THE EFFECT OF CUTTING FLUIDS AND CUTTING SPEEDS TO THE VIBRATIONS OF MILLING CNC MACHINE

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cutting speeds
vibration

Abstract :

Vibration that occur in machining process is forced vibration. This vibration caused by external force excitation. External force that cause vibration in machining process is cutting force. This research was aims to determine the effect of cutting fluids and cutting speeds to vibration in milling process. The specimens were made using a cutting process type face milling, profile milling, pocket milling, and slot milling. Cutting speeds was variated at 62.83 m/min; 110 m/min; 157.14 m/min; 188.5 m/min. Vibration testing was done using the accelerometer sensor. Vibration response taken is the amplitude. The results show any type of cutting process has a different amplitude. Face milling has the smallest amplitude while slot milling has the biggest one. At cutting speeds parameter, the faster of cutting speeds the smaller of the amplitude. The use of cutting fluids can reduce the friction value between cutting tool and workpiece so that the cutting force will decrease. The use of cutting fluids causing the smaller the cutting force. The increase of the cutting force will cause greater vibration

INTRODUCTION

Low specific weight materials application is an effective way to reduce the structure density. Aluminum alloys are the most commonly used to substitute steel since its light weight, it also has pretty good corrosion resistance, strength, and ductility properties. The manufacturing industry was increasingly switching to aluminum as material components. In this study, aluminum 6061 was performed as the testing material. The aluminum alloys 6000 contain of silicon and magnesium that form magnesium silicide, thus making it has heat-treatable capability. Although, it was powerless than most aluminum alloy 2000 and 7000 series, however it became a malleable and has a medium corrosion resistance (Oberg, 2012).

An engineering company provides the production processes machineries that work manually and CNC (Computer Numerical Control). Due to its demand that must be met in the engineering field such as dimensional tolerances are very critical, CNC machine has been chosen since it has numerous advantages than manual/ conventional machine which are faster and more precisely of both quantity and quality in machining process. In this study, it was used MITSUBISHI M-70 2M-2825P CNC milling machine. The factors that affect CNC convenience compared to conventional engines were: fewer settings, the tool moves automatically by requested program, its movement can be monitored on the screen, a small error rate, and time efficiency (Zubaidi, 2012).

Aditya et al (2014) performed a study using a chisel ball nose end mill which made from carbide with conventional milling process on aluminum 6061 material. Its parameters were 700, 800, 900 rpm of spindle speed variations respectively; 100, 200, 300 mm/ min ingestion rate variations correspondingly; and were 2 and 4 chisel eye variations. Each specimen was accomplished tested a surface roughness (Ra). The results showed that feed rate has a positive influence (proportionally) that the higher feed rate, the greater surface roughness. While spindle speed and the eye chisel number have inversely effect which were the higher of them result the smaller surface roughness.

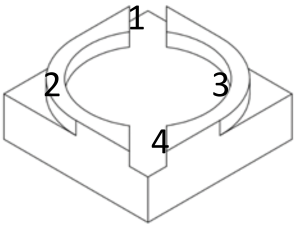
Lazuardhy et al (2012) exhibited a study by exploiting a lathe turning process that aims to determine the chatter conditions feed motion effect of the work piece surface roughness using steel S45C. This study was obtained amplitude vibrations data that occurred during the lathing process and the work piece surface roughness. The results showed that the lowest surface roughness was 0.045 mm/rev of feed motion with 5.47 lm of surface roughness value. The lowest vibration amplitudes data also produced in 0.045 mm/rev of feed motion of 121.4875 m/s^2. The greater feed motion will produce a force which was also affecting the higher vibration amplitude during the lathing process and will increase its work piece value.

Zhong et al (2010) completed a research on comparative studies between cutting and dry cutting process using cutting fluids based on the vibration signal. This study purpose was to examine the LQL effects (Little Quantity Lubrication) and provide effective guidance for applying LQL in machining process. This study employed an aluminum alloy 7050-T7451 with 150x 150x 45 mm of dimensions.

The utilized chisel was diamond coated flat endmill with 20 mm of diameter. The axial cut depth was 5 mm. Study parameters covered 3000, 6000, 10000, 14000, and 18000 rpm of spindle speed variations respectively. Each test was performed three treatments which were dry cutting (Cd), LQL cutting at 150ml/min (C150), and LQL cutting at 300 ml/min (C300). The vibration signal was obtained from the work piece surface. This study results indicated that the vibration signal were significantly affected by milling process cutting fluids. The dry cutting process was not only to prevent the cutting fluid exploiting, but it has a mild vibration. Meanwhile, LQL cutting process can produce a lower value of RMS vibration, machines, and chisel beneficially. The finishing was engaged LQL, which has a high quality work piece surface, but also can reduce the cutting fluids utilization in large quantities.

RESEARCH METHODOLOGY

It was using aluminum 6061 beam-shaped with 50x 50x 20mm of dimensions. The specimen chemical composition were 0.6% Si; 0.28% Cu; Mg 1.0%, and 0.20% Cr. In this study, there were four types of cutting processes (1) face milling, (2) profile milling, (3) pocket milling, (4) slot milling as can be clearly seen on Figure 1. It was applyed (63.83; 110; 157 , 14; 188.5) m/min of cutting speeds, 1 mm depht of cutting, and 71 mm/min. pen feed rate,



Annotation:
1. Face milling,
2. Profile milling,
3. Pocket milling,
4. Slot milling

In this study, a collected data was taken from vibration data. Its collection process at chisel was when cutting process working. It was taken using a piezoelectric accelerometer sensor that was attached to a vise, as in Figure 2. This sensor fucntion to convert the vibration signal into electric voltage signals. Then, it forwarded to a vibration test equipment so it displayed data which indicates a total vibration amplitude vibration of milling process system.

Figure 2. Piezoelectric Accelerometer Sensor Placement

DATA AND ANALYSIS

This study was conducted to compare the vibrations that occur during the cutting process by cutting fluids and cutting process without cutting fluids with (63.83; 110; 157.14; 188.5) m/min of spindle rotational speed cutting parameters variations. The study results was using vibration test equipment to find the vibration amplitude value of that occured during the cutting process.

Data

The aim of this test is to determine the vibration amplitude value during the cutting process. The obtained data in this test was vibration amplitude that generated by friction between the chisel eye and material. Vibrations that occur will be captured by the attached accelerometer to the vise and then forwarded to the vibration test equipment and it was obtained. The data which was taken for cutting process with and without cutting fluids, each cutting process was conducted four types of cutting (face milling, pocket milling, profile milling, slot milling, and drill) and spindle speeds variation. Each cutting process were teseted five times the yield test average are shown in Table 1.

Cutting Speeds	Cutting Type	Vibrations (m/s^2)	
		Cutting Process	
		without cutting fluids	with cutting fluids
62,85 m/min	Face	68,57	51,78
	Profile	95,87	70,55
	Pocket	132,39	81,76
	Slot	248,93	239,47
110 m/min	Face	51,29	44,46
	Profile	91,75	62,05
	Pocket	127,29	73,04
	Slot	207,35	196,58
157,14 m/min	Face	47,47	41,92
	Profile	78,46	53,18
	Pocket	119,50	59,18
	Slot	198,37	184,95
188,57 m/min	Face	38,73	33,06
	Profile	73,89	48,35
	Pocket	116,71	53,88
	Slot	191,82	156,47

Analizing

The cutting speeds parameter effect to the vibrations amplitude

The vibration testing result data on Table 1 was obtained a graph of the cutting speed to vibrations amplitude relations on different cutting types as seen on Figure 3 to 6:

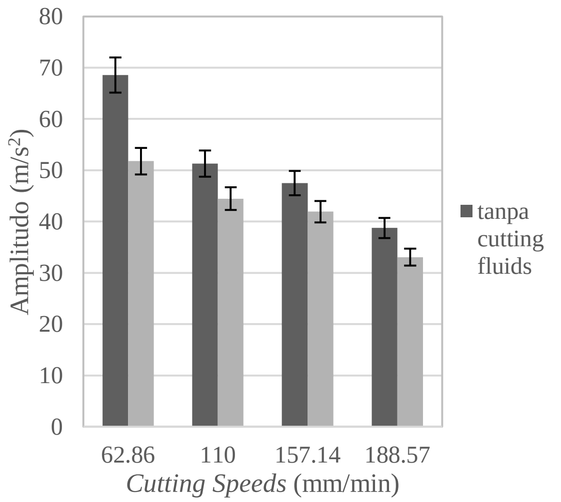


Figure 3. Graph of relationship between cutting speeds to vibration amplitude of face milling cutting style

Figure 3 shows a graph of vibration amplitude to the cutting speeds on face milling cutting type. The amount of cutting speeds gave effect to the value of the vibrations amplitude. It can be clearly seen on Figure 3, that relationship between cutting speeds to the vibrations amplitude is decreased, which each the cutting speeds addition will be decreased the vibrations amplitude. It was proved that the declining which was obtained at 62.86 m/min of cutting speeds on the face milling cutting type without cutting fluids that is equal to 68.57 m/s^2. While at the total cutting speeds of 188.57 m/min on the face milling cutting type without cutting fluids that is equal to 31.08 m/s^2.

The above phenomenon occured since cuttting speeds was increased therefore cutting force will be decreased. Cutting force from this phenomenon was influenced by feed pertooth.

$$f_z = v_f/(n.z) \quad (1)$$

From the equation above feed pertooth became an important variable in the milling process and the feeding rate determined value (v_f), spindle rotational speed (n), and the number of teeth (z). This recent study was used a chisel wih the same number of 4 teeth (flute) and the same feed rate of 71 mm/min. Therefore, the main affecting factors feed pertooth was the spindle rotational speed. In this study, it was utilizing the same cutting tool diameter of 10 mm so that the spindle rotational speed was proportional to the cutting speed. Spindle rotational speed was increasing the chisel feed pertooth speed to the work piece decreasing (Aditya, 2014). Meanwhile, the spindle rotational speed was affected by th cutting speeds value. The greater cutting speeds, the spindle rotational speed is increasing. It can be concluded that magnitude affecting the cutting speeds feed pertooth. The greater the cutting speed, the motion pertooth will be decreased.

$$F_v = k_{s1.1}\, h^{1-p}\, b \quad (2)$$

On Equation 2, can be seen if the feed pertooth influences on cutting forces. Based on Equation 2 in additional feed pertooth, there are other variables that affect the cut force that is specific cutting force reference ($k_{s1 \cdot 1}$), cutting width (b), the square of average thickness chips (p), and a major cut angle (K_r). In this study, it was generating the same workpiece material was 6061, so the specific cutting force was a constant reference. This is because specific cutting force reference by workpiece tension ultimate strength was 124.1 MPa. Cutting width of this phenomenon was the same as when the slaughtering process by utilizating the same type of cuts while the independent variable were cutting speeds. It was influenced by workpiece material and cutting speed (average 0.25). While the primary cutting angle was 90^o, it was because this study used a chisel end slanted tooth milling. Therefore, this phenomenon which affects the cutting forces in Equation 2 was a per tooth feeding motion. The greater it occurred then the greater the cutting force. In the previous paragraph has explained that it was affected by cutting speed. The greater cutting speeds, it value was getting down. It can be concluded the greater cutting speeds, the cutting force was getting decreased. It is convenient to the conducted research by Korkut, et al (2008) which states that the greater cutting speeds then the cutting force will be smaller.

Vibrations which occured in machining process were the forced vibration, it caused by the excitation force from the outside. Therefore, the force that produced in cutting process was influenced by vibration. In this phenomenon the forces which was act upon the milling process due to the cutting speeds repercussion were Boothoroyd cutting forces (1981), it states the greater the force exerted on the cutting process, the vibration generated amplitude will be higher. It is also supported by Budiarto et al research (2011) which states that the greater cutting force, the greater the vibration amplitude value. It can be concluded that the cutting speeds enhancement, the vibration amplitude value will be increase.

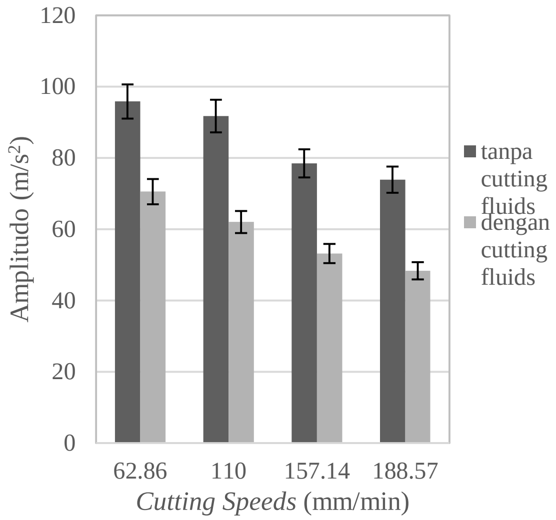


Figure 4. Graph of relationship between cutting speed and vibration amplitudo at profile milling cutting style

Figure 4 shows a graph of the cutting speeds to vibration amplitude on the profile milling cutting type. As in Figure 3 the cutting speeds value impresses of the vibration amplitude value. It can be seen on Figure 4 the cutting speeds relation to vibration amplitude is decreased, where in each cutting speeds addition it will be decreased. This decline was verified by obtained value of vibration amplitude at 62.86 m/min of cutting speeds on the milling profile cuts without cutting fluids that is equal to 95.87 m/s^2. While at the highest cutting speeds of 188.57 m/min on it without cutting fluids that is equal to 73.88 m/s^2. The above phenomenon occurs because of the gained cuttting speeds make the cutting force decreased. As described in the previous paragraph cutting force on this phenomenon was influenced by feed pertooth. The higher cutting speed enhancement generates feed pertooth decreases, as a result of cutting force become smaller. The declining of cutting force value results vibration decreases.

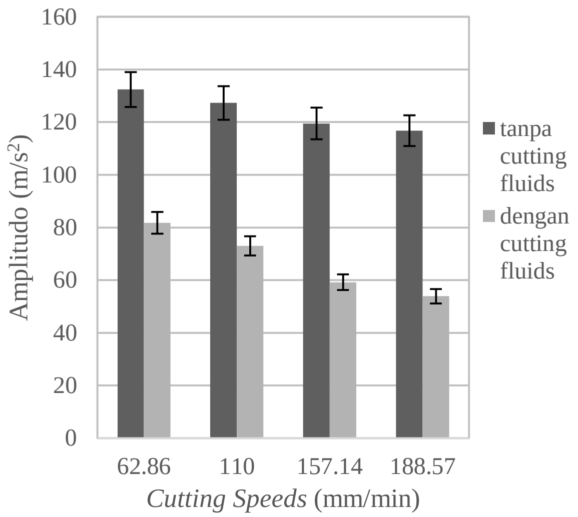


Figure 5. Graph of relationship between cutting speeds and vibration amplitudo at pocket milling cutting style

Figure 5. portrays a relation between cutting speeds and vibration amplitude graph on the pocket milling type. As in Figure 3 and Figure 4 the cutting speeds value provide an effect to vibration amplitude. It can be seen from Figure 5 the relation of cutting speeds to the vibration amplitude is weaken, with each cutting speeds addition value that will cause a vibration amplitude declined. It was illustrated by the vibration amplitude which obtained at 62.86 m/min of cutting speed on the milling slot cuts without cutting fluids that is equal to 132.39 m/s^2. While, at the highest cutting speeds of 188.57 m/min on the pocket milling cutting style without cutting fluids that was equal to 116.71 m/s^2. As described in the previous paragraph that cutting force on this phenomenon was effected by feed pertooth. The growing of feed pertooth expansion made cutting speed decreases, as a result cutting force amount getting smaller. The declining of cutting force value generates amount of vibration reduced.

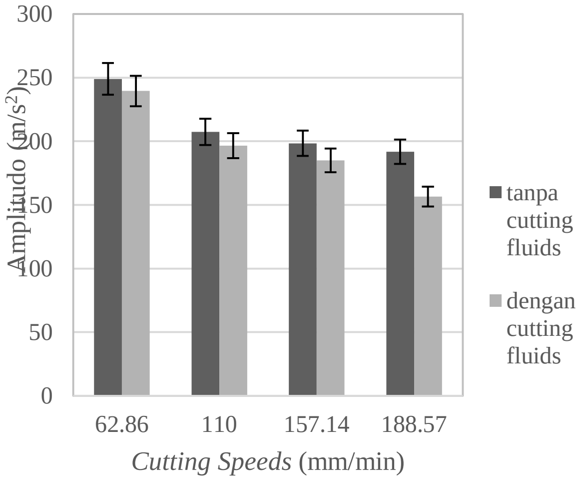


Figure 6. Graph of relationship between cutting speeds and vibration amplitudo at slot milling cutting style

Figure 6 displays a relation of cutting speeds relationship to vibration amplitude graph on slot milling cutting style. As in Figure 3 and Figure 4 4 the cutting speeds value contribute an effect to vibration amplitude. It can be seen from Figure 6 the relation of cutting speeds to the vibration amplitude is lessen, with each cutting speeds addition value that will cause a vibration amplitude depressed. It was described by the vibration amplitude which obtained 62.86 m/min of cutting speed on the slot milling cutting style without cutting fluids that was equal to 248.93 m/s^2. While, at the highest cutting speeds of 188.57 m/min on the slot milling cutting style without cutting fluids that was equal to 191.82 m/s^2. As described in the previous paragraph that cutting force on this phenomenon was effected by feed pertooth. The growing of feed pertooth expansion made cutting speed decreases, as a result cutting force amount getting smaller. The declining of cutting force value generates amount of vibration reduced.

The cutting process effect with and without cutting fluid to the vibrations amplitude

The vibration testing data in Table 1 was obtained relation graph of cutting stlye to the vibration amplitude of cutting speeds different variations as seen on Figure 7 to 10

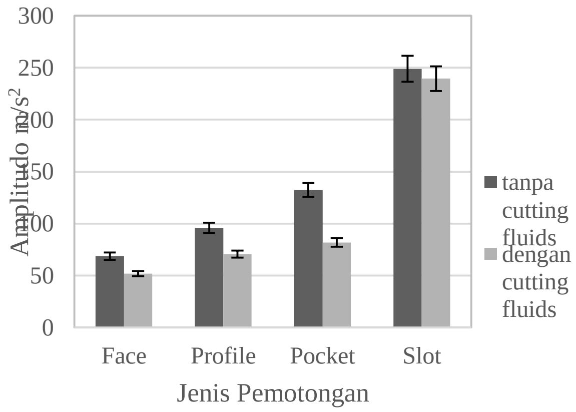


Figure 7. Graph of relationship between vibration amplitude and cutting style at 63,85 mm/min of cutting speed

Figure 7 shows a graph of relationship between vibration amplitude and cutting style at 63.85 mm/min of cutting speed. It can be clearly seen on Figure 7 that the cutting process by utilizing the cutting fluids have a greater result than without it. The difference was confirmed by vibration amplitude value which obtained in the cutting process with cutting fluids when face milling cutting style and 62.85 m/min of cutting speed was 51.78 m/s^2. While, in the cutting process without cutting fluids when applying face milling cutting type and 62.85 m/min of cutting speed was 68.57 m/s^2.

This phenomenon occurs since the cutting process with cutting fluids can reduce cutting force that emerges at machining process. It was influenced by the coefficient of friction that occurs between cutting tool to workpiece. It was convenient to the cutting fluids function which mentioned in the basic theory, where the cutting fluids applications will reduce deformation and decrease the friction between thmen therefore the cutting force would be decreased. This statement was supported by Muktiwibowo et al research (2011) which states that the cutting fluids utilizations at cutting process can reduce cutting force that appears when machining process. The forces which act on this phenomenon was used to determine the vibration amplitude that arises at the cutting process. It has been described in the preceding paragraphs, the greater the cutting force value, the higher the vibration amplitude. It can be concluded that the cutting process with cutting fluids can decrease the of the vibration amplitude value. This statement was legalized by Zhong et al research (2010) which states that the cutting process with cutting fluids can reduce vibration value compared to the process without it.

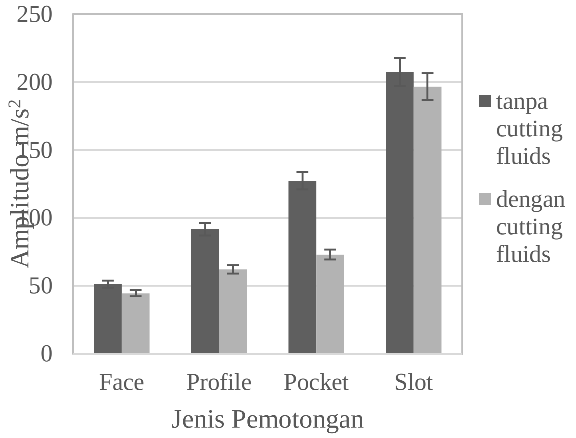


Figure 8. Graph of relationship between vibration amplitude and cutting style at 110 mm/min of cutting speed

Figure 8 displays graph of relationship between vibration amplitude and cutting style at 110 mm/min of cutting speed. It can be clearly seen on Figure 8 that the cutting process by utilizing the cutting fluids have a greater result than without it. The difference was confirmed by vibration amplitude value which obtained in the cutting process with cutting fluids when face milling cutting style and 110 m/min of cutting speed was 51.78 m/s^2. While, in the cutting process without cutting fluids when applying face milling cutting type and 110 m/min of cutting speed was 68.57 m/s^2. This phenomenon has been specified in the preceding paragraph, the cutting process with cutting fluids can scale down cutting force that exists at the machining process. Therefore, if the cutting style decline, it will develop vibrations amplitude value.

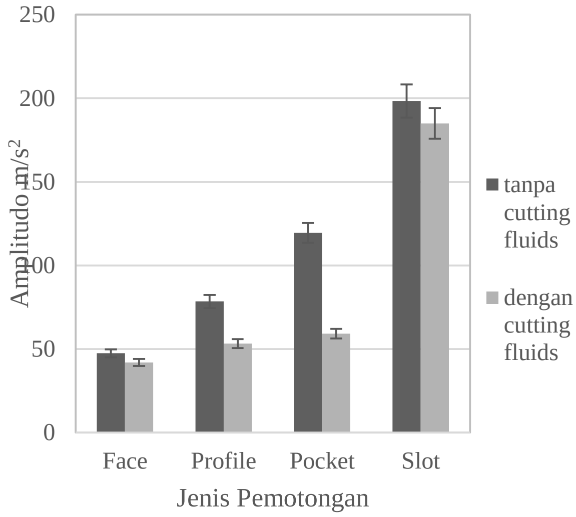


Figure 9. Graph of relationship between vibration amplitude and cutting style at 157.14 mm/min of cutting speed

Figure 9 displays Graph of relationship between vibration amplitude and cutting style at 157.14 mm/min of cutting speed. It can be clearly seen on Figure 9 that the cutting process by utilizing the cutting fluids have a greater result than without it. The difference was confirmed by vibration amplitude value which obtained in the cutting process with cutting fluids when face milling cutting style and 157.14 m/min of cutting speed was 41.92 m/s^2. While, in the cutting process without cutting fluids when applying face milling cutting type and 157.14 m/min of cutting speed was 47.47 m/s^2. This phenomenon has been illustrated in the initial paragraph, the cutting process with cutting fluids can trim cutting force that arises at the machining process. Therefore, if the cutting style fall, it will provoke vibrations amplitude value.

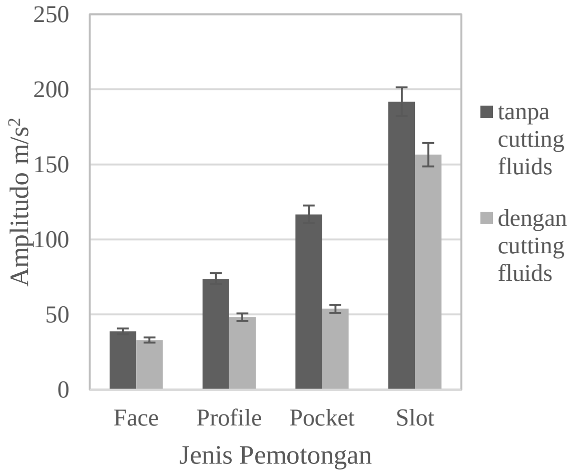


Figure 10. Graph of relationship between vibration amplitude and cutting style at 188.5 mm/min of cutting speed

Figure 10 portrays Graph of relationship between vibration amplitude and cutting style at 188.5 mm/min of cutting speed. It can be clearly seen on Figure 9 that the cutting process by utilizing the cutting fluids have a greater result than without it. The difference was confirmed by vibration amplitude value which obtained in the cutting process with cutting fluids when face milling cutting style and 188.5 m/min of cutting speed was 33.06 m/s^2. While, in the cutting process without cutting fluids when applying face milling cutting type and 188.5 m/min of cutting speed was 38.74 m/s^2. This phenomenon has been illustrated in the initial paragraph, the cutting process with cutting fluids can trim cutting force that arises at the machining process. Therefore, if the cutting style fall, it will provoke vibrations amplitude value.

The effect of cutting style to vibration amplitude

From the vibration testing result data in Table 1 was obtained a graph of relationship between cutting style and vibration amplitude at different cutting process as can be seen in Figures 11 to 12

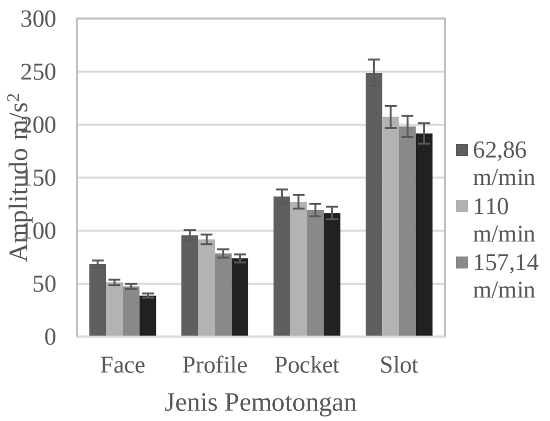


Figure 11. Graph of cutting style relationship at cutting process to vibration amplitude without cutting fluids

Figure 11 shows the current different types of cuts for cutting speed and the same cutting process will affect to the vibration amplitude value. From Figure 11 and 12 can be sorted the cutting types has the smallest amplitude value was face milling, profile milling, pocket milling, slot milling respectively. It could be justified by the magnitude of vibration amplitude values which was obtained on the face milling cutting type without cutting fluids when cutting speeds 62.83 mm/min was 68.87 m/s^2. Although, the slot milling cutting style without it when cutting speeds 62.83 mm/min was obtained 239.47 m/s^2.

The phenomenon proved that wide cutting on each cutting syle has different result. It can be seen in Figure 12.

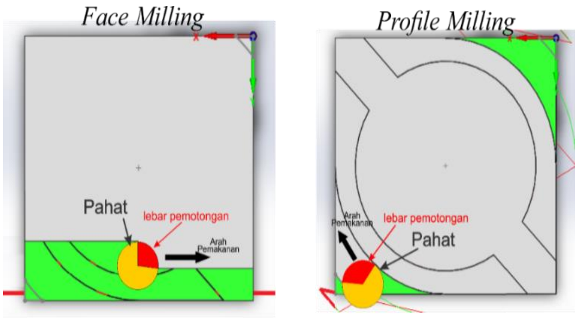


Figure 12. Cutting area at executing process

Figure 12 shows the cutting width of face milling and profile milling cutting style. In the figure 12 can be seen profile milling has a cutting width of 10.59 mm while face milling has a cutting width of 8.44 mm. Pocket milling has a cutting width which equal to the profile milling about one-third of the chisel side surface area. However, pocket milling aside from one-third of the chisel side surface area, this process also cut on the chisel face side. Therefore, the pocket milling cutting style has a cutting width greater than profile milling cutting style. The slot milling cutting style has a cutting width of a half surface area of the side chisel and also trim on the chisel face side. Thus, slot milling cutting style has a cutting width is greater than other types of cuts.

Cutting width is directly proportional to the imposed cutting force on the workpiece (Lazuardhy, 2012). The force which was generated from cutting process by chisel produced a vibration. It will grow up as the cutting forces is generated. The greater the cutting forces exhibited, the higher vibration will be created (Boothoroyd, 1981). Therefore, if the cutting force is establishing a smaller value, the amplitude is also getting smaller.

Pocket milling cutting style has a vibration amplitude value which was greater than other profile milling cutting style. Both these processes were using an end mill chisel with the same diameter of 10 mm, 71 mm/min of feeding rate, and 1 mm of feeding thickness. The main factors that affect the vibration amplitude vibration value was cutting forces when executing. The pocket milling and profile milling cutting style were exploited the same chisels and cutting parameters then the distinguishing factor was the cutting width. The bigger the cutting width, the cutting forces will also rise up (Rochim, 1993). The profile milling and pocket milling cutting style had the same cutting width which was about one-third of the side surface area of the pocket milling chisel but in addition to one-third of the chisel side surface area, this process also cut off the chisel face side. The pocket milling cutting have cutting width larger than profile milling. It can lead pocket milling has a huge vibration amplitude.

The slot milling cutting style has the greatest vibration amplitude value. It caused by the vibration amplitude value greater than the both previous cutting process was cutting width difference as described in the preceding paragraph. The slot milling cutting style has a cutting width which half side surface area of chisel and also trim on the chisel face side. It has a cutting width greater than the pocket milling cutting process which is why the slot milling cutting process has greatre value of vibration amplitude.

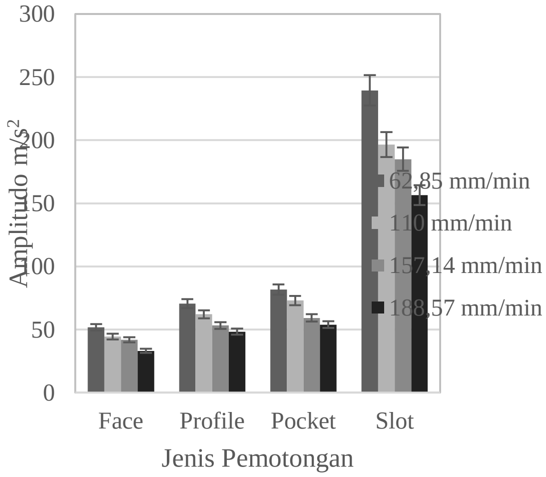


Figure13. Graph of relationship between vibration amplitude value on cutting process with cutting fluids

Figure 13 shows a graph of relationship between vibration amplitude value to the cutting style on cutting process with cutting fluids. It can be seen that the amplitude value of face milling is smaller than other types of cuts. This phenomenon has been described in the preceding paragraph which is voiced that face milling cutting has a cutting width smaller than other styles. While slot milling has greatest cutting width so the amplitude value is getting high. It can be concluded that the greater cutting width, the larger the amplitude value which was generated during the cutting process.

CONCLUSION

From the data analysis and discussion can achieve several conclusions as follows:

1. Vibration of any kind of cutting style, the smallest value were face milling, profile milling, pocket milling, and slot milling respectively.
2. At 62.83 m/min of cutting speed has the largest vibration amplitude of vibration cutting speed while at 188.57 m/min has the smallest.
3. The cutting process with cutting fluids will result the coefficient of friction that occurs in machining process was more and more go down when compared to the cutting process without cutting fluids. It caused a lessen vibrations.

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