		
7	Specimen 2	2.4980	2.4950	-7.9463
	Specimen 3	2.5960		
	Specimen 1	2.8210		
8	Specimen 2	2.9310	2.8310	-9.0421
	Specimen 3	2.7410		
	Specimen 1	15.5010		
9	Specimen 2	15.5010	15.6010	-23.8634
	Specimen 3	15.8010		
		y	81.6553	-144.3564

	ȳ	9.0728	-16.0396

The effect of the level/factors on surface roughness workpiece, temperature of tools, and power consumption on spindle drive motor can be seen in tables 4.

Table 4. Effect of level and factor on surface roughness factor.

Faktor	Level			defference (maks - min)	Ranking
	1	2	3		
Spindel speed	-15.8437	-18.6578	-13.6173	5.0405	3
Feed rate	-9.4631	-15.8911	-22.7647	13.3016	1
Depth of cut	-17.6151	-15.7853	-14.7183	2.8968	4
Cutting Condition	-19.8150	-18.2664	-10.0374	9.7776	2

From table 4 shows that the feed rate is ranked first for the surface roughness response of the turning results region, this means that the feed rate has the greatest effect on the surface roughness of the result of the process. Cutting condition using cold dry cooling with cool air with 10^{o}C occupying the 2nd rank, it shows that the use of cold air can reduce roughness compared to depth of cut and spindle speed, it means the cooling factor promised to develop the sustain machining. Result of high speed turning experiment with Taguchi methods to see the effect and condition of machining process (turning) on brass MS58. Effect level and factor S/N of surface roughness of product at figure 5.

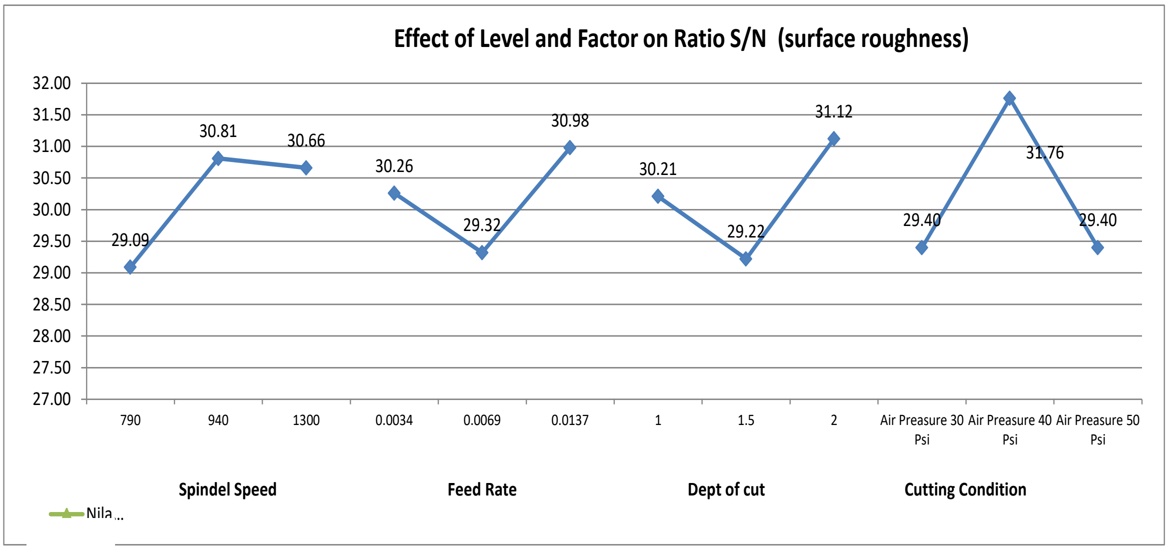


Figure 5. Graph of Effect Level and factor S/N of surface roughness of product.

The influencing factor on the mean value of CBN tools temperature can be seen on table 5.

Table 5. The ranking of effect of factor and level on tool temperature.

Factors	Level			difference (maks - min)	Ranking
	1	2	3		
Spindel speed	-28.72	-29.78	-29.72	1.06	2
Feed rate	-29.05	-29.34	-29.83	0.78	4
Dept of cut	-29.05	-29.31	-29.85	0.80	3
Cutting Condition	-28.82	-30.04	-29.37	1.22	1

From the table 5 it can be seen that, the most influencing factor on the mean value of cutting zone temperature is cutting condition with contribution 42% and the smallest contribution is belong tofeed rate with contribution of 15%. Graph of effect of level and factor ratio S / N temperature of cutting zone is shown in figure 6 and the influence of level and power factor S / N ratio is shown in figure 7.

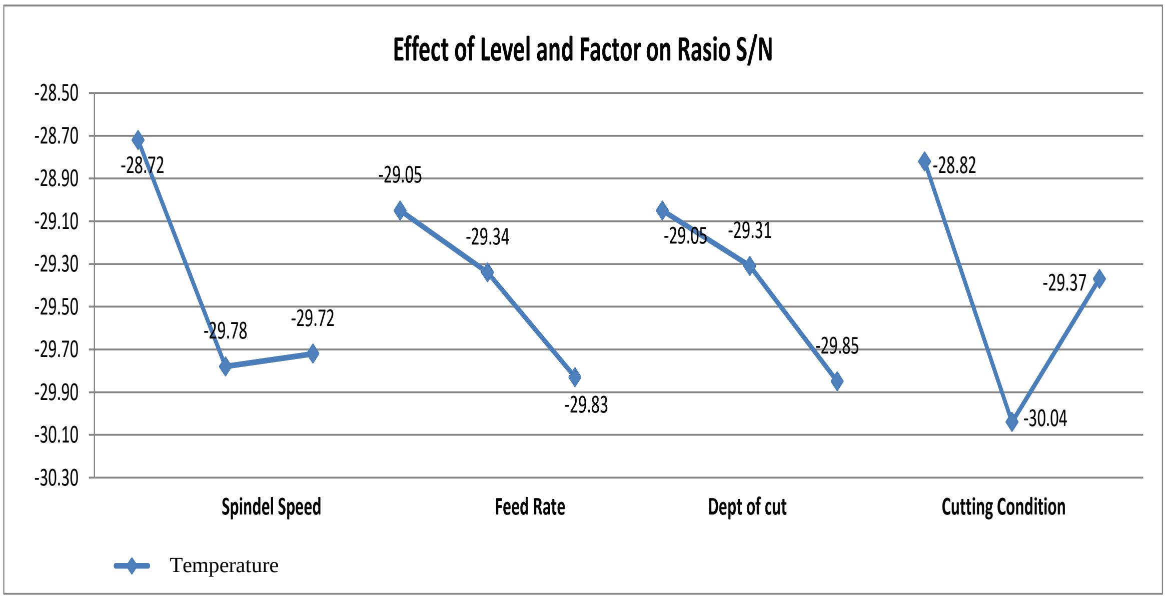


Figure 6. Graph of effect of level and factor ratio S / N temperature of insert tool (CBN).

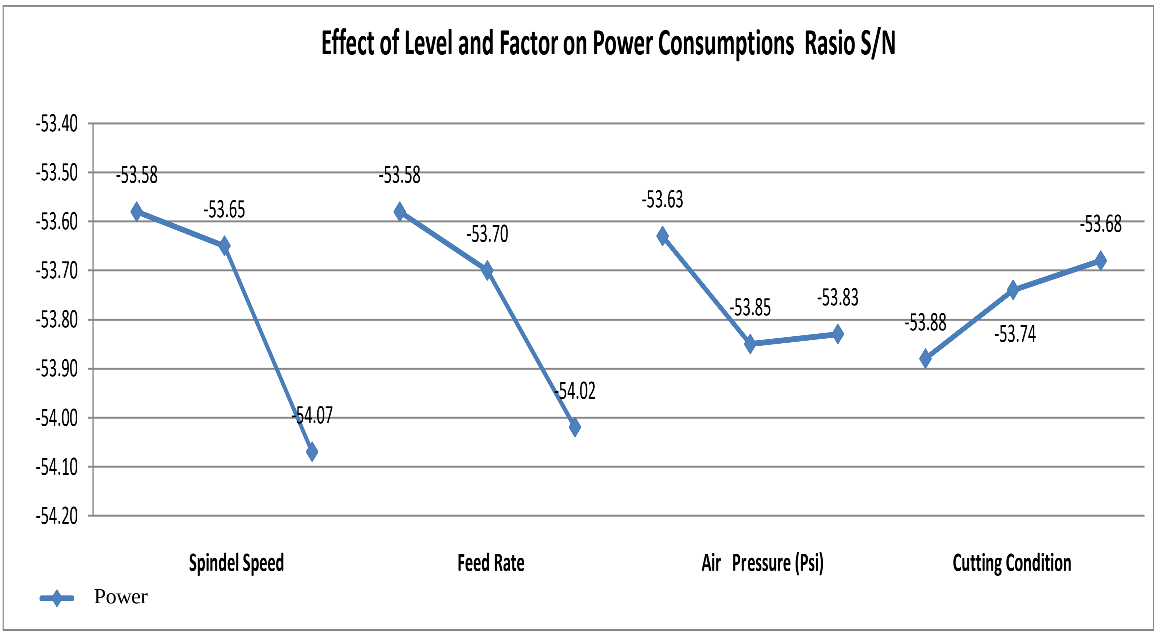


Figure 7. Graph of influence of level and power factor S / N ratio.

Experimental results show for all dry cooling process (cold air) produces roughness identification with the smallest value 1.955 µm, with the smallest temperature 28.40^{0}C and highest 33.23^{0}C. The power consumption depends on highest spindle speed, and highest depth of cut. The biggest wear on the side end of the cutting process turning after 30 minute operation at figure 8. Cutting condition is ranked first for carving temperature response, this means that cutting condition has the greatest effect on chisel temperature yield.

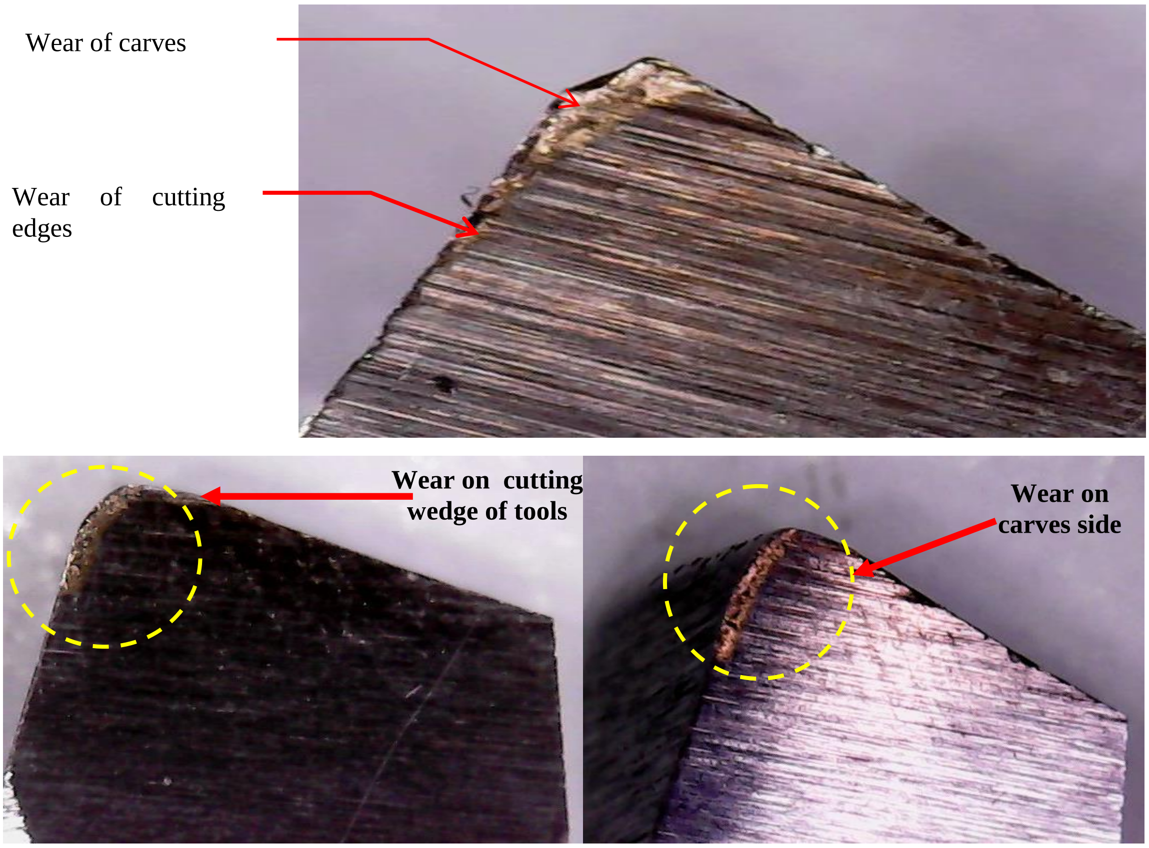


Figure 8. The wear positions on carving insert/cutting edge of CBN tool.

The results of brass research for all cooling processes with as in the above table resulted in a good roughness with the smallest value 1.955 ra, and the largest 28.791 ra. The most optimum roughness in brass then the cutting conditions used are at spindle speed at 790 rpm, Feed rate 0.0034 mm /min, dept of cut 1.5 mm and cold cutting condition at 50 Psi pressure. The lowest temperatures in the smallest number 28.40^0C and the highest 33.23^0C. Cutting condition is ranked first for the chisel temperature response, this means that the cutting condition has the greatest effect on the chisel temperature results. The cooling with cold air by utilizing refrigeration with constant temperature at 10°C occupies the 2^{nd} rank for surface roughness.

From the above conditions, the most dominant factor on brass MS58 machining is the feed rate because it is ranked first for the surface roughness response of the resultant turning region, this means that the feed rate has the greatest effect on the surface roughness result [18, 19], This result is in accordance with the results of study [20, 21] that carbide-based sculpting improves machining performance, better than vortex tube [22], in other studies spindle speed becomes the most dominant factor [23, 24]. The wear rate dominant occurs on the CBN insert sculpture side of the crater and the chisel side.

4. Conclusion and future work

From the test results to get the optimization of machinery Turning on Brass with cooling dry with cold air using Taguchi methods can be summed up that the cooling process that has the most effect on brass surface roughness level is on cutting condition at 50 Psi (pressure), at constant temperature at 10ºC, the most optimum roughness in brass then the cutting conditions used are at spindle speed at 790 rpm, feed rate 0.0034 mm /min, dept of cut 1.5 mm and cold cutting condition at 50 Psi pressure and the highest level of sculptural wear on the brass turning process at the edges and the carving crater.

The use of cold air can be optimized by increasing the lubrication properties with the minimal addition of lubricating oil (very little oil mist). In accordance with the development of green maschining, cooling with air is the target of future cooling. The potential of cold air becomes the potential to be developed for environmentally friendly machining in the future.

Acknowledgments
Head of Research and Community Service, P3M STT Wiworotomo Purwokerto, For Founding Basic Research conducted in 2016-2017.

References

[1] Jain A and Kansal H 2017 Green machining–machining of the future *4th National Conference on Advancements in Simulation & Experimental Techniques in Mechanical Engineering (NCASEme-2017)*
[2] Dahmus J B and Gatowski T G 2004 An environmental analysis of machining *Proceeding of IMECE, ASME International Mechanical Engineering Congress and Expo* Anaheim, California, USA, November 12-19 pp 643-52
[3] Atisková D M 2012 The methodology of economic costs influential on automation of component production *American Journal of Economics* vol 2 no 7 pp 164-70
[4] Rusnaldy P and Utomo T S 2012 Effect of air jet cooling on surface roughness and tool wear *Jurnal Tekno Sains* vol 1 no 2
[5] Rusnaldy P, Utomo T S and Umardani Y 2010 Effect of air jet cooling on surface roughness and tool wear *Proceeding of 2nd International Graduate Student Conference* Yogyakarta, Indonesia.
[6] Waydande R and Ghatge D 2016 Performance evaluation of different types of cutting fluids in the machining of hardened steel–A review *International Journal of Mechanical and Production Engineering* vol 4 issue 3 pp 34-9
[7] Adegbuyi P A O, Lawal G, Oluseye O and Odunaiya G 2010 Analyising the effect of cutting fluids on the mechanical properties of mild steel in a turning operation *American Journal of Scientific and Industrial Research* vol 2 issue 1 pp 1-10
[8] Grover M and Khan Z A 2014 The comparison on tool wear, surface finish and geometric accuracy when turning EN8 steel in wet and dry conditions *Proceedings of the World Congress on Engineering* Vol 2 pp 2-4
[9] ASM Handbook 2009 *13A-Corrosion-Fundamentals* Testing, and Protection
[10] Vilches F J T, Hurtado L S, Fernández M F and Gamboa C B 2017 Analysis of the chip geometry in dry machining of aeronautical aluminum alloys *Appl. Sci.* vol 7 issue 2 p 132
[11] Palakudtewar R K and Gaikwad S V 2014 Dry machining of superalloys: Difficulties and remedies *International Journal of Science and Research (IJSR)* vol 3 issue 7
[12] Rao C J, Rao N and Srihari P 2013 Influence of cutting parameters on cutting force and surface finish in turning operation *Procedia Engineering* vol 64 pp 1405-15
[13] Lawrence I D, Pandiarajan M and Kaviprakash G 2015 Prediction of machining parameters in turning on EN36 *International Journal of Applied Engineering Research* vol 10 no 55 pp 4070-75
[14] Sugiantoro B, Rusnaldhy and Widyanto S A 2014 Optimalisasi parameter proses milling terhadap kualitas hasil permesinan Aluminium dengan Metode Taguchi *TRAK SI* vol 14 no 1
[15] Srithar A, Palanikumar K and Durgaprasad B 2014 Experimental investigation and surface roughness analysis on hard turning of AISI D2 steel using coated carbide insert *Procedia Engineering* vol 97 pp 72-7
[16] Ramanujan R, Venketesan K, Saxena V and Joseph P 2014 Modeling and optimization of

cutting parameters in dry turning of Inconel 718 using coated carbide inserts *Procedia Materials Science* vol 5 pp 2550-9

[17] JMP 2014 *Design of experiments guide* (Cary, NC, USA: SAS Institute Inc.)

[18] Sulaiman S, Ariffin M K A and Norsat R M 2015 Influence of dry machining parameters in minimization of tool wear *3rd International Conference on Advances in Engineering Sciences & Applied Mathematics (ICAESAM'2015)* March 23-24 London (UK) vol 3

[19] Sargade V, Nipanikar S and Meshram S 2016 Analysis of surface roughness and cutting force during turning of Ti6Al4V ELI in dry environment *International Journal of Industrial Engineering Computations* vol 7 issue 2 pp 257–66

[20] Davis R, Madhukar J S, Rana V S and Singh P 2012 Optimization of cutting parameters in dry turning operation of EN24 steel *International Journal of Emerging Technology and Advanced Engineering* vol 2 issue 10 pp 559-63

[21] Andriya N, Rao P V and Ghosh S 2012 Dry machining of Ti-6Al-4V using PVD coated TiAlN tools *Proceedings of the World Congress on Engineering* July 4 – 6, London, UK pp 4-6

[22] Taha Z, Salaam H A, Ya T T, Phoon S Y, Tan C F and Akiah M A 2013 Vortex tube air cooling: The effect on surface roughness and power consumption in dry turning *International Journal of Automotive and Mechanical Engineering (IJAME)* vol 8 p 1477

[23] Ojolo S J and Ogunkomaiya O 2014 A study of effects of machining parameters on tool life *International Journal of Materials Science and Applications* vol 3 no 5 pp 183-99

[24] Okokpujie I, Okonkwo U and Okwudibe C 2015 Cutting parameters effects on surface roughness during end milling of Aluminium 6061 alloy under dry machining operation *International Journal of Science and Research (IJSR)* vol 4 issue 7 pp 2030-36