Development of Turn-milling in Conventional Lathe Machine

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ABSTRACT

Turn-milling is a machining method with a system of merging turning and milling operations, which the workpieces and cutting tool perform rotary motion synchronously to optimize the disposal process of chip materials. Development of turn-milling can be done on the lathe and milling conventional machining. The purpose of this study is to modify a conventional lathe with a stationary cutting tool and use a single cutting edge into a rotary tool using 4 (four) cutting sides (multy point cutting). In the manufacture and installation of rotary tool on conventional lathes, tools are made portable and can work on tangential, orthogonal and co-axial turn-milling systems. For the orthogonal and co-axial operating system of the turn-milling are divided into up and down operating systems. In this research the phenomenon of material disposal process of the work-piece surface was investigated. In the process of turn-milling test, the chip was removed automatically as the turn of the cutting edge of the endmill cutting tool. The high decreasing of cutting knife rotation during testing was resulted a space during the process of disposal of material. Sequence, it was occurred pores or cavities in the work-piece.

KEY WORDS: *Conventional lathe, Rotary tool, Turn-milling, Type of feeding.*

NOMENCLATURE

n_F	Tool Speed (ft/s)
β	Tool Helix Angle (˚)
r	Tool Radius (˚)
R	Work-piece Radius (ft)
λ	Ratio of Tool and Work-piece Speed
f_a	Axial Feed Rate per Revolution (ft/rev)
f_Z	Feed Rate per Tooth $(ft/tooth)$
Δh	Differtential Element Lenght Along Cutting Depth (ft)
a_e	Radial Cutting Depth (ft)
a_{pp}	Nominal Axial Cutting Depth (ft)
a_p	Actual Axial Cutting Depth (ft)
φ_{ij}	Instantancous Cutting Angle (˚)
$h_0(\varphi_{ij})$	Static Cutting Thickness (ft)
$h(\varphi_{ij})$	Dynamic Cutting Thickness (ft)
φ_{en}	Start Angle (˚)
φ_{ex}	Exit Angle (˚)
$dF_{t,ij}$	Tangential Cutting Force of the *i*th Differential Element of the *j*th Edge (lb_f)
$dF_{r,ij}$	Radial Cutting Force of the *i* the *i*th Differential Element of the *j*th Edge (lb_f)
F_x	The x-direction Cutting Force (lb_f)
F_y	The y-direction Cutting Force (lb_f)

1.0 INTRODUCTION

Conventional lathe machining can be used on low carbon steel up to medium carbon steel materials, which the process of using single point cutting and use of coolant to reduce temperature and increasing of durability. The purpose of this research is to modify the conventional lathe machine. Which performs the cutting process of a rotating workpiece using stationary cutting tool that is a single point cutting to be a rotary tool, which the cutting process of a rotating workpiece with multi point cutting or also it is called turn-milling.

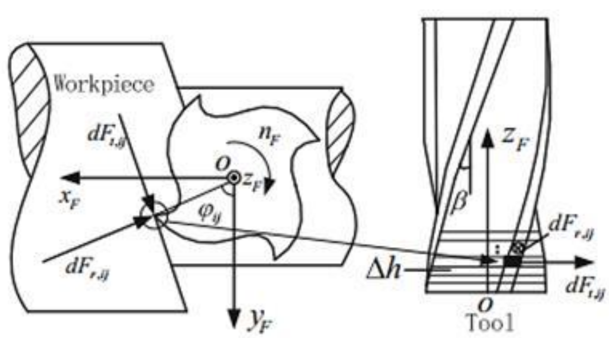
The research has been done by Savas, V. and Ozay, C. 2007 explained that the cutting temperature and cutting force are two parameters that often affect the final quality and life of the tool on the machine. According to them studies the rotary tool movement generated heat in the area of direct contact between the workpiece and the cutting tool. The rotary tool is will be displacement of the cutting contacts, so that a reduction in temperature of the heat from the cutting area results.

Some methods to reduce the cutting temperature and to improve machining productivity are to use rotary cutting tool in turning (Suryadiwansa et al. 2009). To understand turn-milling mechanism, it is important to pay attention to chip formation. Unlike turning conventional method, in turn-milling removal chip is obtained with a combination of 2 (two) rounds that are cutting tool and workpieces. As a result, there is circular feeding and axial feeding (Yan et al, 2015).

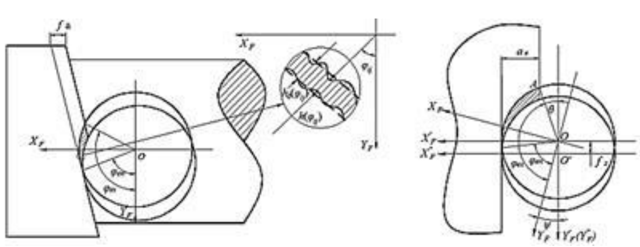
Turn-milling has several advantages such as rotating workpiece and cutting tool, achievement of high cutting speed, high surface quality can be achieved, reducing the working temperature, and reducing the catalyst (Karaguzel et al., 2012). Each time the turn-milling work of the tool side is in contact with the workpiece, so that each side has sufficient cooling time and a portion of the heat is transferred to the chip resulting in a low workpiece temperature, while good chip disposal rates and automatic chip discharges can be achieved because the chips produced at turn-milling are short.

Provision of existing conventional milling and turning chip models can not be used for orthogonal turn-milling chips (Zhu et al, 2015). According to Ratnam, C.H. Vikram, A.K. Ben, B.S. Murthy.B.S.N. (2016). Explained the chips of a crescent shaped that was generated by insert tool. which the rate of feed would increase the thickness of the chip so that the surface roughness will increase. Such as with cutting depth, but if there is an increase in the velocity of the workpiece and the tool will then lower the friction between workpiece and cutting tool so there will be a decrease in roughness.

Research conducted by Yan et al (2015) explain that the decomposition of basic elements of cutting in gemmetris such as cutting force of the depth of feeding, feeding can be seen in Figure 1.



(a)



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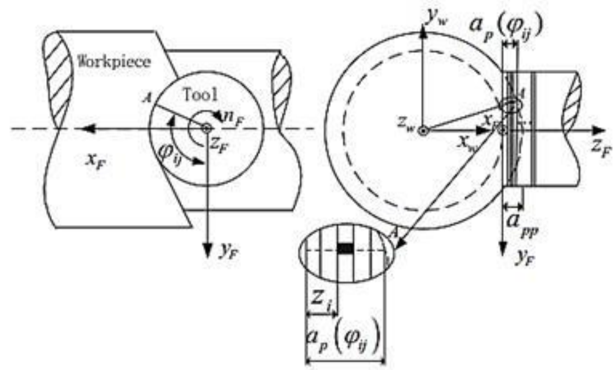

(c)

Figure 1: (a) The division of differential elements along the cutting depth of orthogonal turn-milling (b) The cutting thickness of orthogonal turn-milling (c) The cutting depth of orthogonal turn-milling (Yan, R. dkk. 2015)

2.0 SYSTEM OPERATION TURN-MILLING

In the conventional cutting process spindle rotation can be seen in equation 1. Where the spindle speed on the lathe is forwarded to the workpiece while the milling machine is forwarded to the tool. This combination of both spindle speeds (turn-milling) results in a new equation described in Figure 1.

$$n = \frac{vc\ .\ 1000}{\pi\ .\ d} \tag{1}$$

Based on the principle movement of feeding and tool rotation on the milling process then the direction of motion in turn-milling can be divided into three types of movement, namely:

1) *Orthogonal turn-milling*

In orthogonal turn-milling, the axis to rotation vertical of the axis workpice rotation. The chip formed by main edge cutting tool formed by edge tool. The working step orthogonal turn-milling can be seen in Figure 2.

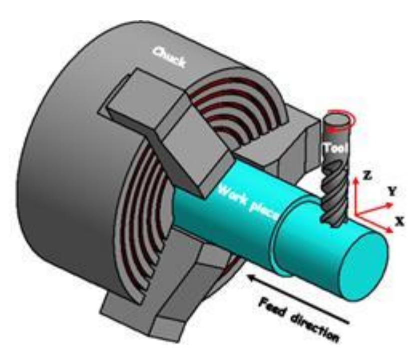

Figure 2: Movement of feeding processes orthogonal turn-milling

The orthogonal turn-milling, the turn-milling process is differentiated into up turn-milling and down turn-milling. Up and

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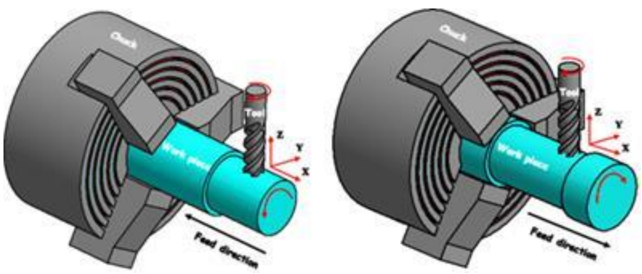
down turn-milling is influenced by the direction of rotation of the tool and direction of feeding.

a) Up orthogonal turn-milling

Up orthogonal turn-milling is influenced by the direction of rotation of the workpiece and the direction of the feeding tool. In the orthogonal process turn-milling. The direction of motion feeding tool to chuck with the direction of rotation of the workpiece counter clock wise as shown in Figure 3 (a). In other conditions it may be said to be turn-milling when the direction of the tool feed away from the chuck with the rotation of the workpiece clock wise as shown in Figure 3 (b).

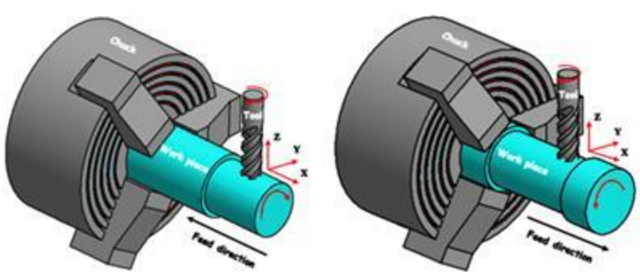


(a) (b)

Figure 3: Up orthogonal turn-milling

b) Down orthogonal turn-milling

The down orthogonal turn-milling is influenced by the rotation of the workpiece and the direction of the feeding tool. In orthogonal process turn-milling is said down turn-milling when the direction of motion feeding tool to chuck with the direction of rotation of workpiece clock wise as shown in Figure 4 (a). In other conditions it can be said down turn-milling when the direction of motion feeding tool away from the chuck with the direction of rotation of the work object counter clock wise as shown in Figure 4 (b).



(a) (b)

Figure 4: Down orthogonal turn-milling

2) Tangential turn-milling

The tangential turn-milling is another type of turn-milling operation where the tangent cutting tool to workpiece. As a result, unlike in the case of orthogonal turn-milling, in this case the chip is formed only by the side of the cutting tool as shown in Figure 5.

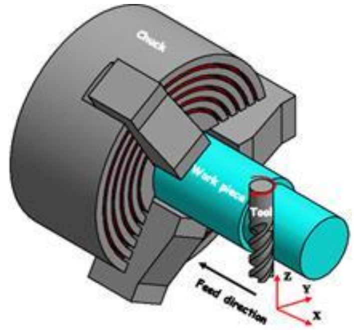
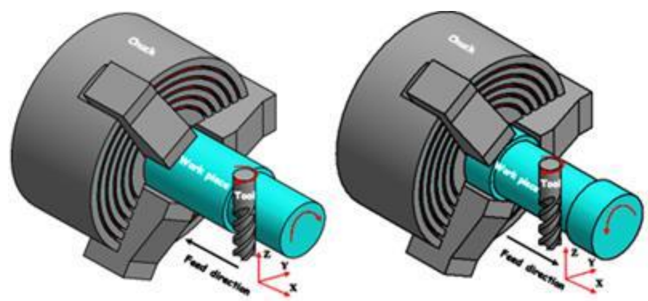


Figure 5: Movement of feeding processes tangential turn-milling

In the tangential turn-milling, the turn-milling process is differentiated into up turn-milling and down turn-milling. Up and down turn-milling is influenced by the direction of rotation tool and the direction of feeding.

a) Up tangential turn-milling

The up tangential turn-milling is influenced by the rotation of the workpiece and the direction of the feeding tool. In the tangential turn-milling process is said to turn-milling when the direction of motion feeding tool to chuck with the direction of rotation of workpiece clock wise as shown in Figure 6 (a). In other conditions it can be said to turn-milling when the direction of the tool feed away from the chuck with the direction of rotation of the workpiece counter clock wise as shown in Figure 6 (b).



(a) (b)

Figure 6: Up tangential turn-milling

b) Down tangential turn-milling

The down tangential turn-milling is influenced by the rotation of the workpiece and the direction of the feeding tool. In orthogonal process turn-milling is said to be down turn-milling when the direction of motion feeding tool to chuck with the direction of rotation of workpiece counter clock wise as shown in Figure 7 (a). In other conditions it is said down turn-milling when the direction of motion feeding tool away from the chuck with the rotation of the workpiece clock wise as shown in Figure 7 (b).

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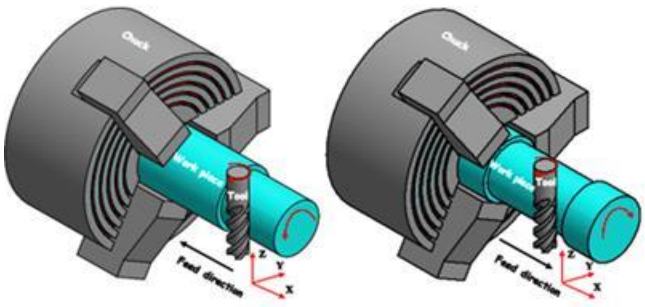

(a) (b)

Figure 7: Down tangential turn-milling

3) *Co-axial turn-milling*

In the co-axial test turn-milling the axis of the equal cutting tool with the workpiece, when the removal of material in the form of chip cutting tool tangent to the workpiece in this case the chip is formed by edge tool. The working step of co-axial turn-miling can be seen in Figure 8.

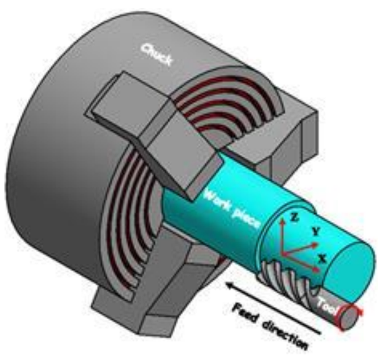

Figure 8: Movement of feeding processes co-axial turn-milling

In the co-axial turn-milling, the turn-milling process is differentiated into up turn-milling and down turn-milling. The up and down turn-milling is influenced by the direction of rotation tool and the direction of feeding.

a) Up co-axial turn-milling

The up co-axial turn-milling is influenced by rotation of workpiece and direction of tool rotation. In the co-axial turn-milling process is said to turn-milling when the direction of rotation of workpiece in the direction of rotation tool so that the rotation direction of the tool is opposite to the direction of rotation of the workpiece as shown in Figure 9.

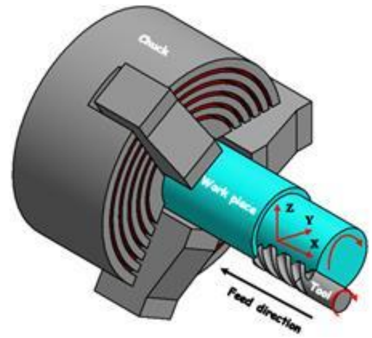

Figure 9: Up co-axial turn-milling

b) Down co-axial turn-milling

The down co-axial turn-milling is influenced by the rotation of the workpiece and the direction of the tool rotation. In the co-axial turn-milling process it is said down turn-milling when the direction of rotation of the workpiece is opposite to the direction of the rotation of the tool so that the rotation direction of the tool is in the direction of the rotation of the workpiece as shown in Figure 10.

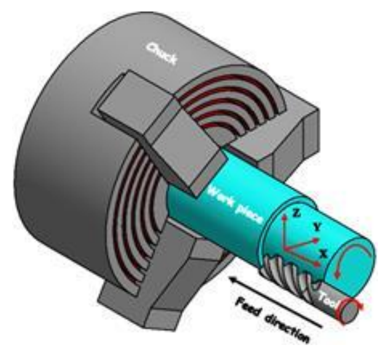

Figure 10: Down co-axial turn-milling

3.0 RESEARCH METHODOLOGY

The development of turn-milling on conventional lathe is done in Production Technology Laboratory of Mechanical Engineering Department of Universitas Riau. In order to perform turn-milling testing on a conventional lathe, a rotary tool is made to be mounted on a conventional lathe. The components of the rotary tool is attached on a conventional lathe that can be seen in Figure 11.

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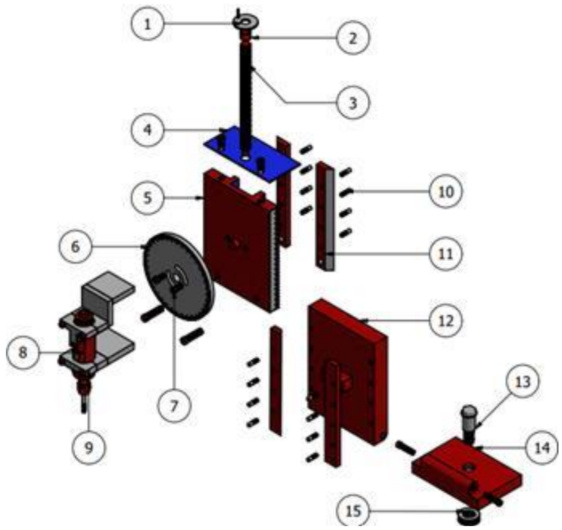


Details :
1. handle, 2. Bushing, 3. Threaded axis, 4. Buffer plate, 5 .Sled part II, 6. Setting holder, 7. Bold M 10, 8. diegrinder, 9. Bracket, 10. Bold M 6, 11. Rail track, 12. Sled part I, 13. Tool holder bold, 14. Tool holder, 15. Underpinning

Figure 11: Rotary tool components

Assembly of the rotary tool components can be seen in Figure 12.

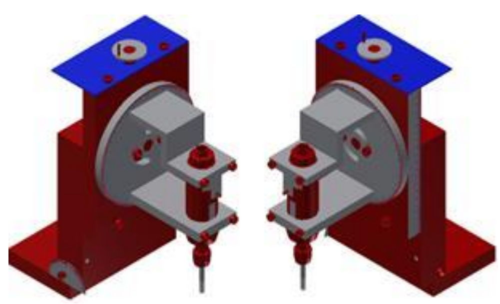


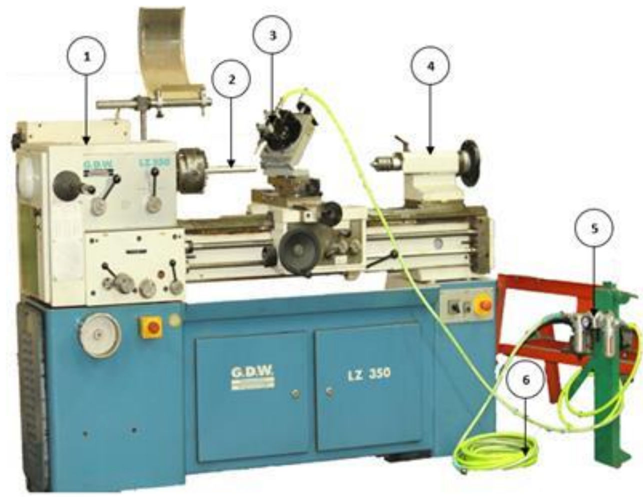
Figure 12: Assembly rotary tool

In the development of turn-milling, a motor was used diegrinder pneumatic with specifications that can be seen in Table 1.

Table 1: Specification of diegrinder

Specification	Dimension
Free Speed	25.000 (rpm)
Air Pressure	90 (psi)
Air Consumption	2,6 (cfm)
Air Inlet	1/4″ (npt,pt)
Hose Size	3/8 (inch)
Overall Length	6,1 (inch)
Horsepower	0,45 (hp)

The manufacture of turn-milling on a conventional lathe can be seen in Figure 13.



Details :
1. Conventional lathe machining, 2. Workpiece, 3. Rotary tool, 4. Tailstock, 5. Air filter regulator pneumatic, 6. Pneumatic house

Figure 13: Manufacture turn-milling

The conventional lathe specification in this research was used a lathe series G.D.W.LZ 350 with the specifications that can be seen Table 2.

Table 2: Specification of conventional lathe machine

Specification	Dimension
Length x width x height	1950 x 890 x 1300 mm
Weight	approx. 800 kg
Speed range	45-2000 r/min
Max. Turning length	750 mm
Automatic longitudinal	0,017 – 1,096 mm/rev
Motor power	2,4 kW

For specification air filter regulator pneumatic in this research was used the air filter regulator pneumatic series C80 with the specifications that can be seen Table 3. The air filter regulator functions were as air supply, pressure regulation and lubricating on diegrinder.

Table 3: Specification of air filter regulator pneumatic series C80

Specification	Dimension
Max. Temperature	60˚C
Max. Input Pressure	241 psi
Max. Output Pressure	214 psi
Air Inlet/Outlet	¼", 3/8", ½"
Gauge Ports	1/8"

On turn-milling test required measuring instrument digital tachometer. Type of digital tachometer used in this research that was a digital tachometer series DT.2234C with specifications that can be seen in Table 4. Digital tachometer can be peformed to measure the value of rotation cutting tool.

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Table 4: Specification of digital tachometer DT.2234C

Specification	Dimension
Testing Range	5 to 99999 rpm (r/min)
Resolution	0.1 rpm (2.5 TO 9 rpm)
Accuracy	± 0.05%
Sampling Time	0.8 sec (over 60 rpm)
Operation Temperature	0°C to 50°C
Detecting Distance	2 to 20 inch.
Testing Parameters	rpm, m/min, ft/min

4.0 RESULTS AND DISCUSSION

In the turn-milling process, the test parameters used for the cutting process can be seen in Table 5. The testing was performed on type of operating up and down in each orthogonal, tangential and co-axial operating system.

Table 5: Cutting was conditions used in turn-milling

Operating systems of turn-milling	Type	Tool radius (mm)	Number of teeth	Number of tool revolutions (rpm)	Workpiece radius (mm)	Number of workpiece revolution (rpm)	Actual Axial Cutting Depth (mm)	Axial Feed Rate per Revolution (mm/rev)
Orthogonal	Up	3	4	25.000	12,5	400	0,25	0,051
turn-milling	Down	3	4	25.000	12,5	400	0,25	0,051
Tangential	Up	3	4	25.000	12,5	400	0,25	0,051
turn-milling	Down	3	4	25.000	12,5	400	0,25	0,051
Co-axial	Up	3	4	25.000	12,5	400	0,25	0,051
turn-milling	Down	3	4	25.000	12,5	400	0,25	0,051

The specification of cutting tool milling was used in turn-milling test that can be seen in Table 6.

Table 6: Specification of milling cutter

Specification	Dimension
Diameter (mm)	6
Number of flutes	4
Helix angle (˚)	20
Flute lenght (mm)	19
Cutter overhang (mm)	57
Cutter material	HSS

During testing on the operating system of orthogonal, tangential and co-axial turn-milling decreases the rotation of the tool and the pneumatic pressure. Measurement of tool rotation was observed using a digital tachometer and pneumatic pressure measurements seen at the pressure gauge present in the air filter regulator.

The decreasing of tool rotation and pneumatic pressure were resulted in space during the testing process. So there were fine lines on test specimens.

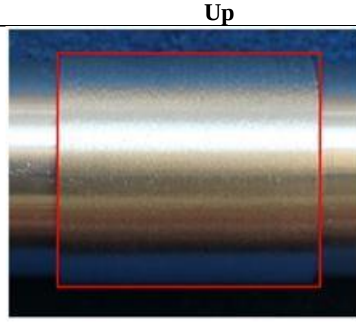
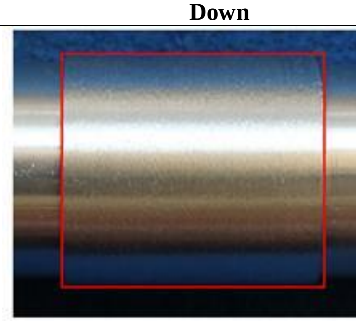
The value of tool rotation and pneumatic pressure on the orthogonal, tangential and co-axial operating systems can be seen in Table 7.

Table 7: Decreasing of tool rotation and pneumatic pressure

Operating systems of turn-milling	Type	Length of testing steps (mm)	Decreasing value	
			Tool revolution (rpm)	Pressure Pneumatic (psi)
Orthogonal	Up	25	600	15
turn-milling	Down	25	600	15
Tangential	Up	25	400	10
turn-milling	Down	25	400	10
Co-axial	Up	25	500	10
turn-milling	Down	25	500	10

The results of the turn-milling test can be seen in Table 8. The turn-milling test was performed by operating-up and down types on each orthogonal, tangential and co-axial operating system.

Table 8 Turn-milling test results

Operating systems of turn-milling	Type of operating systems of turn-milling	
	Up	Down
Orthogonal turn-milling		

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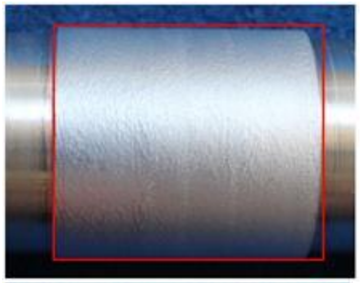
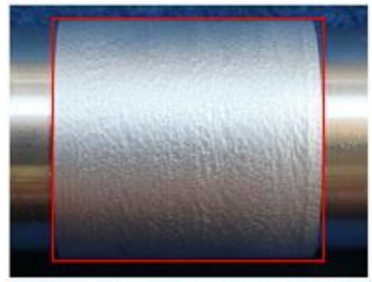
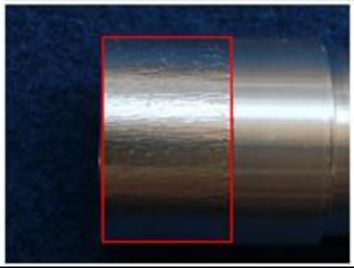
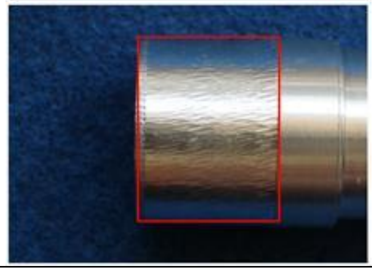
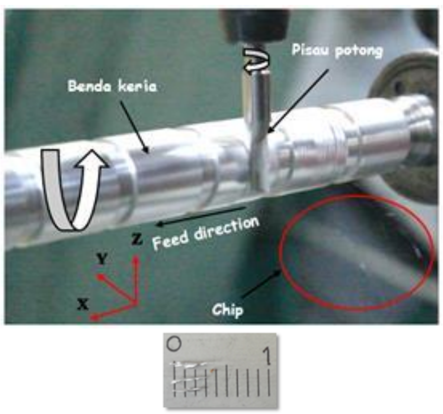
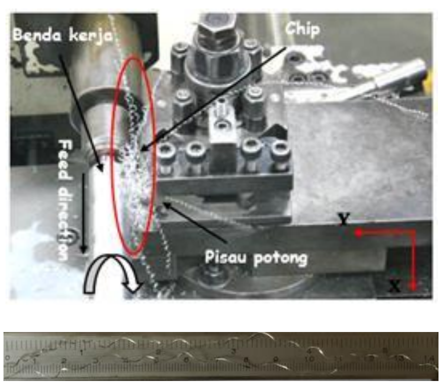
Tangential turn-milling		
Co-axial turn-milling		

For chips generated in the turn-milling test and conventional lathe with the same test parameters the radius of the workpiece 12,5 mm, the value of the workpiece revolution of 400 rpm, The actual axial of cutting depth of 0,25 mm, The axial feed rate per revolution of 0,051 mm/rev.



(a)



(b)

Figure 14: (a) Chip turn-milling (b) Chip convensional lathe

During the process removal material on work piece progressed on turn-milling that released automatically chips that can be achieved. That was due to the average length of the resulting chip size of ± 4 mm, so the chip did not stick to the work piece, which can be seen in Figure 14 (a). In the conventional lathe, the average length of the resulting chip was sized ± 15 cm and tend to roll up resembles a spring shape.

In conventional lathe work, the chip attached to the workpiece that can be seen in Figure 14 (b). Attaching the chip to the workpiece can increased in temperature at the time of material removal, subsequence, it can be a decreasing in the quality of test results.

5.0 CONCLUSION

Based on the results of development and testing of turn-milling on conventional lathe, it can be concluded as follows:

1) By modifying the conventional lathes machine to be the turn-milling process on a conventional lathe that can be performed successfully in this research.
2) On turn-milling process there is no chip attached during progress. Chips are discarded automatically with the turn of the cutting edge of the endmill cutting tool.
3) Development of turn-milling on conventional lathe is capable of to perform 3 (three) types of the operating system of turn-milling orthogonal, tangential, and co-axial turn-milling. Then, it can perform variations of testing with up and down types of operating system of turn-millng.
4) The 3 (three) types of operating system of turn-milling: orthogonal, tangential, and co-axial turn-milling, the good surface results are found in orthogonal turn-milling tests. For testing up and down feeds are obtained the good surface on the up feed tests.
5) The high decreasing of cutting tool rotation at the time of progress is, resultied the workpiece test results to be rough.
6) The amount of space that occurs during the test is caused by a diegrinder drive system using a pneumatic system, which the pneumatic drive system is a compressible system type.

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