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APPENDIX A

Table A1 Cutting tool evaluation report

Cutting Tool Evaluation Report													Company:			
☐ Turning ☐ Milling ☐ Endmilling ☐ Drilling													Name:			
													Date:			
Customer		Diagram/ Work Piece size, dimensions/Tooling/Number of Passes/etc.														
Product item																
Part name																
Work material																
	☐ HRC															
Hardness	☐ HB															
	☐ HS															
	☐ NC lathe ☐ Machining center															
Maching	☐ Special purpose machine															
type	Horsepower HP															
	(Kw)															

Tool	Manufacturer	1( )		2( )		3( )		4( )				
	Insert Cat. No.											
	Grade											
	Holder (Cutter Body)											
Cutting Conditions	Revolution (R.P.M.)											
	Speed:V (m/min or SFM)											
	Feed:f (mm/rev or IPA)											
	Feed:F (mm/min or IPM)											
	Depth of cut (mm or inch)											
	Cutting time (min/pe)											
	Coolant (dry or wet)											
Test data		No. of pcs	Reason for indexing*	No. of pcs	Reason for indexing*	No. of pcs	Reason for indexing*	No. of pcs	Reason for indexing*			
	1st Edge											
	2nd Edge											
	3rd Edge											
	4th Edge											
	Average per Edge											
	Results	Excellent Good Satisfactory Poor		Excellent Good Satisfactory Poor		Excellent Good Satisfactory Poor		Excellent Good Satisfactory Poor				

Tested Inserts
(Please attach on the right)

*Please select the number corresponding to the reason for indexing	(1) When surface finish deteriorates unacceptably	(4) When power consumption reaches limit
	(2) When a fixed amount of tool wear is reached	(5) Sparking or Chip Discoloration and Disfigurement
	(3) When work piece dimension is out of tolerance	(6) Cutting Time or Component Quantity

Table A2 Man-Machine chart

WORK NAME	MAN-MACHINE CHART	Y	M	D	T1: OPERATING TIME
LINE					T2: MACHINE TIME
					T3: IDLE TIME

No	PROCESS	T1	T2	T	MAN	1	2	3	4	5	6
	total T1										

T(MAX)	
SUM T1	

LINE LAYOUT

Table A3 Daily production report

Daily productin report

Part No.	(1)				DATE	/ 199
Quantity require	(2)		SHIFT	(3)	LINE	(4)

Part name	Production time	Finish work		Down time	Code	Cause	Lost time code	Total time
		pcs/time	accumulate	From- To			A :Change new model	
	8.00-10.00	(5)	(6)	(7)	(8)	(9)	B: Change tool	(10)
	10.00-10.20						C: internal R/M shortage	
	10.20-12.00						D: Lubrication	
	12.00-12.40						E: machine breakdown	
	12.40-15.00						F: Adjustment	
	15.00-15.10						G: Electric & Air	
	15.10-17.00						H: Lack of raw material	
Over time	(12)						I: Quality of raw material	
							J: Other	
Total quantity(pcs)			(13)				Total time(min)	(11)

Non-conforming form machining

Code	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
PROBLEM	DIAMETER OVER SPEC	DEPTH OVER SPEC	PARALLEL NG(//)	PERPENDICULAR NG	CIRCULARITY NG	RUNOUT NG	CONCENTRICITY NG	P.C.D NG	SCREW OVER SPEC	DAMAGE OF DRILL	TAPPING NG	ROUGHNESS NG	PITCH NG	RADIUS NG	SETTING NG	ELECTRIC PROBLEM	MACHINE MISTAKE	FORGET MACHINE	FLAW	MACHINE NOT FINISH
QTY	(14)																			
PCs																				

Raw material NC

	001	002	003	004	005	006	007	008	009	010	011
	MACHINING ALLOWANCE(-)	MACHINING ALLOWANCE(+)	HARDNESS	BLOW HOLE	APPEARANCE	CRACK	DELAMINATION	RUST, OXIDATION CORROSION	DIMENSION	LEAK	COMPONENT PART NG FORM DISASSY
QTY	(15)										
PCs											

TOTAL M/C-NC (16) PCs

TOTAL R/M-NC (17) PCs

TRANSFER FW FROM SHIFT PCS (18)		TOTAL FW (19) PCS		Qty for stock shift (20) 2 3	Total (21) pcs
Reporter (22)	leader (23)	supervisor (24)	comp (25)	Operator (26)	

Explanation of daily production report

1) Product's part number
2) Quantity needed
3) Shift number
4) Machine line number
5) Quantity of product
6) Accumulate quantity
7) Stop time
8) Code of stop time
9) Cause of stop time
10) Total lost time
11) Total working time
12) Over time period
13) Total quantity
14) Quantity of machining NC part
15) Quantity of NC form raw material
16) Total quantity of machining NC part
17) Total quantity of raw material NC part
18) Quantity of finished work from previous shift
19) Total finished work = 13) + 18)
20) Total stock in shift
21) Total quantity in stock
22) Recorded by
23) Leader's name
24) Supervisor's name
25) Computer recorded by
26) Operator's name

Table A4 tooling inspection report

INSPECTION REPORT							
CUSTOMER				MFG. NO.			
TOOL No.				DWG.NO.			
TOOL NAME				P.O.NO.			
QUANTITY				INSPECTOR		DATE	
DESCRIPTION							
DIMENSION							
TOLERANCE							
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
DESCRIPTION							
DIMENSION							
TOLERANCE							
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
NOTE							

Table A5 Improvement report

IMPROVEMENT REPORT	
FROM: PRODUCTION ENGINEER DEPT.	DATE
	M.C. No.

1. ข้อมูลจากแผนกผลิต/MANUFACTURING INFORMATION

LINE	PART NAME	PROBLEM
MACHINE	PROCESS	

2. การตรวจสอบและสาเหตุ / DISCOVERY AND CAUSE OF DEFECT

3. การแก้ไขเบื้องต้น / IMMEDIATE COUNTERMEASURE ACTION/TAKEN:

4. การแก้ไขระยะยาว / PERMANENT COUNTERMEASURE

ACTIVITY PLAN

Action Item	by	Date

Action Item	by	Date

ประมาณราคา/COST EVALUATION

Approved b	Report by	Checked by

APPENDIX B

Table B1Time for check dimension and record data in check sheet.

No.	MACHINE	JIG No.	Process	Tooling	DIMENSION	UPPER LIMIT	LOWER LIMIT	INSTRUMENT CHECK	TIME/ SHIFT
1	AUTO DRILL		DRILL DIA 4	DRILL	DIA 4	+0.2	-0.1	VERNIER	2
2	CNC MACHINE	JIG 1	REAMER DIA 10	BURINSHING REAMER	DIA 10	+0.3	0.1	VERNIER	2
	(OKK)								
			TAP M8	TAP M8	M8*1.25			GO-NOGO GAGE	2
					DEPTH 15	+1.5	-0.5	SPECIAL GAGE	2
			DRILL DIA 13	STRAIGHT DRILL					
			FACING	FACE DIA 125					
			ENDMILL	ENDMILL DIA 50					
				THICKNESS	53.6	0	-0.2	VERNIER	3
				THICKNESS	24	+0.1	-0.1	VERNIER	3
			BORING	BORE DIA 90	DIA 90	+0.046	0	CYL.GAGE	5
				DEPTH 10	10	+0.05	0.015	DIAL DEPTH GAGE	5
			BORING	BORE DIA 53	DIA 53	+0.03	0	CYL.GAGE	5
			2- REAMER	REAMER DIA 6	DIA 6	-0.03	-0.055	PLUG GAGE	2
				DEPTH 9					
			ROUGH REAM DIA 16.5						
			2- DIA 11	REAMER DIA 11	DIA 11	+0.027	0	CYL.GAGE	5
					DEPTH 16.5				
			DRILL DIA 28*60	DIA 60	DIA 60	+0.046	0	CYL.GAGE	5
				DEPTH 7.5	7.5	+0.3	-0.3	DEPTH VERNIER	2
				DIA 28	DIA 28	+0.033	0	CYL GAGE	5

No.	MACHINE	JIG No.	Process	Tooling	DIMENSION	UPPER LIMIT	LOWER LIMIT	INSTRUMENT CHECK	TIME/ SHIFT
				DEPTH 7.5	7.5	+0.3	-0.3	DEPTH VERNIER	2
			GROOVE	DEPTH	3			VERNIER	2
				WIDTH	3.2	+0.025	0	SPECIAL GAGE	2
				DIA 30.8	30.8	+0.2	-0.2	PLUG GAGE	2
			CHAMFER						
3	TAP MACHINE		PT 3/8					THREAD PLUG GAGE	2
4	DRILL DIA 9		DRILL HSS DIA 9	POSITION	31.8	+0.3	-0.3	SPECIAL G.	2
5	CNC MACHINE		END MILL	ENDMILL DIA 36	36	+0.2	-0.2	PLUG GAGE	2
	(ENSHU)	JIG 1		DEPTH 1.8	1.8	+0.05	-0.05	SPECIAL GAGE	2
			REAM COVER	REAMER DIA 18.5	18.5	+0.021	0	CYL GAGE	5
			TAP M20	TAP M20					
			REAM DIA 17	REAMER DIA 17	DIA 17	+0.018	0	CYL GAGE	5
			TAP M6	TAP M6	M6*1.0			GO-NOGO GAGE	2
			DEPTH 10		10	+1.5	-0.5	SPECIAL GAGE	2
			DEPTH 12		12	+1.5	-0.5	SPECIAL GAGE	2
6	CNC MACHINE								
	OKK	JIG 1	DRILL DIA 14.7	CARBIDE					
			REAM DIA 15	BURNISHING REAMER	DIA 15	+0.018	0	CYL.GAGE	5
			DEPTH 41		41	+0.3	-0.3	VERNIER	2
			SPOT FACING	SPOT FACING					

No.	MACHINE	JIG No.	Process	Tooling	DIMENSION	UPPER LIMIT	LOWER LIMIT	INSTRUMENT CHECK	TIME/ SHIFT
			TAP M18		M18 * 1.5			PLUG GO-NOGO	2
			DEPTH		10	+1.5	-0.5	SPECIAL GAGE	2
		JIG2	FACING DIA 80						
			TAP M8	THREAD	M8*1.25			PLUG GO NOGO	2
				DEPTH	12	+1.5	-0.5	SPECIAL GAGE	2
			TAP M6	THREAD	M6*1.0			PLUG GO NOGO	2
				DEPTH	10	+1.5	-0.5	SPECIAL GAGE	2

APPENDIX C

TableC1 Data of lost time form Jan-Aug 97

LOST TIME (min)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	avg.
M05	7782	10832	11730	8895	6565	7958	8513	4765	8380
M16	8758	5865	7785	9742	7002	8364	8759	6948	7903
M06	7379	5792	7758	6594	4318	6283	6396	1960	5810
M20	6055	7082	7280	5180	3739	5257	6790	3450	5604
M22	7267	5542	5717	7310	2195	5344	5464	1404	5030
M17	6009	3917	5306	4957	3810	4810	4414	2442	4458
M07	6402	4008	5596	3951	4019	3551	5476	2439	4430
M04	7769	5915	6658	4446	2013	1915	2471	642	3979
M08	5750	2957	3520	1755	2430	0	4795	5317	3789
M18	7473	3344	3161	1676	2395	1787	6840	2045	3590
M03	1188	3124	4943	3666	1960	5034	0	0	3319
M24	7266	5525	4907	710	1879	1582	1812	980	3083
M02	3820	2815	3115	3224	2552	3127	2815	2943	3051
M19	3698	2231	3048	3210	2644	2221	2137	1383	2572
								TOTAL	64998

Table C2 Data of time study for manual operation

Time study of manual operation

Proces	Description		Operation time(min)										
	Start	Finish	1	2	3	4	5	6	7	8	9	10	Avg.
1	Pick up R/M from rack	Push start bottom of M/C1	0.12	0.1	0.1	0.1	0.1	0.12	0.09	0.1	0.11	0.1	0.10
2	Push start bottom of M/C1	Push start bottom of M/C2	0.52	0.53	0.53	0.53	0.53	0.52	0.53	0.53	0.53	0.52	0.53
3	Push start bottom of M/C2	Push start bottom of M/C3	0.27	0.3	0.27	0.31	0.3	0.27	0.31	0.31	0.3	0.3	0.29
4	Push start bottom of M/C3	Push start bottom of M/C4	0.1	0.1	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.10
5	Push start bottom of M/C4	Push start bottom of M/C5	0.2	0.21	0.2	0.21	0.22	0.2	0.22	0.22	0.2	0.16	0.20
6	Push start bottom of M/C5	Assembly cover with O/P	0.34	0.35	0.34	0.35	0.34	0.35	0.34	0.36	0.34	0.34	0.35
7	Assembly cover with O/P	Push start bottom of M/C7	0.2	0.23	0.22	0.2	0.21	0.2	0.22	0.21	0.21	0.2	0.21
8	Push start bottom of M/C7	Push start bottom of M/C8	0.24	0.23	0.25	0.26	0.25	0.25	0.25	0.24	0.25	0.23	0.25
9	Push start bottom of M/C8	Unload work form jig	0.35	0.37	0.36	0.36	0.37	0.38	0.37	0.36	0.37	0.36	0.37
10	Pick up work from jig	Push start bottom of M/C7	0.11	0.11	0.11	0.1	0.1	0.11	0.1	0.1	0.1	0.1	0.10
11	Push start bottom of M/C7	Unload work form jig	0.15	0.17	0.15	0.16	0.17	0.17	0.16	0.17	0.18	0.17	0.17
12	Unload work from jig	Push start bottom of leak checker	0.4	0.41	0.4	0.41	0.42	0.4	0.4	0.39	0.4	0.4	0.40
13	Push start bottom of leak checker	Pick up R/M form rack	0.41	0.4	0.41	0.4	0.41	0.39	0.41	0.4	0.4	0.4	0.40
											Total time		3.47

APPENDIX D

Burnishing reamer.

Problem of burnishing reamer is 2.1 % of total working time. Function of burnishing reamer is to make an existing hole dimensionally more accurate than can be obtained by drilling alone and surface finish is better than drilling.

This tool used for cutting and burnishing the relief valve hole. Surface roughness is the important characteristic for this part because it will affect the movement of valve.

Problem

Generally, there are many source of roughness

1) feed marks left by the cutting tool
2) built-up edge fragment embedded in the surface during the process of chip information
3) Chatter marks from vibration of the tool, workpiece, or machine tool.

Problem of roughness in this process comes from 2 case, there are roughness from inappropriate cutting condition and from melt at cutting tool (B.U.E). The BUE causes cyclic gorging and smoothing of the surface as the BUE sloughs off. The different between graph of surface roughness are as follow (figure D1-figure D3).

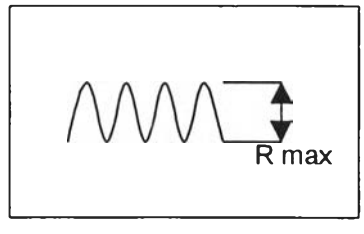


Figure D1 Ideal roughness

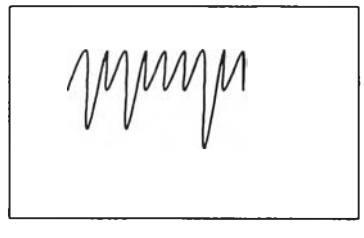


Figure D2 Roughness with affect of chatter

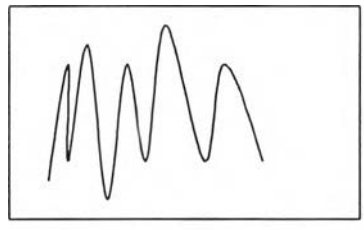


Figure D3 Roughness with BUE

Description about burnishing reamer

Tool in this process is burnishing reamer. It composes of 2 cutting edges and 2 burnish point. As figure show the cutting position of tooling (figure D4).

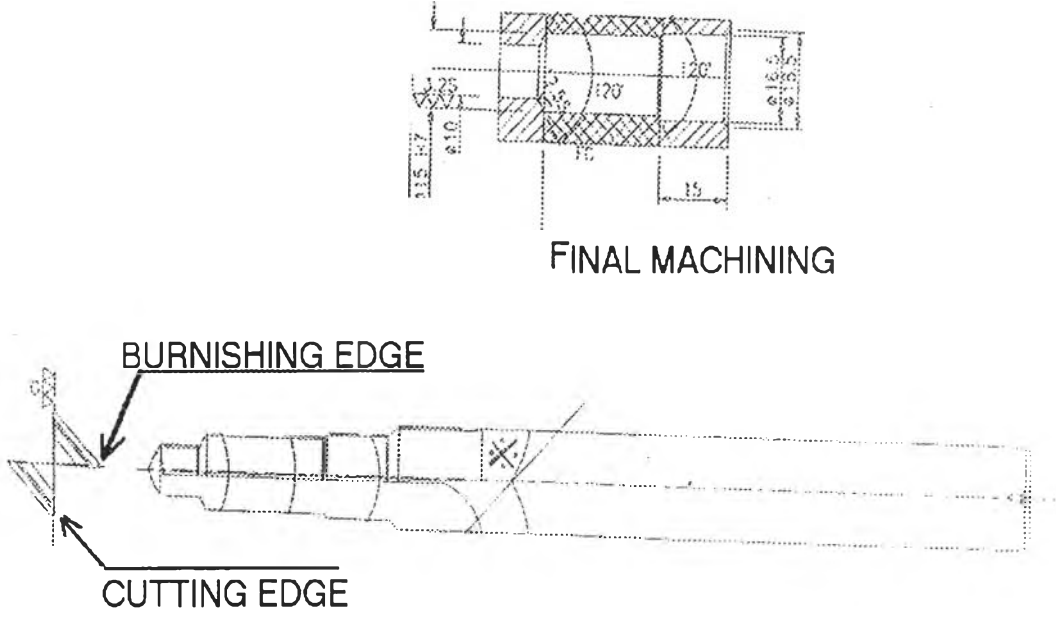


Figure D4 Burnishing reamer

Cutting edge use to cut the diameter of hole and burnishing edge will make a fine surface roughness.

Objective of using burnishing reamer is to make a good surface finish and accurately size of hole. Recommendations for using burnishing reamer are

- Burr form the cutting edges should be removed to produce surface finish
- Cutting fluid should be used in the reaming gregration to improve the hole finish and increase tooling life.
- Roughing reamer need for good surface finish and hole accuracy
- If chatter occurs, stop the machine, reduce the speed, and increase the feed. To overcome the chatter marks.
- Slower speeds should be used when the set up is less rigid.
- Feed which are too low generally result in glazing, excessive reamer wear, and sometimes chatter. Too high a feed tends to reduce the hole accuracy and sometimes results in poor surface finish.

Analyze cause

Check cause and effect of each problem(figure D5), list all the possible cause and improvement plan(Table D1).

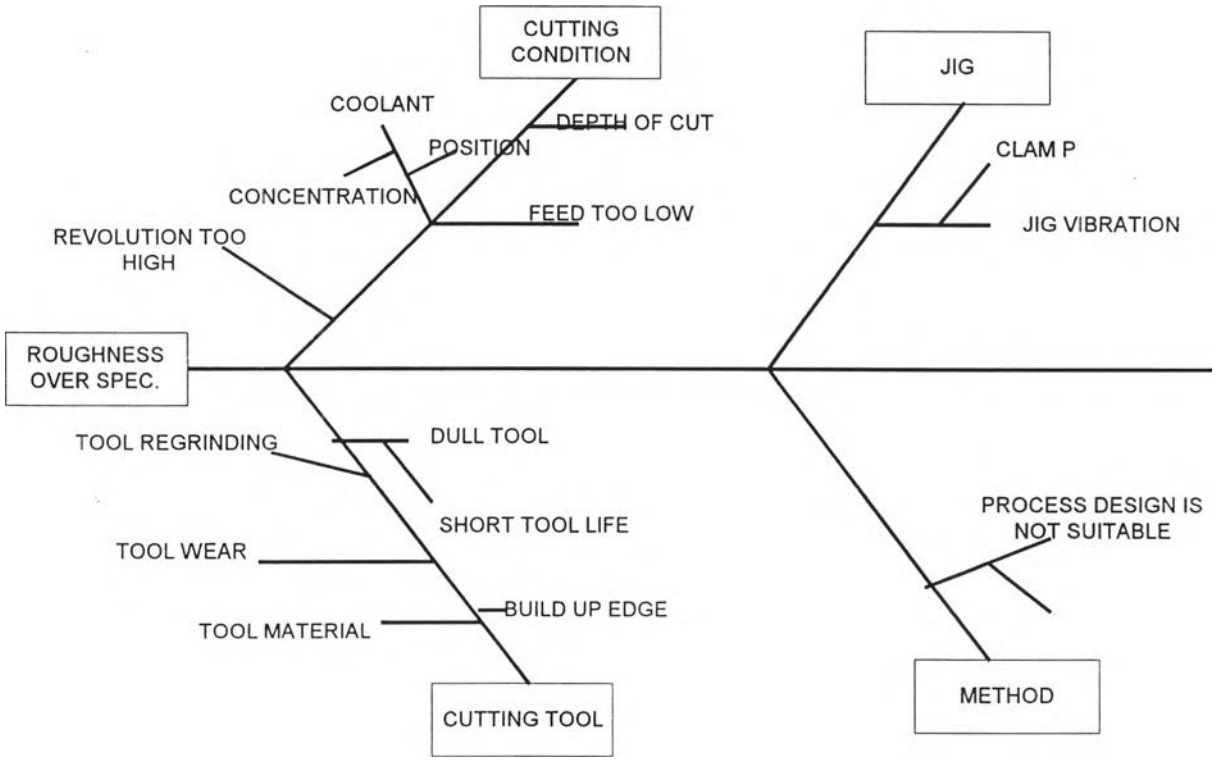


Figure D5 Cause – effect diagram of faulty surface roughness

Table D1 Improvement plan

Tool name	*Main problem*	*1st cause*	*2nd cause*	*Improvement plan*
Burnishing reamer diameter 15	*Roughness*	*Built-up-edge*	*Coolant flow is not enough.*	*Adjust coolant flow.*
				Use a special tool
		Cutting condition	*Feed speed is high*	*Check and adjust feed speed*
			Depth of cut	*Increase rough cutting process*
		Coolant is not enough	*Coolant concentration is not enough.*	*Increase concentration of coolant.*
			Filter of coolant is clogged	*Clean coolant tank*
			Coolant oil is dirty	*Clean coolant tank*
		Cutting tool is not sharp	*Regrinding is not good*	*Tooling section will check tool after*
			No standard frequency to regrinding tool.	*Set tool life*

Target of improvement

1. improve surface roughness
2. eliminate BUE

1. **Improve surface roughness**

   The strong effect which should be checked by collecting data

Objective of experiment

Feed and cutting speed are factor, which affect surface finish. The experiment is used to investigate the relationship between feed, cutting speed and surface roughness of burnishing reamer.

Tool and test equipment

1) Tool pre-setter foe check run-out of tool.
2) Roughness tester

Experiment procedure.

1) Set burnishing reamer in tool holder by control run-out of tool after checking would be less than 0.005mm. The big run-out will cause over sized hole2s and when used on a machine with low rigidity, it may cause tool breakage.
2) Set tool at machine spindle.
3) Varies feed and cutting speed and check surface roughness after machining.
4) Check result after improvement (Table D2, figure D6 , figure D7)

Experiment result

Table D2 Experiment result

Cutting speed	Feed		
	0.05	0.1	0.25
20	4.9	6.2	6.5
30	5.5	6	7.6
50	5.9	6.2	7.7
0	5.6	6.4	8.2
80	6.1	6.9	8.5

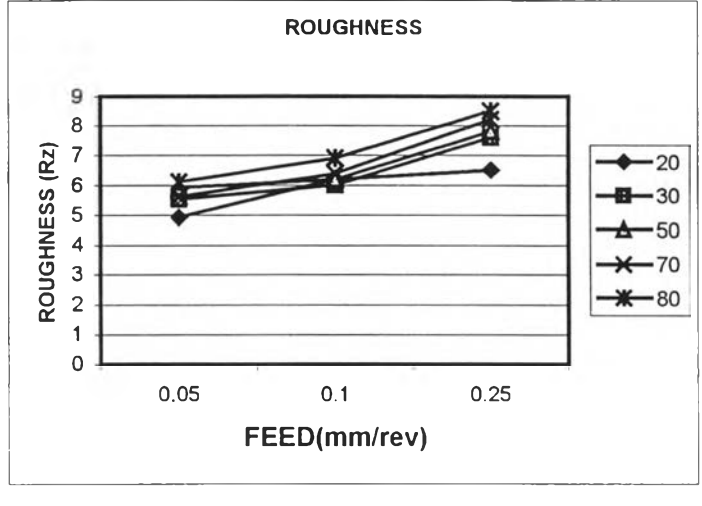


Figure D6 Relationship between surface roughness and feed speed

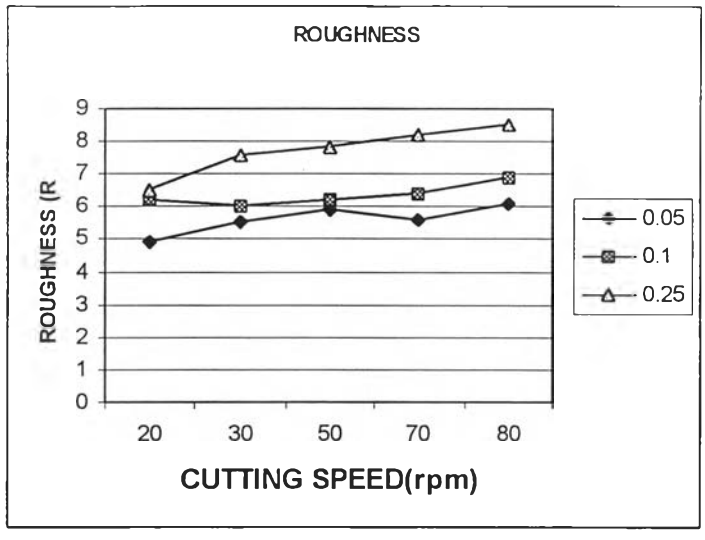


Figure D7 Relationship between surface roughness and cutting speed

Conclusion

Surface roughness depends on cutting speed and feed. From the experiment, if cutting speed increase, surface roughness will be increase. On the other hands, high feed causes high surface roughness. Conditions for control roughness within 6.25 z is between 20-70 rpm and 0.05-0.1 mm/rev.

Effect of coolant with surface roughness.

Coolant concentration, which is recommended by seller, is between 3-5%. But for some case for higher quality of surface roughness, the concentration of coolant may be increase.
A different concentration causes a different surface roughness. As the following experiment compare between coolant concentration at 5% ,10 % and 20 % which affect roughness of valve hole.
The experiment will test the effect of surface roughness and concentration of coolant.

Tool and test equipment.

1. Refractrometer for check concentration of coolant.
2. Roughness tester.

Experiment procedure.

1) Use the same jig and tool as previous process.
2) Prepare coolant for test. 4 types of coolant
    1. 5%

2. 10%
3. 20%
4. neat oil

Set cutting speed and feed rate at 1480 rpm and 0.1 mm/rev.

Cutting condition

Work material: FC

Tool type: Burnishing reamer (carbide grade K10)

Cutting speed (V): 70 m/min

Feed rate (f): 0.06 mm/rev

Depth of cut: 0.15 mm

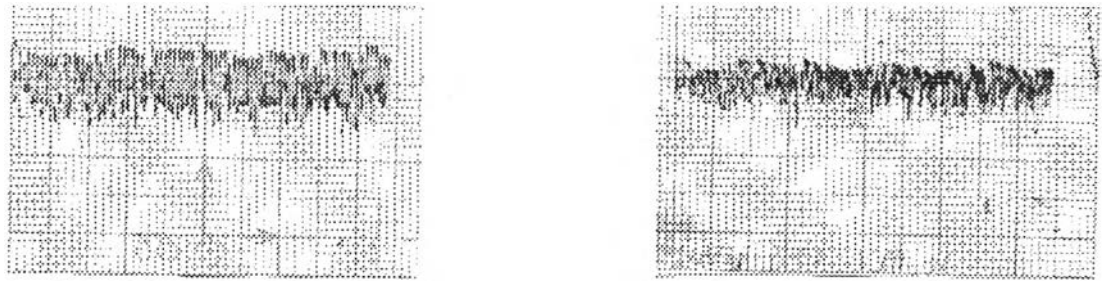
3) Cutting and check surface roughness for each condition.

Result of experiment.

Table D3 Result of coolant concentration with surface roughness

	5%	10%	20%	Neat oil
1480,148	6.0	5.2	4.2	8.0

Graph of surface roughness between coolant concentration 10% and 20%(figure D8)



COOLANT 10%

10.8z

COOLANT 20%

8.0z

Figure D8: Surface roughness with coolant concentration.

1. Built-up edge chips.

Chips melts at the tip of tool during cutting. It's one factor that affects surface finish in cutting. BUE occurs at the tip of cutting edge. Frequency of adjusting from Jan to Mar is 10,11 and 12 times. The NC product form roughness is 18 pieces.

We can decrease the melt by

1.1 Adjust coolant flow.

Coolant pipe at the spindle head is not directly injected at the hole. To increase the coolant flow at specify point, we use the longer coolant pipe joint from spindle. The longer coolant pipe is easier to adjust coolant flow to the fix point.

1.2 Depth of cut.

High depth of cut makes the high resistant force. Diameter of raw material is 14.3 mm , depth of cut is 0.7 in the diameter. The recommendation for burnishing reamer is 0.2-0.3 mm on diameter. The rough cutting by carbide drill will be used for reduce depth of cut.

1.3 Cutting condition is not suitable.

- Feed speed is high
- Cutting speed is high or low.

As the experiment of relationship between cutting speed, feed speed and roughness.

Result

Lost time of adjust tool burnishing reamer diameter 15(Table D4, Figure D9)

Table D4 Result after improvement

TOOL NAME	*JAN*		*FEB*		*MAR*		*APR*		*MAY*		*JUNE*	
	Time(min)	*%*	*Time(min)*	*%*	*Time(min)*	*%*	*Time(min)*	*%*	*Time(min)*	*%*	*Time(min)*	*%*
BURNISHING REAMER DIA 15	*270*	*1.7*	*360*	*2.3*	*420*	*2.2*	*190*	*0.9*	*190*	*0.9*	*185*	*0.6*

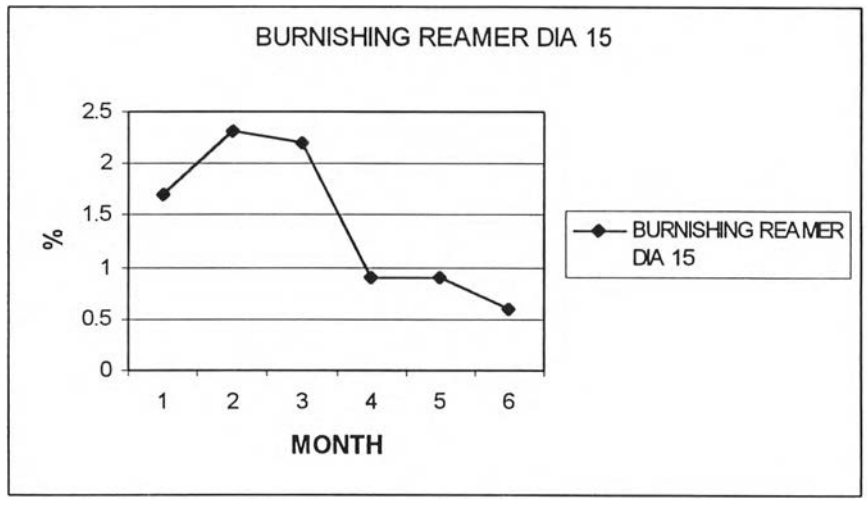


Figure D9 Result after improvement

APPENDIX E

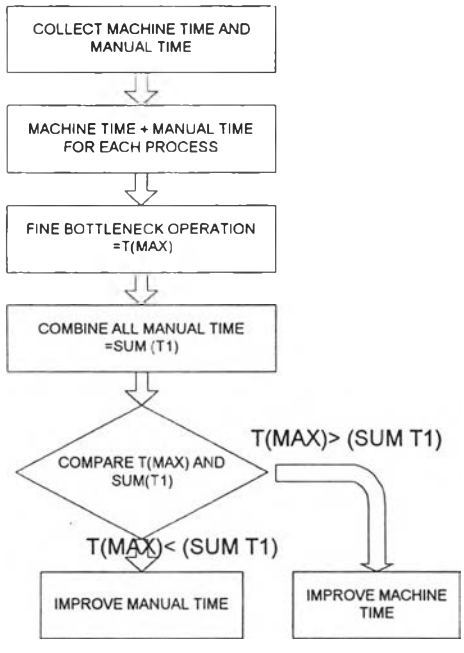
Appendix E1 Machining process of line M05

Process No.	Machine	Equipment	Description
Drill oil drain	SUGINO multi-drill	3-drill diameter 4	Drill 3 holes diameter 4mm
Rotor room machining	OKK machining center	Reamer diameter10	Ream dia. 10 +0.3 +0.1
		Tap M8	TAP 3 hole size M8
		Drill diameter 13	Drill hole diameter 13
		Face milling diameter125	Milling surface
		Endmill diameter 50	Rough cutting for boring dia 90,53
		Boring diameter 90	Cutting diameter of gear room.
		Boring diameter 53	Cutting diameter of gear room.
		Reamer diameter6,16.5,11	Ream hole for press pin
		Cutter diameter 28X60	Cutting hole for press oil seal.
		Grooving cutter	Groove o-ring hole
		Chamfer	Chamfer diameter 60
TAP PT 3/8"	KIRA tapping machine		TAP PT 3/8"
Drill diameter 9	Bench drill machine		Drill hole 9 depth 31.8
Press pin	Press machine	Press	Press pin height 4.5
Set bolt and cover	Jig & air tool		Assembly balance gear cover with oil pump case
2-side machine	ENSHU machining center	Endmill diameter 36	
		Reamer diameter 18.5	
		TAP M20	
		Reamer diameter 17	
		Tap M6	TAP 6-M6 for assembly
Valve hole	OKK machining center	Drill diameter14.5	Rough cutting for valve hole
		Reamer diameter 15	Burnish valve hole
		Spot facing diameter 15	Milling valve hole
		Tap M18	TAP M18 1 hole
		Face milling diameter 80	Make good surface finish
		TAP M8	2- TAP M8
		TAP M6	6-TAP M6

Appendix E1 Machining process of line M05 (continue)

Process No.	Machine	Equipment	Description
Set bolt & cover	Jig		Unassembled balancing gear and oil pump case
Cleaning	Cleaning machine		For cleaning oil pump after machining
Press plug	Air tool		Tightening torque 29-44 N-m
Check leak	Leak checker		Check leak of oil pump body
blowing	Blowing machine		Eliminate water from product.

Appendix E2 : Method of operation analyzing



Procedure for using man-machine chart

1. Collect data of machining time for each machine.
2. Collect data of operating time for each process.
3. Combine machining time and operation time for each process.
4. Find bottleneck operation (Tmax).
5. Combine all operation time (Sum T1).
6. Compare between (Tmax) and (Sum T1).

   If Tmax > sum T1, Standard time = T (max)

   If Tmax < sum T1, Standard time = Sum T1
7. Record data into man-machine chart. As in Appendix A ,table A2

BIOGRAPHY

Ms. Surasa Mahakantha was born on 2 June 1972. She got her Bachelor Degree in Industrial Engineering from Chiangmai University in 1994.In 1996. She was registered as a part-time student and study in Engineering Management Program of Chulalongkorn University and in Manufacturing System Engineering of the University of Warwick at the Regional Centre for Manufacturing system Engineering, Chulalongkorn University, Thailand. She has been working in auto-part industry for 3 years.