Technical University of Liberec

Faculty of Mechanical Engineering

Basis of Machine Tool Selection

Diploma project

Study discipline: 2301 T Manufacturing Systems

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KVS - 149

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Extent of the Diploma Project

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Number of drawings: 1

Acknowledgment

From all the people that have helped me through out my studies, my greatest gratitude goes to my parents for their patience and constant support during all stages of my life, without which I would have never made it so far.

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Annotation

THEME: Basis of Machine Tool Selection

ANNOTATION: Diploma project deals with detailed description of machine tool procedure of assessment for particular part machining. It shows all steps in process procedure description, time calculation, CNC programme development, and economy calculation.

TÉMA: Základy pro výběr obráběcího stroje

ANOTACE: Diplomová práce se zabývá detailním popisem postupu hodnocení stroje při obrábění typové součásti (dílu). Ukazuje postupné kroky nezbytné pro hodnocení, technologický postup, výpočty časů, CNC vývoj programu a ekonomické hodnocení.

Declaration

I declare that I developed my diploma project independently with aid of referred literature under the control of supervisor and consultant.

In Liberec, 23- 5- 2003

Signature

…….……………

Symbols and Abbreviations

L_{PL}	[mm]	Length of semi-part
$L_{max.Part.}$	[mm]	Max. Length of part
P_{RL}	[mm]	Additions for rough cutting length
P_{FCL}	[mm]	Addition for finishing length
D_{PL}	[mm]	Diameter of Semi-part
$D_{max.Part.}$	[mm]	Max. Diameter of part
P_{RD}	[mm]	Additions for rough cutting diameter
P_{FD}	[mm]	Additions for rough cutting diameter
L_{PL}	[mm]	Length of semi-part
$L_{Bar\ length}$	[mm]	Minimum. length of bar
t_A	[min]	Unit time
t_{A11}	[min]	Unit time when machine still stand
t_{A13}	[min]	Manual unit time machining
t_{Ax}	[min]	Irregular time for service
t_{AC}	[min]	Standard unit time with shift time rate
t_{BC}	[min]	Standard Batch time with shift time rate
t_B	[min]	Batch work portions
t_{B1}	[min]	Batch work portions for conventional operation
t_{B2}	[min]	Batch work portions for automated operation
t_C	[min]	Total Shift time
t_{C1}	[min]	Times of shift work
t_{C2}	[min]	Times of shift generally necessary breaks
t_S	[min]	Machine time
k_C		Coefficient of shift time
T		Average time of working shift
Q_S	[kg]	Part weight
Q_V	[kg]	Restoring material
Z_M	[kg]	Material lost
N_M	[kg]	Standard of material consumption
K_M		Coefficient usable material
Ss	[Kč]	Comparable machine cost
F_O	[hours]	Factor of repayment
D_0	[years]	Lifetime for repayment
F_{UO}	%	Factor of maintenance
N_U	%	Cost of maintenance
T_R	[years]	Machine effective time
P_D		Working days per year
S		Shifts
F_E	[kW]	Factor of energy
P	[kW]	Power input
K_{pr}	%	Coefficient of power
K_v	%	Coefficient of work of machine
C_E	[Kč/KWh]	Costs of energy
C	[Kč]	Cost of machine

t_k	[hour]	Piece time
Np	[Kč]	Costs of machine adaptation
M	[kč / h]	Operator wage
R_m	[kč / h]	Overhead
S_{CS}	[kč / h]	Large machine cost
Nc	[kč/piece]	Piece cost
n	[rpm]	Number of revolution
v	[m/min]	Cutting speed
i		Number of Path
S	[mm/rev]	Cutting feed
h	[mm]	Depth of cut
Ts	[hour]	Setup time in shift
Cs	[Kč]	Setup cost
CPO		Cost per order
U	[kč/batch]	Total cost of production per Batch
Mc	[kč/piece]	Material cost
C_{KO}	[Kč]	KOYO TURN 42T Cost
C_{SP}	[Kč]	SPACESAVER Cost
C_{SH}	[Kč]	HACKSAW Cost
Cs_{32}	[Kč]	S32 Cost
Ssc	[kč/h]	Conventional machine repayable time
Ss_A	[kč/h]	Automated machine repayable time
Scs	[kč / h]	Total machining cost

1. Introduction

This project is designed to fill the need for a concise elementary text for those who are in need of acquiring theoretical and practical information about procedures of Basis of Machine Tool Selection.

A Good selection of machine tool, causes an improvement of production, we have to consider the following steps:

-Reasons for acquiring machine tools

-Product considerations (workpiece analysis, batch size)

-Method of production (Choice of manufacturing process and type of machine tool)

-Defining the specification of the machine tool (User's requirements and manufacturer's offers)

-Company consideration (financial, human and commercial consideration)

-Market situation

to achieve the efficient economical way of selection.

GOAL

To show and develop steps necessary to justify machine tool.

The product of concern is special tool nozzle as on drawing **0-KVS-VS-149-001** from:

Material of AlCuMgPbF37

Size ∅12 x 48.3

2. Technical procedures

2.1 Workpiece analysis from technological point of view.

From drawing - 0-KVS-VS-149-001 - : (see appendix)

- Material is aluminum AlCuMgPbF37,
- Final product is rounded bar ∅ 12 – 48.3 mm ČSN 424254.6, corresponding machineability 8d (for turning work).
- Part weight 0.0034 kg
- Turning lathe center is involved in machining the semi-part.
- Surface roughness R_a= 3.2µm

Fig 1.1

Production capacity:

- Small to middle series 1000 [pieces/year], for conventional machining.
- Large series– 100000 [pieces/year] for automated CNC machining.

2.2 Design of semi-part considering the way of production and minimum allowances.

For production is selected semi-part ČSN 424254.6. Semi-part is rounded bar of aluminum AlCuMgPbF37,

2.2.1 Minimal length of semi-part

Minimal length of semi-part L_{PL} considering the minimum working allowance for machining is defined according to relation (2.1)

$$L_{PL} = L_{\max.Part.} + 2 \cdot P_{RL} + 2 \cdot P_{FL} \quad (2.1)$$

where $L_{max.Part.}$ max. Length of part added by two times of P_{RL} Additions for rough cutting length, and two times of P_{FL} Addition for finishing length.

2.2.1.1 Length of semi part for Conventional operation

The additions of semi-part for conventional operation Fig *2.1*. Can be slightly longer than the operation with the automated operation *Fig 2.2*, because of the less accuracy of machining with conventional machines.

$$L_{PL} = 48.3 + 2 \cdot 3 + 2 \cdot 0.3 = 55.3\ mm$$

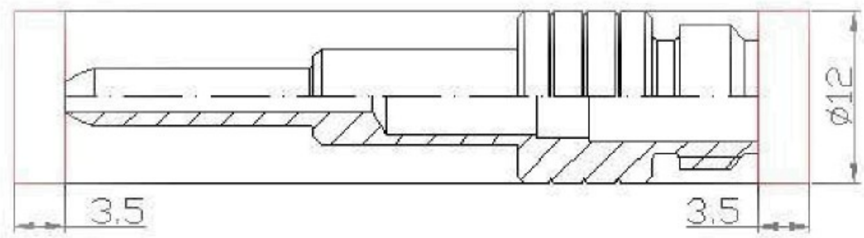


Fig 2.1

2.2.1.1 Length of semi part for automated operation

There will be some difference with the additional part machining arrangements *Fig 2.2*, so that there will be added 0.5mm for finishing of the face and 3.2mm for cutting off the part.

$$L_{PL} = 48.3 + 0.5 + 3.2 = 52\ mm$$

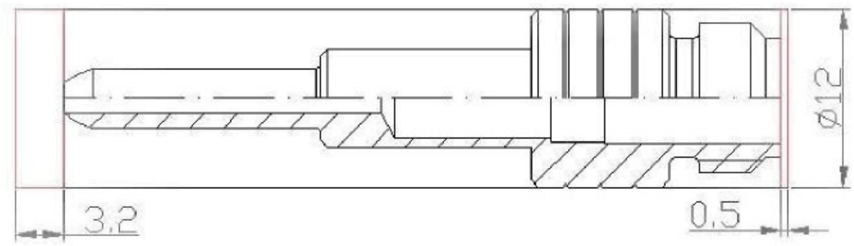


Fig 2.2

2.2.2 Minimal diameter of semi-part

Operational allowances for maximum part diameter D_{PL} is given by help of material stock catalogs or by relation (2.2)

$$D_{PL} = D_{\max.Part.} + 2 \cdot P_{RC} + 2 \cdot P_{FC} \tag{2.2}$$

where $D_{max.Part.}$ Max. Diameter of part added by two times $P_{RD} = 0$ additions for rough cutting diameter and $P_{FD} = 0$ addition for finishing diameter

$D_{PL} = 12 + 0 + 0 = 12\text{mm}$

The minimal semi-part diameter is recommended

2.2.3 Semi-part material requirement

∅ 12 – 55.8 ČSN 424254.6

Stock size are suggested, ∅ 12[mm], with costs of 60 [Kč] for 1m

$L_{Bar\ length.}$ Minimum Length of Bar

$$L_{Bar.lenght} = N \cdot L_{PL} \tag{2.3}$$

N Number of pieces in series, L_{PL} Length of semi-part

2.2.3.1 Length of bar needed for conventional operation

$$L_{Bar.length} = 1000 \cdot 0.0553 = 55.3\text{m}$$

For producing 1000 pieces there must be ordered 60m of bar length, which costs 3600[Kč], which means 3.6 [Kč] for each piece.

2.2.3.2 Length of bar needed for automated operation

$$L_{Bar.length} = 100000 \cdot 0.052 = 5200\ m$$

For producing series of 100,000 piece there must be ordered bar of minimal length 5250m, which costs 315000 [Kč], that means 3.15 [Kč]for each piece.

2.3 Determinations of bases clamping method.

2.3.1 Conventional clamping device

Standard 3-jaws chuck equipment.

Fig 3.1

2.3.2 Automated clamping device

Collet clamping D =∅ 12mm, operated by hydraulic cylinders.

Fig 3.2

2.4 Selection of technological methods.

2.4.1 Conventional operation technological method

For cutting the rounded bar hacksaw – PR15 is used (see. chapter 3.1.1).
For turning work including center drilling and boring holes might be used universal center lathe S32 see chapter (3.1.2)

2.4.2 Automated CNC operation technological method

KOYO TURN 42T will be used for all operations (see. chapter 3.2.1).
For bar loading will be used SMW SPACESAVER 2000 (see. chapter 3.2.2).

2.5 Determination of basic operation sections.

Setting up the basic machining sequences and selection of cutting tools selected, step by step are descried by the help of sketch's of material removal for each section, table 2.5.1, shows the sequences for conventional operation, and table 2.5.2, shows the sequences for automated operation.

2.6 Completion of secondary operation.

2.6.1 Conventional product checking

The following dimensions should be checked during operation to satisfy the tolerances required (see drawing 0-KVS-VS-149-001 and table 2.5.1):

a) Check ∅ 6.6 mm using micrometer (operation 2 section 3c)
b) Check ∅ 4 mm using micrometer (operation 2 section 3d)
c) Check ∅ 5.3 mm using special gauge block (operation 2 section 6a)
d) Check ∅ 5.85 mm using special gauge block (operation 2 section 6b)
e) Check ∅ 6.1 mm using caliper (operation 2 section 6d)
f) ALL lengths are checked using caliper

2.6.2 Automated product checking

For automated machining there will be complete checking of first part, then each 2 hours in shift time.

3. Machine tool selection

Defining the specification of the machine tool

After considering the product and possible methods of production it should now be possible to specify the machine tool required. There the lists will determine the specification, one containing the requirements laid down by the user and the second the features offered by machine tool manufacturers products.

1) User's requirements

To select machine tool suitable for certain type of product it is needed, To provide potential suppliers with a production drawing of the workpiece, an estimate of the quantities required and a statement of the labor and environmental conditions under which the machine has to work. This will enable machine tool manufactures to submit detailed specification of machines, which they consider to be suitable for the job. For the more general cause of a multipurpose machine, however, it is important to establish a checklist of those items, which have to be specified and examined:

a) Type of manufacturing process.
b) Size capacity, series.
c) Range of operational speeds and feeds.
d) Number of different speed and feeds.
e) Operational forces (cutting forces, forming or blanking forces, etc.).
f) Power.
g) Quality of product (accuracy, surface finish).
h) Cutting fluid to be used.
i) Types and number of tools.
j) Auxiliary equipment (workpiece handling, swarf removal, tool changing).
k) Environmental needs (permissible noise level, temperature, fumes, guarding).

In addition, it may sometimes be necessary to specify other features such as the maximum weight of the machine, the color etc.

2) Manufacturer's offer

a) Requirements mentioned under (1) must be met
b) Type of labor required
c) Weight of machine, lifting points, overall size (dimention)
d) Foundation requirements
e) Environmental and safety considerations
f) Maintenance and lubrication
g) Services required (electrical, hydraulic, pneumatic)
h) Setup, change over and tool changing times
i) Appearance, color etc.
j) Service facilities available and current charges for service.

In addition, suppliers may offer alternatives to the request put forward by the prospective customer.

3.1 Conventional machinery selected:

3.1.1 hacksaw PR 15

Produced by TOS ČESKÁ KAMENICE

It's simple cutting method for cutting metal and non-metallic bars. Tool used is saw-blade 150x25x1, 5. It's recommended to cut of more bars at one time.

Figure 3.1, Hacksaw

Maximum proportions of cut off material:

Circular cross-section	mm	150
Stroke size	mm	80
Engine power	kW	0,37
Machine weight	kg	50
Machine dimension	mm	950x350x420
Machine cost	Kč	50000

3.1.2 Universal center lathe S 32.

Produced by INTOS spol. s r.o., Žebrák

Figure 3.2, Conventional lathe S32

The universal precision lathe S 32 ensures suitable cutting conditions for economical machining of all normally used materials. All kinds of threads over a large of pitches can be cut on the machine. Further outstanding properties:

Lasting precision, High spindle speed and wide range of spindle speeds, High universality, Safety and simple operation, Simple maintenance.

Basic technical data:

SWING OVER BED	mm	320
Swing over cross slide	mm	190
Distance between centers	mm	750; 1000;
Maximum weight of workpiece between centers	kg	85; 110
Spindle Bore	mm	36
Speed range	min^{-1}	20-3200
Longitudinal feed	mm/ot	0,03-3,52
Cross feed	mm/ot	0,01-1,22
Total input required	kVA	4,0
Main motor power	kW	5,5
Machine dimension L x W x H	mm x mm x mm	1925x953x1305
Machine cost	Kč	300000

Speed range:

31,5	40	50	63	80	100	125	160	200
125	160	200	250	315	400	500	630	800
500	630	800	1000	1250	1600	2000	2500	3150

Feed range 500-3150
1:1

0,030	0,031	0,034	0,036	0,047	0,050
0,060	0,062	0,068	0,072	0,094	0,100
0,120	0,125	0,135	0,145	0,188	0,200
0,240	0,250	0,280	0,290	0,375	0,400

Feed range 31,5-800
1:1

0,060	0,062	0,068	0,072	0,094	0,100
0,120	0,125	0,135	0,145	0,188	0,200
0,240	0,250	0,280	0,290	0,375	0,400
0,490	0,500	0,540	0,580	0,750	0,800

Feed range 125-800
8:1

0,120	0,125	0,135	0,145	0,188	0,200
0,240	0,250	0,280	0,290	0,375	0,400
0,490	0,500	0,540	0,580	0,750	0,800
0,950	1,000	1,080	1,160	1,500	1,600

Feed range 31,5-200
8:1

0,490	0,500	0,540	0,580	0,750	0,800
0,950	1,000	1,080	1,160	1,500	1,600
1,920	2,000	2,160	2,320	3,000	3,200
3,840	4,000	4,320	4,640	6,000	6,400

3.2 Automated machinery

3.2.1 Automated turning center (CNC) KOYO TURN 42T

Produced by TOS Čelákovice a.s.

Figure 3.3, KOYO TURN 42T

Turning center KOYOTURN 42 T has been designed for complete finishing of rotary components. It is possible to machine outside and inside cylinder surfaces, cone and sphere surfaces, to drill and to ream holes, to cut threads, to realize out of axis drilling and to mill parallel or vertical to turning axis. Three-axis machine version enables simultaneous machining with two turrets and is suitable for production out of bars and for machining of flange-type parts. Principal electrically controlled eight-station turret head moves in longitudinal and cross way and is determinated for turning tools. Every second station can be used also for driven rotary tools that together with spindle positioning five by five grades enable to perform also out of axis operations. Secondary six-station turret head moves only in longitudinal direction and is predetermineded only for axes operations. Machine can be equipped by removal and transport of workpieces conveyor. AC regulation motors carry out drive of spindle and of feeds. Cooling of tools is inside three tool holders or an outside one. Hi-pressure cooling can be used for drilling tools. A belt conveyer carries out removal of chips. The machine is equipped by control system FANUC.

Basic technical data:

Machine capacity		
-Bar capacity DIAMETER	mm	42
-MAX. Turning diameter	mm	140
Main spindle		
Spindle nose	DIN 55026	A-5
Collet type	DIN 6343	173E
Speed range	RPM	50-5000
Motor power (cont./temp.)	kW	5,5/7,5
MAX. Torque (cont./temp.)	Nm	38/52
Indexing increment	degrees	5
Power chuck		
Diameter	mm	140
Main turret		
Number tooling stations	Nbr	8
MAX. Number of driven tools	Nbr	4
Tool shank size	mm x mm	20x20
Indexing time (45°/180°)	sec	0,54/1,32
Sub-turret		

Number tooling stations	Nbr	6
Indexing time (60°/180°)	sec	0,48/1,32
Driven tools		
Speed range	RPM	45-4500
Power	kW	2,2
MAX. Torque	Nm	14
Control system (FANUC OT-C)		
Number of controlled axis	Nbr	3
Dimensions and weights		
Width/Depth/Height	m x m x m	2,9/1,6/1,7
Weight	kg	3450
Machine cost	Kč	2000000

3.2.2 SMW SPACESAVER Bar Loader

Produced by SMW Systems, Inc.

Figure 3.4, SPACESAVER 2000

Spacesaver barfeeders is included to support automation of process, and enable unmanned shift operation. Spacesavers permit reclaiming this idle time by running through breaks.

One of the principle advantages of barfeeding is that the part can often be cutoff complete. This eliminates the need to set up (bore jaws, etc.) to hold the second end of the part

Changing from job to job with the Spacesaver takes less than five minutes. Spindle filler tube changeover, in particular is easy. The Spacesaver provides open access to the rear of the lathe, allowing tube change without time and floor space wasted by moving the barfeeder.

Spacesaver 2100 is the industry's only all electric barfeeder. It is run by two electric motors: no cylinders, valves, piping, leaks etc., Bar positioning can be either to a turret, or by servo-feed; in the latter mode of operation, the barfeeder positions the bar without the assistance of the lathe turret. Bar reloading is electric by the patented "soft touch" system, which eliminates "banging" detrimental to barfeeder alignment.

Automatic bar loading system features 20 sec. bar reload, 2 min. changeover, servo driven, no separate control to program, feeds to stop, accepts all shapes and handles 32 of 25.4mm bars. Actual bar length is determined by spindle length of machine, requires lathe interface. No end of bar preparations is needed.

SPACESAVER specification

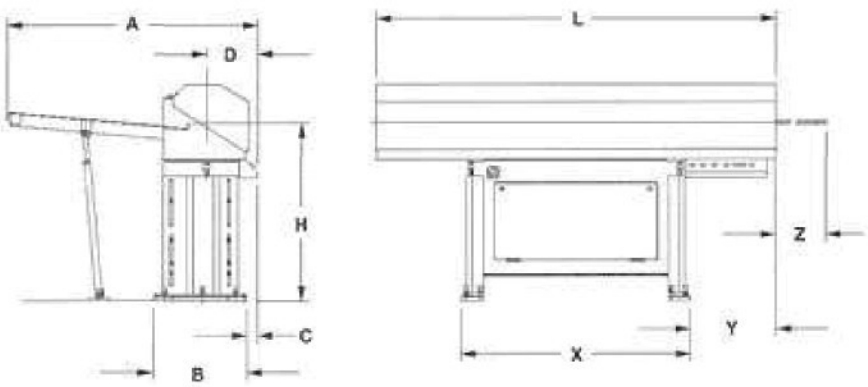


Figure 3.4.1, SPACESAVER DIMENTIONS

DIMENSIONS		
A	965.2mm	(38")
B	558.8mm	(22")
C	5.08mm	(0.2")
D	279.4mm	(11")
H Max.	1,173.48mm	(46.2")
H Min.	774.7mm	(30.5")
L	2,082.8mm	(82")
X	1,244.6mm	(49")
Y	355.6mm	(14")
Z Max.	1,574.8mm	(62")

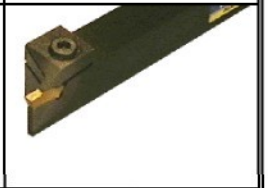
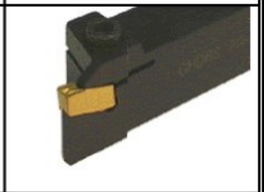
Table 4.3.1, Machine dimensions

Basic technical data:

FEEDING DRIVEN BY	ELECTRIC SERVO MOTOR
Reloading driven by	Electric servo motor
Feeding method	Feed using servo motor or to turret
Minimum/Maximum bar diameter	6.35mm (1/4") to 79.375mm (3 1/8")
Minimum/Maximum bar length	101.6mm (4") to 1,524mm (60")
Approximate changeover time	2 Minutes
Material tray capacity 25.4 mm (1") diameter bars	25 Bars
Weight net/Gross	358/ 544
Machine costs	200000 [Kč]

3.3 Equipments selection (tools, gauge, etc.).

<table>
<tr><th>Purpose</th><th colspan="3">TOOLS</th></tr>
<tr><td rowspan="3">Splitting material:</td><td colspan="3">Conventional machining
Mechanical saw-blade 300x25x1.5 ČSN 222962</td></tr>
<tr><th>Specifications</th><th>Insert</th><th>Toolholder</th></tr>
<tr><td>Automated CNC
Recessing cutting tool
DGR 3102j-6D
Tool holder
DGFH 32-3 DO-GRIP
ISCAR company catalogue</td><td></td><td></td></tr>
</table>

Turning work:	**Rough and finish cutting tool** CNMG 120408-TF **Tool holder** PCLNR ISCAR company catalogue		
	Groove rough cutting tool TGMF 302 **Tool holder** TGDR 2020 3M ISCAR company catalogue		
	Groove finishing cutting tool GIP 1.96-0.15 **Tool holder** GHDR 20-3 ISCAR company catalogue		
	Thread cutting tool 16 ER 1.5 ISO **Tool holder** SER 2020 K16 CARMEX company catalogue		
	Inner turning tool PICCOR050.5-20 **Tool holder** PICCO 16.D3-5 ISCAR company catalogue		
Drilling:	**CHAMDRILL** IDI 160-CG **TOOL HOLDER** DCM 160-048-20A ISCAR COMPANY CATALOGUE		
	Drill ∅ 2 mm ČSN 221125		
	Drill ∅ 5.3 mm ČSN 221125		
Measuring dimensions:	Digital caliper Micrometer Gauges blocks for diameter checking.		
Tools cost	23000 [Kč]		

Total tools cost used for conventional machining approximately 10000 [Kč]

Total tools cost used for automated machining approximately 22100 [Kč]

4. Detailed process description.

According to process sections and sketch's which are in table 2.5.1 and 2.5.2 See chapter.2

Detailed process description contains:

1. Job specification
2. Equipments and Tools used for each operation
3. Speeds and feeds recommended for cutting
4. Setup and machining time.

Are described on tables:

4.1 Conventional operation process description

Table 2.7.1.1, Contains process description,

4.2 Automated operation process description

Project workpiece is done by STEINEL technik s. r. o.

Process description**.** Table 2.7.2.1, Contains steps of machining as done by STEINEL Company, it includes real speeds and feeds used, machining time has been followed and measured using STOP-WATCH

4.2.1 CNC program development

KOYO TURN 42T is controlled by FANUC control system from GE Fanuc Automation, CNC program Table 2.7.2.2, (See appendix), has been developed by STEINEL COMPANY, program is developed to control both turret heads, Main turret, A' and Auxiliary turret, B'. Both heads are able to work in the same time using sub program to make the connection between them, Positions of each of cutting tools in turret heads are defined by T codes Table 2.7.2.3. (See appendix).Explanation of G, M, and other codes which has been used for CNC program to control each movement of machine drive Table 2.7.2.4, (See appendix).

The following CNC program is done using general codes for programming; later on it has been developed to the final form as in Table 2.7.2.2:

```
N0010 T0101 G54 M04 M51 S2500 F0.3
N0020 G92 X0.000 Z25
N0030 G59
N0040 G00 X15. 000 Z2.000
N0050 G01 X0.000 Z0.500
N0060 G94 S2500 F0.3
N0070 G00 X15 .000 Z2.000 M08
N0080 G01 X10.000 Z-7.250
N0090 G00 X8.600 Z2.000
N0100 G01 Z-3.000
N0110 G00 X13.000 Z4.000

N0120 T0404 S2000 F0.3
N0130 X12 Z1 M8
N0140 G1 X8.25 G99 F0.3
N0150 Z-1
N0160 X10.15 Z-1.65
N0170 Z0.2
N0180 X6.9
N0190 X7.35 Z-0.15
N0200 Z-1
N0210 X9.9 Z-2
N0220 Z-7.5
N0230 X12.25
N0240 Z-8.35
N0250 X10.8 Z-7.5
N0260 X7.72
N0270 X11
N0280 G0 X12.8
N0290 Z-17.35
```

```
N0300 G1  X10.8  Z-18.75
N0310 G0  X20  Z10

N0320  T0505  S2000 F0.05
N0330  X12.5  Z-10.325
N0340  G1  X11.7
N0350  G0  X13
N0360  Z-12.65
N0370  G1  X11.7
N0380  G0  X13
N0390  Z-14.975
N0400  G1  X11.7
N0410  G0  X13 Z10.5
N0420  S1500  M04  G97  F0.05
N0430  G00  X9.340  Z3.810  M08
N0440  G 33  X9.340  Z-7.500
N0450  G01  X13.000  Z-7.500
N0460  G00  X13.000  Z3.620
N0470  G00  X8.680  Z3.620
N0480  G33  X8.680  Z-7.500
N0490  G01  X8.680  Z-7.500
N0500  G00  X13.000  Z3.420
N0510  G00  X8.000  Z3.420
N0520  G33  X8.000  Z-7.500
N0530  G01  X13.000  Z-7.500  M09

N0540  T0202 G97
N0560  S1500  M03 G94
N0570  G00  X0.000  Z2.000  M08
N0580  X0.000  Z0.800
N0590  G01  Z-4.500  F 0.05
N0600  G00  X0.000  Z0.800
N0610  X0.000  Z-4.200
N0620  G01  Z-9.500
N0630  G00 X0.000  Z0.800
N0640  X0.000  Z-9.200
N0650  G01  Z-14.500
N0660  G00  X0.000  Z0.800
N0670  X0.000  Z-14.200
N0680  G01  Z-19.500
N0690  G00  X0.000  Z0.800
N0700  X0.000  Z-19.200
N0710  G01  Z-26.000
N0720  G00  X0.000  Z0.800
N0730  X15.000  Z-3.0000  M09

N0740  G00  T0606  Z2 M8
N0750  X-5.75
N0760  G1 G99 Z-11.9
N0770  X-5.5
N0780  G0 Z1
N0790  G1 G99  X-6.25
N0800  Z-11.96
N0810  X-5.78
N0820  Z-15.53
```

```
N0830  X-5.25
N0840  Z-16
N0850  Z-11.9
N0860  X-5.81
N0870  Z-11.9
N0890  G0  Z7
N0900  X120  M3  S3000

N0910  T73  G97           '
N0920  S1500  M03 G94
N0930  G00  X0.000  Z2.000  M08
N0940  X0.000  Z0.800
N0950  G01  Z-4.500
N0960  G00 X0.000  Z0.800
N0970  X0.000  Z-4.200
N0980  G01  Z-9.500
N0990  G00  X0.000 Z0.800
N1000  X0.000  Z-9.200
N1100  G01  Z-14.500
N1120  G00  X0.000  Z0.800
N1130  X0.000  Z-14.200
N1140  G01  Z-19.500
N1150  G00  X0.000  Z0.800
N1160  X0.000  Z-19.200
N1170  G01  Z-24.500
N1180  G00  X0.000  Z0.800
N1190  X0.000  Z-24 200
N1200  G01  Z-29.500
N1210  G00  X0.000  Z0.800
N1220  X0.000  Z-29.200
N1230  G01  Z-34.500
N1240  G00  X0.000  Z0.800
N1250  X0.000  Z-34.200
N1260  G01  Z-39.500
N1270  G00  X0.000  Z0.800
N1280  X0.000  Z-39.200
N1290  G01  Z-44.500
N1300  G00  X0.000  Z0.800
N1310  X0.000  Z-44.200
N1320  G01  Z-49.500
N1330  G00  X0.000  Z0.800
N1340  X0.000  Z-49.200
N1350  G01  Z-50.300
N1360  X0.000  Z0.800
N1370  X0.000  Z2.000
N1380  X20.000  Z3.000 M09

N1390  T0606 G97
N1400  S2500  M04  G94
N1410  G00 X19.000  Z-48.3 M08
N1420  X7.000  Z-49.000
N1430  G01  Z-17.000
N1440  X15.000  Z-49.000
N1450  X4.300  Z-49.000
N1460  G01  Z-27.500
```

```
N1470  G01  X16.000

N1480  S2000  M04  G94 F0.03
N1490  X4.000  Z-4.900
N1500  G01  X4.000  Z27.800
N1510  G02  X5.000  Z-27.3
N1520  G01  X6.600  Z-26.8
N1530  G01  Z-16.8
N1540  G01  X11.000  Z-16.800
N1550  G01  X13.000  Z-16.300
N1560  G00  X15.000  Z2.000 M09

N1570  G0  T0404  Z-28.4
N1580  X12
N1590  G1  X7  F0.25
N1600  X505  Z-29.3
N1610  G1  X505
N1620  G02  X4.05  Z-29.975  R0.675
N1630  G1  X4.08  Z-51.3
N1640  X12
N1650  G0 X80  Z-10


N1670  G0  T0707  Z-48.868  M8
N1680  X5
N1690  G1  G99  X4.23  F0.15  M9
N1700  X4.05  Z-49.868
N1710  G03  X2.8  Z-51.4  R2.075
N1720  G1  G99  X-0.5
N1730  G0  X80
N1740  Z20

M30
```

5. Calculation of time and material consumption.

Time concern's table reference

5.1 UNIT TIME - t_A [min]

Time of producing one piece including fixed term from limit (processed in detailed production process) table 4.1 and 4.2
(see appendix).

$$t_A = t_{A11} + t_{A13} + t_{Ax} \quad (5.1)$$

$$t_{Ax} = 0{,}08 \cdot (t_S + t_{A13}) \quad (5.2)$$

where 0.08 is chip removal rate, t_A unit time, t_{A11} unit time when machine still stand, t_S machining time t_{A13} manual machining unit time, t_{AX} irregular time for service

5.1.1 Production unit time for Conventional machining

$$t_{Ax} = 0{,}08 \cdot (2.98 + 0.89) = 0.309 \min$$

Then:

$$t_{A1} = 11.02 + 0.89 + 0.309 = 12.21 \min$$

5.1.2 Production unit time for Automated machining

Unit time is measured directly using stopwatch during machining, the time measured is t_{A2} = 1.3 [min] between clamping the first part to clamping the next one.

5.2 BATCH WORK PORTIONS– t_B [min]

5.2.1 Batch work portions for conventional operation

Arrangement and study process documents:	**Σ 9,0**
- Work order and material	2,0
- Fit up drawing and instruction	3,0
- Read through work	4,0
Ensure working stouts:	**Σ 11,90**
- Borrow gauge and equipments	6,90
- Borrow preparation	5,0
Machine setup and clamping device:	**Σ 3,0**
- Clamp universal chuck	2,0
- Set jaws for clamping diameter	0,4
- Adjust tailstock	0,6
Tooling set-up:	**Σ 8,0**
- Clamp tool on to tool head	3,6
- Clamp tooling head	1,4
- Insert tool into tailstock sleeve	3,0
Check first piece	**Σ 2,0**
Finish work:	**Σ 5,0**
- Work protocol	1,5
- Clean machine from chip	3,5

$\sum t_{B1} = 38{,}9$ min

5.2.2 Batch work portions for automated operation

To go from one work order to the next on a CNC machine tool the following tasks generally occurs:

- tearing down tool holders
- assembling tool holders
- locating and securing work holding devices
- measuring program zero
- entering offsets for program zero and for tool diameters and lengths
- loading the program into the machine control unit
- verifying the program
- inspecting the first piece

These settings take one shift work. Which is 8 hours

$\sum t_{B2} =$ 8 hour

5.3 SHIFT PREPARATION TIME - t_C [min]

5.3.1 Times of preparation shift work t_{C1}

Equipment preparation and setout at the beginning of shift	3,00
Lubricate and cleanout machine during shift	3,00
Refilling cooling liquid during shift	3,00
Necessary cleaning workplace during shift	2,00
Service talk	3,00
Cleaning at the end of shift (or shift changeover)	4,00
Protocol daily work	2,00

t_{C1} = 20 min

5.3.2 Times of shift generally necessary breaks t_{C2}

Snacks order	2,00
Regular break	30,00
Personal hygiene	6,00
Natural needs (toilet)	10,00

t_{C2} = 48 min

Total time needed during shift: t_C = 68 min

Shift times for both conventional and automated operation are the same.

5.3.3 Coefficient of shift time k_C

$$k_C = \frac{T}{T - t_C} = \frac{510}{510 - 68} = 1.154 \tag{5.3}$$

Coefficient shift time k_C was fixed term from average time of working shift T. Time standard it is possible to determine either by, specification the, t_A, t_B, t_C separately, (in first variant) or in second variant t_{AC}, t_{BC}., For this specification then applies:

$$t_{AC} = t_A \cdot k_C \qquad (5.4) \qquad\qquad t_{BC} = t_B \cdot k_C \qquad (5.5)$$

where t_{AC} standard time of machining one piece per shift time rate t_{BC} shift preparation rate time per standard Batch time.

5.3.3.1 Standard operation time during shift time

Standard operation time	CONVENTIONAL	AUTOMATED
t_{AC} [min]	14.09	1.50
t_{BC} [min]	44.8	553.92

5.4 STANDARD OF MATERIAL CONSUMPTION - N_M

$$N_M = Q_S + Q_V + Z_M \tag{5.6}$$

where Q_S Part weight Q_V Restoring material Z_M Material lost

$$N_M = 0.016 + 0 + 0.0034 = 0.0194\ kg$$

Coefficient usable material:

$$K_M = \frac{Q_S}{N_M} = \frac{0.016}{0.0194} = 0.82 \tag{5.7}$$

6. Conditions and economy assessment

Company situation

If a company designs and manufactures its own products, price of units might be less than to produce the same product for some other companies, in the following there will be calculated a case that a company is producing for another company according to contract which has to be fulfilled during one year time.

6.1 Comparable machine cost.

Comparable machine cost Ss is defined according to relation:

$$Ss = (1 + F_o + F_{UO} + F_E) \cdot \frac{(C + N_P)}{T_R \cdot D_0} \tag{6.1}$$

Where:

Factor of lifetime repayment F_O is defined according to relation:

$$F_O = \frac{1}{D_0} = 0.1 \text{ [hours]} \tag{6.2}$$

where D_0- lifetime for repayment = 10 [years].

Factor of maintenance F_{UO} is defined according to relation:

$$F_{UO} = \frac{N_U}{100} = 0.01 \ \% \tag{6.3}$$

where N_U is cost of maintenance =1 %

Machine effective time T_R is defined according to relation:

$$T_R = 8 \cdot P_D \cdot 0.8 \cdot S \tag{6.4}$$

where 8 is number of hours per shift, 0.8 = 80% of the machine effective time. S- shifts= 1,2 or 3 shifts, P_D- Working days = 252 days in a year

Slandered working hours in a year depends on shift time:

	NUMBER OF SHIFTS	NUMBER OF WORKING HOURS PER 1 YEAR
T_{R1}	1	1612.8
T_{R2}	2	3225.6
T_{R3}	3	4838.4

Factor of energy F_E is defined according to relation:

$$F_E = \frac{P \cdot C_E \cdot T_R}{C + N_P} \cdot K_{pr} \cdot K_v \qquad (6.5)$$

where P is power input, K_{pr} is coefficient of power = 0.2, K_v is coefficient of work of machine = 0.5, C_E- Costs of energy = 3.5 [Kč/KWh], Np- Costs of machine adaptation = 10 % of machine price, C- cost of machine [Kč].

6.1.1 Conventional machining cost

S32

P = 5.5 kW, C_{S32} = 300000 Kč

HACKSAW

C_{HS}= 50000 Kč

Total machines cost C_C= 350000 Kč

$T_R = 8 \cdot 252 \cdot 0.8 \cdot 2 = 3225.6$ [hours per year]

$$F_E = \frac{5.5 \cdot 3.5 \cdot 3225.6}{350000 + 7000} \cdot 0.2 \cdot 0.5 = 0.0173 \text{ [kW]}$$

$$Ss_{C1} = (1 + 0.01 + 0.1 + 0.0173) \cdot \frac{(350000 + 7000)}{1612.8 \cdot 10} = 22.25 \text{ [kč]}$$

Ss_{C2} =12.4 [kč]

Ss_{C3} = 8.3 [kč]

6.1.2 Automated machining cost

KOYO TURN 42T

$P = 5.5$ kW, $C_{KO} = 2500000$ Kč

SPACESAVER

C_{SP}=200000 Kč

Total machines cost C_A= 2700000 Kč

$T_R = 8 \cdot 252 \cdot 0.8 \cdot 2 = 3225.6$ [hours per year]

$$F_E = \frac{5.5 \cdot 3.5 \cdot 3225.6}{2700000 + 54000} \cdot 0.2 \cdot 0.5 = 0.002254[kW]$$

$$Ss_{A1} = (1 + 0.01 + 0.1 + 0.00225) \cdot \frac{(2700000 + 20000)}{1612.8 \cdot 10} = 187.58[kč]$$

Ss_{C2} =93.79 [kč]

Ss_{C3} = 62.527 [kč]

6.2 Economical calculation

Each company has it's arrangements for finding a way how to repay it's invests, that depends on the amount invested, market situation, competition, and many other factors. But in the same time each company looks forward to repay it's invest during shortest time possible

If the series has to be delivered during 1-year time then there occur possibilities of arrangements, in order to fulfill the job.

a) It's possible to take the risk, make the whole order for year, store it and supply the customer with the quantities required. During the other time of the year the machine will be able to do other individually products. The disadvantage of such approach is that the company will be in risk that the company may bankrupt, waste investing into not sold product, as well the product will occupy place for storage, there the product can age and corrode.

b) Usually the job is split to batches during the year, so that the supplements will be according to the customer needs during the year. Among these batches the machine will be free to fulfill other orders for other customers

Also If order can't be done during 1-shift in a year time

c) the works have to be divided into 2 or 3 shifts during the year, according to the capacity require to be manufactured.

d) If the shifts will not satisfy to fulfill the whole capacity required, then it's recommended to add new machine in order to fulfill the capacity required and any other individually customized products.

The following points are defining the costs, which are used to calculate the final batch cost.

- Operator wage M

  M defines operator wage that can differ between operator and another, it's chosen for the project that the salary is the same for both conventional and automated operation operator, which is 50[kč / h]
- Overhead R_m = 250% of operator wage (6.2.1)

  R_m defines the side cost such as other needed work (accountant, supplies, etc.)
- Total Services cost $S_o = M + R_m$ (6.2.2)

  S_o defines cost of operator and side's cost.
- Total machining cost $S_{CS} = S_S + S_o$ (6.2.3)

  S_{CS} defines the total cost paid for the machine per hour.
- Piece cost Nc = $\frac{t_A \cdot Scs}{60} + Mc$ (6.2.4)

  Nc defines the total cost of each part per hour; t_A piece (unit) time [min], *Mc* is material cost per piece

- Setup cost $Cs = Ts \cdot S_{CS}$ (6.2.5)

  Cs defines the cost of batch setup. T_S setup time in shift

Economic contribution

- $K_S = \frac{T_R \cdot 60}{t_A}$ piece per year (6.2.6)

  Ks define the number of pieces produced per year. Ks is also defined by the number of series needed to be produced, T_R machine effective year time [hours]

- $U = (Nc \cdot Ks) + Cs$ (6.2.7)

  U defines the total cost of production per Batch, Cs number of Batches /year

- $\text{Repayment ratio} = \frac{\text{Year income}}{\text{Overall investment}}$ (6.2.8)

  defines the repayment of the all equipment costs in percentage for 1 batch job

6.2.1 Conventional operation economy calculation

There are calculated the cost for 1-shift during 1- batch of work in a year,

6.2.2 Automated operation economy calculation

There are calculated the cost for 2-shifts during 1-batch of work in a year

The table 6.1 below shows the economy calculation for both conventional and automated operation:

	CONVENTIONAL	AUTOMATED
t_A [hour]	0.2	0.0216
Ss [kč]	22.25	93.8
M [kč / h]	50	50
R_m [kč / h]	125	125
S_o [kč / h]	175	175
S_{CS} [kč / h]	197.25	268.8
Nc [kč /piece]	43.05	8.95
Ts [hour]	0.64	8
Cs [kč/shift]	126.24	2150.4
K_S	1000	100000
U [kč /batch]	43176.24	897150.4
Repayment ratio	0.12	0.3

Table 6.1, Economy calculation

Cost-per-order is defined according to relation (6.2.9):

$$CPO = Cs \cdot N + Nc \cdot X \qquad (6.2.9)$$

where X is number of units produced and N=1 is number of batches setup

6.2.3 Conventional product Cost-per-order

COP = Kč 126.24 + Kč 43.05X

6.2.4 Automated product Cost-per-order

COP = Kč 2150.4 + Kč 8.95 X

ORDER [UNIT] X	PRICE FOR CONVENTIONAL PRODUCTS [KČ]	AUTOMATED FOR CONVENTIONAL PRODUCTS [KČ]
25	1202.49	2374.15
59	2666.19	2678.45
60	2709.24	2687.4
100	4431.24	3045.4
500	21651.24	6625.4
1000	43176.24	36054
100000		897150.4

Table 6.2 Orders costs

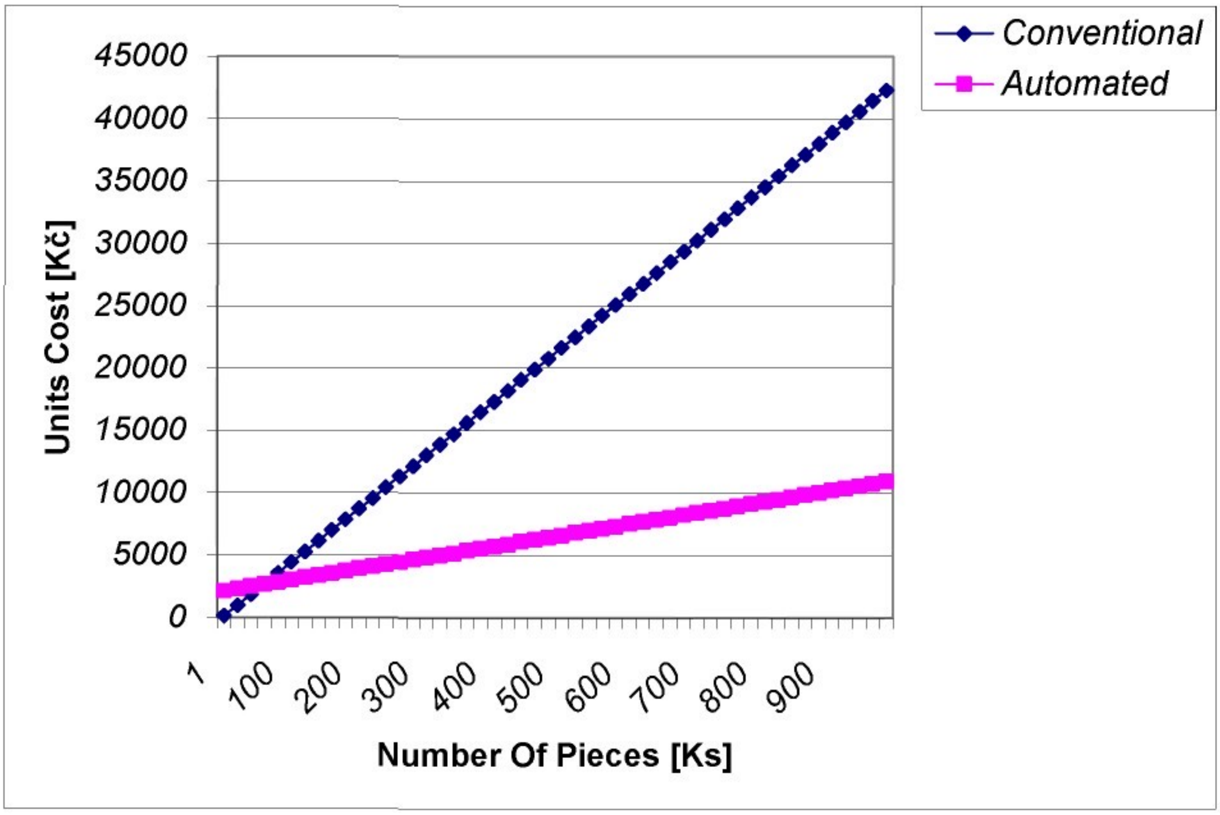


Figure 6.1, relation between cost and pieces

Break-even point

$$X = \frac{2150.4 - 126.24}{43.05 - 8.95} = 59.36 \text{ units}$$

7. Conclusion and recommendations

The work shows procedures of machine assessment for particular part (machining tool nozzle drawing **0-KVS-VS-149-001).** Conventional and automated machining was considered to show particular differences in technology and economy costs calculation. The part has been regularly machined by STEINEL company in a large series. In Figure 6.1 graph shows comparison of automated production system and conventional production system. From it is seen that from series of 60 pieces the automated production is more effective.

Automated production has the workpiece machining time of t_A= 1.3 [min]. This is done with improved CNC program applying simultaneous movement of both turret heads.

Selection of proper machining conditions (speed, feed, etc.) according to the material machineability and machine abilities for each workpiece, will lead to better machining performance for the future, which means longer lifetime of machine, optimal tool duration with greater reliability of the process.

Machine tool selection depends on the financial amount available for investors.

Utilization of the automated machine for the time available in the year raises investment repayment ratio to 0.3, that means that automated production machine could be repaid in 3.3 years. In comparison the conventional machine having repayment ratio of 0.12, which means that machine investment will be repaid in 8.3 years.

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1. Literature

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ISBN 0-85510-019-2, IPE, London, 1979

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2. Internet web Pages

http:// www.manufacturing.net/

http://www.mini-lathe.com/Mini_lathe/Operation/Turning/turning.htm

http://www.tos.celakovice.cz/

http://www.iscar.com/ecat/open.asp

http://www.amta-rtc.org/amta/amta.htm

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http://www.build-to-order-consulting.com/mc.htm

http://www.nedians.8m.com/lathe.htm

http://mmu.ic.polyu.edu.hk/handout/0102/0102.htm#3

http://iesu5.ieem.ust.hk/dfaculty/ajay/courses/ieem513/GT/GT.html

http://www.smwsystems.com/

http://www.carmex.com

Appendix

Tables and Drawing

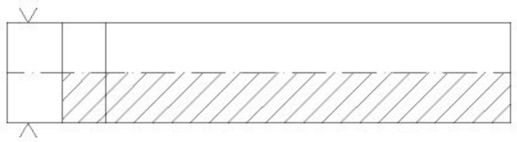
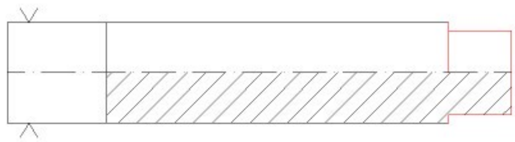
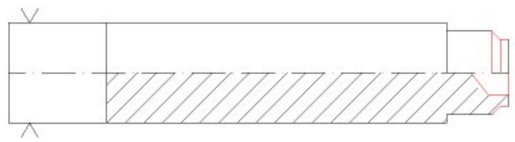
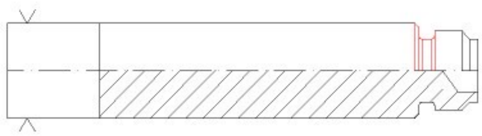
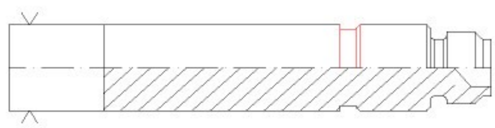
Table 2.5.2				List 1 Lists 3
Opr. No.	**Section**	**Sketch**	**Description**	**Tools**
1 Space-saver	1		Load Bar to machine Diameter 12 mm Length 56 mm	
2 KOYO	1		Clamp on 56mm Cut face (level) h=0.5mm Finishing Ø10 mm L= 7.25mm , Finishing	CNMG 120408-TF
	2a		Turn shape Groove Ø8 x1mm Edge 1x45^{o} Finishing	GIP 1.96-0.15
	2b		Drill center hole	IDI 160-CG
	2c		Turn shape Groove Ø8 x 2mm Edge 0.5x45^{o} Finishing	GIP 1.96-0.15 groove
	2d		Turn shape Edge 0.5x45^{o}	GIP 1.96-0.15 groove

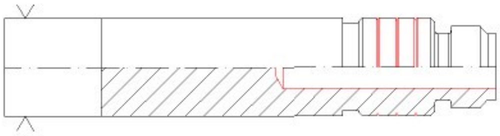
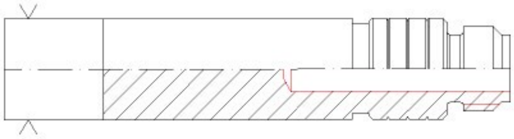
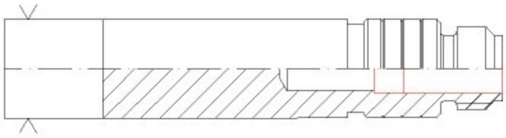
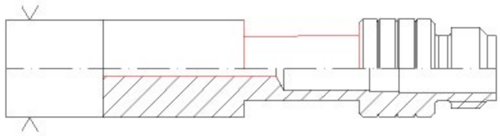
Table 2.5.2				List 2
				Lists 3
Opr. No.	**Section**	**Sketch**	**Description**	**Tools**
	3a		Turn shape 3x grooves ∅11.4	16 ER 1.5 ISO
	3b		Drill a hole ∅ 5.3mm to depth 26mm	Drill ∅ 2 mm ČSN 221125
	3c		Turn thread M10 length 5.5 mm Finishing	16 ER 1.5 ISO
	3b		Drill a hole in the center ∅ 5.3mm to depth 26mm	
	4a		Bore inner hole ∅ 6.1mm L=11.9mm Finishing	PICCOR050.5-20
	4b		Bore inner hole ∅ 5.85mm L=15.5mm Finishing	
	5a		Turn ∅ 7.9mm,L=17.1 mm to L=31mm Rough cutting	TGMF 302
	5b		Drill ∅2 mm L=51 mm Finishing	

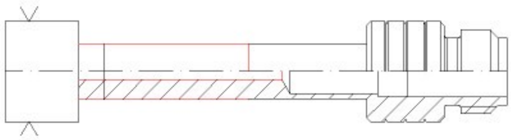
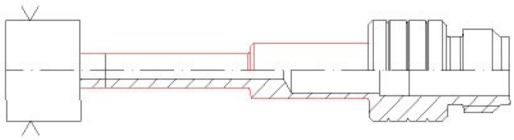
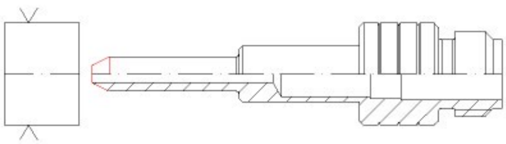
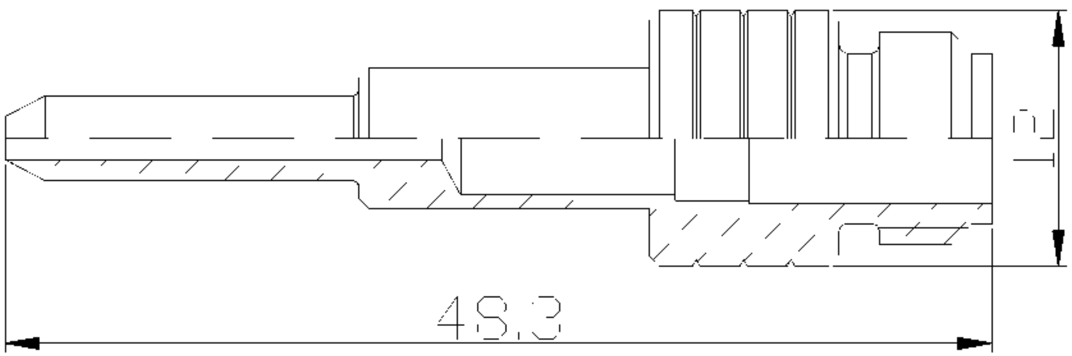
Table 2.5.2				List 3 Lists 3
Opr. No.	**Section**	**Sketch**	**Description**	**Tools**
	6		Turn ∅ 6.7mm,L=31 mm to L=51.3mm Rough cutting	TGMF 302
	5b		Drill ∅2 mm L=51 mm Finishing	Drill ∅ 2 mm ČSN 221125
	7		Turn∅6.6mm, L=16.8 mm to L= 31mm Finishing Turn shape Turn∅4mm, L=27.3 mm to L= 51.3mm	GIP 1.96-0.15
	8		Turn radius R=2mm Cut off part at L=48.3mm	DGR 3102J-6D

Table: 2.7.2.1	**MANUFACTURING PROCESS**	**List 1** / **List 5**	**Machine used:** **KOYO 42 T**		
			Part :	Drawing No : **0-KVS-VS-149-001**	
			Department:	Workplace:	TKK
			Material: **AlCuMgPbF37** Machineability: **8d-10d**	Semi-part: **42 42 54.6**	No of pieces: **100000** Batch:
			Executed by: **El wadiya K.** Date:	Controlled by: Date:	Agreed by: Date:
			Changes: Date:		



Oper.No	**Machine**	**Section**	**Job specification**	**Equipments and setouts**	**n**	**v**	**s**	**h**	**i**	t_{A11}	t_{A13}	t_S
1	Space-saver	1	Load bar to machine							0,13		
$T_{AC} = 1.5$				$t_{BC} = 44.8$	$K_C = 1.154$				$\sum = 7.26$			1.9

Table: 2.7.2.1			**MANUFACTURING PROCESS**									**List 2** / **Lists 5**
Oper.No	**Machine**	**Section**	**Job specification**	**Equipments and setouts**	**n**	**v**	**s**	**h**	**i**	**t_{A11}**	**t_{A13}**	**t_S**
			Clamp part on ∅ 12mm L=56 mm									0.15
			Clamp cutting tool to tool head	CNMG 120408-TF						0,75		
				TGMF 302						0,75		
				GIP 1.96-0.15 groove						0,75		
				16 ER 1.5 ISO thread						0,75		
				PICCOR050.5-20 inner cut						0.75		
				DGR 3102J-6D						0.75		
				IDI 160-CG						0.75		
				Drill ∅ 5.3 mm						0.75		
				Drill ∅ 2 mm						0.75		
2	KOYO 42T	1	Programme of n, s		3000		0.25	0.5	1			
			Set tool	CNMG 120408-TF						0.008		
			Start spindle, drive into cut							0,01		
			Cut face.									
			Turn ∅ 10 L=7.2mm									0.07
			Move out of cut and stop spindle							0,01		
			Programme of n, s		3000		0.3	2	1			
			Set tool	GIP 1.96-0.15						0.008		
		2a	Start spindle, drive into cut							0.01		
			Turn groove									
			Turn edge									
			move out of cut and stop spindle							0.01		
		2b	Programme of n, s									
			Set tool	IDI 160-CG						0.008		
			Start spindle, drive into cut		4000		0.18		4	0.01		
			Drill center hole									
			move out of cut and stop spindle							0.01		

Table: 2.7.2.1			MANUFACTURING PROCESS							List 3 / Lists 5			
Oper.No	Machine	Section	Job specification	Equipments and setouts	n	v	s	h	i	t_{A11}	t_{A13}	t_S
		2c	Programme of n, s Start spindle, drive into cut Turn groove Turn edge Move out of cut and stop spindle	 GIP 1.96-0.15 groove	3000		 0.25 0.15		2	 0.01 0.01		0.15
		2d	Programme of n, s Start spindle, drive into cut Turn edge move out of cut and stop spindle	 GIP 1.96-0.15 groove	3000		 0.25 0.1		2	 0.01 0.01		
		3a	Programme of n, s Set tool Start spindle, drive into cut Turn 3x grooves Move out of cut and stop spindle	 16 ER 1.5 ISO	3000		 0.05		2	 0.008 0.01 0.01		0.2
		3b	Programme of n, s Set tool Start spindle, drive into cut Drill hole ∅ 5.3 x 26 mm move out of cut and stop spindle	 Drill ∅ 5.3 mm	3000		 0.05		3	 0.008 0.01 0.01		
		3c	Programme of n, s Start spindle, drive into cut Turn thread move out of cut and stop spindle	 16 ER 1.5 ISO	2000		 0.1		3	 0.01 0.01		

Table: 2.7.2.1			**MANUFACTURING PROCESS**						**List 4** **Lists 5**			
Oper.No	**Machine**	**Section**	**Job specification**	**Equipments and setouts**	**n**	**v**	**S**	**h**	**i**	**t_{A11}**	**t_{A13}**	**t_S**
		4a	Programme of n, s		3000				2			
			Set tool	PICCOR050.5-20						0.08		
			Start spindle, drive into cut							0.01		
			Bore inner hole ∅ 6.1mm L=11.9mm				0.1					
			Move out of cut and stop spindle							0.01		
		4b	Programme of n, s		2000				2			0.2
				PICCOR050.5-20								
			Start spindle, drive into cut							0.01		
			Bore inner hole ∅ 5.85mm L=15.5mm				0.16					
			Move out of cut and stop spindle							0.01		
		5a	Programme of n, s		3000				3			
			Set tool	TGMF 302						0.008		
			Start spindle, drive into cut							0.01		
			Turn ∅ 7.9mm,L=17.1 mm to L=31mm				0.05					
			move out of cut and stop spindle							0.01		
		5b	Programme of n, s		2000				3			
			Set tool	Dril ∅ 2 mm						0.008		
			Start spindle, drive into cut							0.01		
			Drill a hole ∅ 2 mm, L=51 mm				0.13					
			Move out of cut and stop spindle							0.01		

Table: 2.7.2.1	MANUFACTURING PROCESS	List 5
		Lists 5

Oper.No	Machine	Section	Job specification	Equipments and setouts	n	v	S	h	i	t_{A11}	t_{A13}	t_S
		6	Programme of n, s		3000		0.32		2			
			Set tool	TGMF 302								
			Start spindle, drive into cut							0.01		
			Turn ∅ 6.7mm,L=31 mm to									0.3
			L=51.3mm									
			Move out of cut and stop spindle							0.01		
		7	Programme of n, s		2000		0.1		4			
			Set tool	GIP 1.96-0.15						0.008		
			Start spindle, drive into cut							0.01		
			Turn shape									
			Turn∅6.6mm, L=16.8									0.125
			mm to L= 31mm									
			Turn∅4mm, L=27.3									
			Move out of cut and stop spindle							0.01		
		8	Programme of n, s		3000				3			
			Set tool	DGR 3102J-6D						0.008		
			Start spindle, drive into cut				0.16			0.01		
			mm to L= 51.3mm				0.02					
			Radius R=0.5 mm				0.03					
			Edge 0.5x45^{o}									0.08
			Move out of cut and stop spindle							0.01		

CNC PROGRAM

Table 2.7.2.2

```
&HE:%
N1  G21  M213
N2  G50  S3500
/M98 P1000
N3  G0  T0101  Z20
N4  G0  X-79  Z-18.5
N5  M17
N6  G04  U2
N7  G1  G98  Z3.1  F1250
N8  M18
N9  G04  U1.5  M8
N10  G0  X13  Z5.5  M3  S3000
N11  G0  Z-0.05
N12  G1  G99  X-0.8  F0.25
N13  G0  Z2.5
N14  X10
N15  G1  G99  Z-7.25  F0.3
N16  X12
N17  G0  X80  Z20

M1

M198 R0221

N18  G0 T0404  X12  Z1 M8
N19  G1  X8.25  G99  F0.3
N20  Z-1  F0.25  M215
N21  X10.15  Z-1.65
N22  Z0.2  F0.3
N23  X6.9
N24  X7.35  Z-0.15 F0.2
N25  Z-1  F0.15
N26  X9.9  Z-2
N27  Z-7.5  F0.25
N28  X12.25
N29  Z-8.35
N30  X10.8  Z-7.5  F0.12
N31  X7.72  F0.1
N32  G04  U0.1
N33  X11  F0.3
N34  G0  X12.8
```

```
N35 Z-17.35
N36 G1 G99 X10.8 Z-18.75 F0.05
N37 G0 X80 Z10

N38 G0 T0505 X12.5 Z-11.5
N39 G1 X11.7 G99 F0.05
N40 G0 X13
N41 Z-13.15
N42 G1 X11.7 G99 F0.05
N43 G0 X13
N44 Z-14.8
N45 G1 X11.7 G99 F0.05
N46 G0 X13 Z10.5

N47 G97 G99 M3 S2000

N48 G0 X12 Z7.5
N49 G76 P020060 Q260 R0.02
N50 G76 X8.02 Z-7.25 P920 Q400 F1.5

N51 G0 X13 Z-6.5 S3000 M3
N52 G1 G99 G97 X8.1 F0.15
N53 Z-7.25 F0.1
N54 G0 X15
N55 X80 Z30

M190

M1

N56 G0 T0606 Z2 M8
N57 X-5.75
N58 G1 G99 Z-11.9 F0.3
N59 X-5.5
N60 G0 Z1
N61 G1 G99 X-6.25 F0.16
N62 Z-11.96
N63 X-5.78 F0.13
N64 Z-15.53
N65 X-5.25
N66 Z-16
N67 Z-15.5
N68 X-5.81
N69 Z-11.9
N70 G0 Z7
N71 X120 M3 S3000

M1
```

```
M198 R0225

N72  G0  T0202  Z-31  M8

N73  X12.5
N74  G1  G99  X10  F0.1
N75  Z-20  F0.32
N76  X8.8  F0.1
N77  Z-31  F0.32
N78  X7.9  F0.08
N79  Z-20 F0.32
N80  X13  F0.4
N81  G0  X70

N82  G0  T0404  Z-17.5
N83  X12.5
N84  G1  G99  X10.7  Z-18.75  F0.05
N85  X6.45
N86  X6.57
N87  Z-30.8  F0.15
N88  X13  F0.4
N89  G0  X80  Z-10

N90  G0  T0202  Z-31
N91  X12.5
N92  G1  G99  X9.5  F0.1
N93  Z-51.3  F0.32
N94  X8  F0.1
N95  Z-31  F0.32
N96  X6.7  F0.1
N97  Z-51.3  F0.32
N98  X13  F0.4
N99  G0  X80  Z-10

N100  G0  T0404  Z-28.4
N101  X12
N102  G1  G99  X7  F0.25
N103  X505  Z-29.3  F0.03
N104  G1  G99  X5.5  F0.1
N105  G02  X4.05  Z-29.975  R0.675  F0.02
N106  G1  G99  X4.08  Z-51.3  F0.16
N107  X12  F0.3
N108  G0  X80  Z-10

M190

M1
```

```
N109  G0  T0707  Z-48.868  M8
N110  X5  M35
N111  G1  G99  X4.23  F0.15  M9
N112  X4.05  Z-49.868
N113  G03  X2.8  Z-51.4  R2.075  F0.07

N114  G1 G99  X-0.5 F0.15
N115  G0  X80 M5

N116  Z20  M36
N117  T0101  M25
M30
%
```

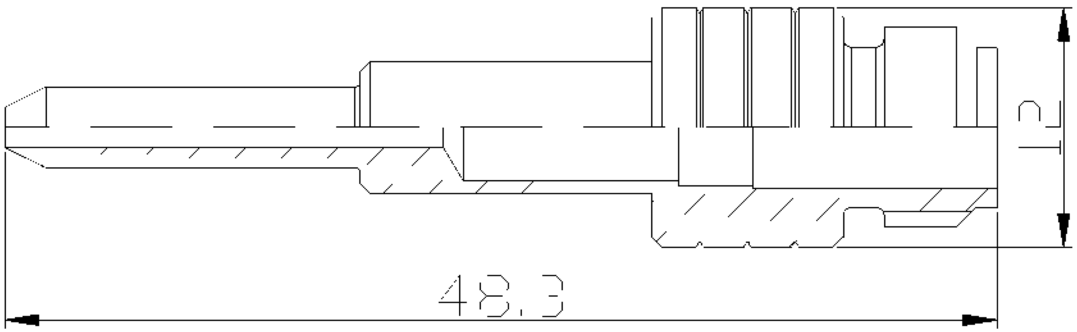
Sub-programs 1

```
&HE:%
:0221
M161
T71
G0  B2
G1  B-4.5  G99  F0.15
G04  U0.7
G0  B60

M162
T72
G0  B0

J83  B-27.25  R0  Q400  F0.18

G0  B120
M190
M99
%
```

Sub-program 2

```
&HE:%
:0225
M164
T73
G0B0
J82  B-51  R-26.25  Q2000  F0.1
G0  135
M161
M190
M199
M99
%
```

Table : 2.7.1.1	MANUFACTURING PROCESS	List 1 Lists 5	Machine used: S 32



Part :	Drawing No : 0-KVS-VS-149-001	
Department :	Workplace :	TKK:
Material : AlCuMgPbF37 Machinability: 8d-10d	Semi-part: 42 42 54.6	No of pieces: 1000 Batch:
Executed by: El wadiya K. Date:	Controled by : Date:	Agreed by: Date :
Changes : Date :		

Oper.No	Machine	Section	Job specification	Equipments and setout	n	v	s	h	i	t_{A11}	t_{A13}	t_S
2	SU 32		Clamp part on ∅ 12 Clamp cutting tool to tool head	Universal chuck CNMG 120408-TF GIP 1.96-0.15 groove 16 ER 1.5 ISO inner cut PICCOR050.5-20 thread						0,30 0,75 0,75 0,75 0,75		

T_{AC} = 14.09 | t_{BC} =44.8 | K_C = 1.154 | Σ =14.02 0.89 2.98

Table : 2.7.1.1

MANUFACTURING PROCESS

List 2

Lists 5

Oper.No	Machine	Section	Job specification	Equipments and setout	n	v	s	h	i	t_{A11}	t_{A13}	t_S
		1a	Set n, s; Start spindle, drive into cut Cut face . move out of cut and stop spindle Check size	CNMG 120408-TF Caliper	1600	60.3	0.25	3	1	0,10 0,02 0.32 0,03 0.15		0.015
		1b	Set n, s; Start spindle, drive into cut Cut face . move out of cut and stop spindle Check size	CNMG 120408-TF Caliper	2500	94.24	0.1	0.5	1	0.10 0.02 0.22 0.03 0.15		0.216
2	SU 32	2	Clamp tool on tail-stock Set n, Start spindle, drive into cut Drill a hole ∅ 2 mm move out of cut and stop spindle Check size	Drill ∅ 5.3 mm ČSN 221125 Caliper	3000	18.85	manual		1	0.18 0,10 0.18 0.62 0.03 0.15	0.49	
		3a	Set n, s; Start spindle, drive into cut Turn diameter to ∅7.2 mm length 31.2 mm move out of cut and stop spindle Check size	CNMG 120408-TF Caliper	2210	50	0.25	2.4	1	0,10 0,02 0.34 0,03 0.15		0.056
		3b	Set n, s; Start spindle, drive into cut ∅4.6 mm length 20.7 mm move out of cut and stop spindle Check size	CNMG 120408-TF Caliper	2000	28.9	0.25	1.3	1	0,10 0,02 0.34 0,03 0.15		0.051

Table : 2.7.1.1			MANUFACTURING PROCESS						List 3 / Lists 5			
Oper.No	**Machine**	**Section**	**Job specification**	**Equipments and setout**	**n**	**v**	**s**	**h**	**i**	**t_{A11}**	**t_{A13}**	**t_S**
		3c	Set n, s; Start spindle, drive into cut ∅6.6 mm length 31.5 mm,. move out of cut and stop spindle Check size	CNMG 120408-TF Micrometer	2500	51.8	0.1	0.3	1	0,10 0,02 0.34 0,03 0.15		0.126
		3d	Set n, s; Start spindle, drive into cut ∅4 mm length 21 mm move out of cut and stop spindle Check size	CNMG 120408-TF Micrometer	2500	31.4	0.1	0.3	1	0,10 0,02 0.34 0,03 0.15		0.084
3	SU 32	1	Re-clamp workpiece							0.32		
		2a	Set n, s; Start spindle, drive into cut Cut face . move out of cut and stop spindle Check size	CNMG 120408-TF	1600	60.3	0.25	3	1	0,10 0,02 0.32 0,03 0.15		0.015
		2b	Set n, s; Start spindle, drive into cut Cut face . move out of cut and stop spindle Check size	CNMG 120408-TF Caliper	2500	94.24	0.1	0.5	1	0.10 0.02 0.22 0.03 0.15		0.216

Table : 2.7.1.1			MANUFACTURING PROCESS						List 4 Lists 5			
Oper.No	Machine	Section	Job specification	Equipments and setout	n	v	s	h	i	t_{A11}	t_{A13}	t_S
	SU 32	3a	Set n, s; Start spindle, drive into cut Turn diameter to ∅10.6 x 7.2 mm move out of cut and stop spindle Check size	CNMG 120408-TF Caliper	1500	50	0.2	1.4	1	0,10 0,02 0.32 0,03 0.15		0.024
		3b	Set n, s; Start spindle, drive into cut Turn diameter ∅10x 7.5 mm move out of cut and stop spindle Check size	CNMG 120408-TF Micrometer	2250	63.61	0.05	0.3	1	0,10 0,02 0.32 0,03 0.15		0.070
		4	Turn tool post to tool position Set n, s; Start spindle, drive into cut Turn edge move out of cut and stop spindle Check size	GIP 1.96-0.15 groove Caliper	800	16.8	0.1	2	2	0.08 0,10 0,02 0.32 0,03 0.15		0.025
		5	Set n, s; Start spindle, drive into cut Turn groove path length 2.23 mm move out of cut and stop spindle Check size	GIP 1.96-0.15 Caliper	500		0.125	2	1	0,10 0,02 0,03 0.15		0.035
		6	Turn tool post to tool position Set n, s; Start spindle, drive into cut Turn 3 x grooves move out of cut and stop spindle Check size	16 ER 1.5 ISO caliper	300	9.4	0.05	1	3	0.08 0,10 0,02 0.40 0,03 0.15		0.916

Table : 2.7.1.1			MANUFACTURING PROCESS							List 5 / Lists 5		
Oper.No	**Machine**	**Section**	**Job specification**	**Equipments and setout**	**n**	**v**	**s**	**h**	**i**	t_{A11}	t_{A13}	t_S
		7	Turn tool post to tool position	16 ER 1.5 ISO	300	9.4	0.05	1	3	0.08		
			Set n, s;							0,10		
			Start spindle, drive into cut							0,02		
			Turn thread M10							0.20		0.916
			move out of cut and stop spindle							0,03		
			Check size	Thread gauge						0.15		
		6	Clamp tool on tail-stock	Drill ∅ 5.3 mm ČSN 221125	2800	46.6	manual		4	0.18		
			Set n,							0,10		
			Start spindle, drive into cut							0.18		
			Drill a hole ∅ 5.3 mm							0.25	0.40	
			move out of cut and stop spindle							0.03		
			Check size	Gauge block						0.15		
			Turn tool holder to tool position	16 ER 1.5 ISO	2500	45.95	0.05	0.275	1	0.08		
		7	Set n, s;							0,10		
			Start spindle, drive into cut							0,02		
			Bore inner groove ∅ 5.85 mm							0.27		0.124
			move out of cut and stop spindle							0,03		
			Check size	Gauge block						0.15		
			Set n, s;	16 ER 1.5 ISO	2500	47.9	0.05	1.25	1	0,10		0.0952
		8	Start spindle, drive into cut							0,02		
			Bore inner groove ∅6.1 mm							0.27		
			move out of cut and stop spindle							0,03		
			Check size	Gauge block						0.15		

Table 2.7.2.4

G code

Code	Function
G0	Point to point position (Rapid traverse)
G01	Linear interpolation (Cutting feed)
G02	Circular interpolation arc CW
G03	Circular interpolation arc CCW
G04	Dwell time
G21	Input in Metric mm
G33	Threading (Lathe)
G50	Coordinate system setting. max. Spindle speed setting
G54	Work coordinate offsets 1 through 6
G76	Multiple threading cycle
G92	Spindle speed limit
G94	Feed rate in ipm
G97	Constant surface speed control cancel
G98	Return to initial level
G99	Return to R point level

M Code

Code	Function	Explanation
M01	Optional program Stop	This code is effective when the optional stop switch on the machine operator's panel has been pressed.
M03	Spindle On CCW	start main spindle on direction Counterclockwise the code can be in the same block or before. M3 at opening the Collet clumping makes error.
M05	Stop spindle	M5 stop main spindle spinning
M08	Coolant switch ON	switch on cooling system
M09	Coolant switch OFF	switch off cooling system
M17	Open Collet clumping	
M18	Close Collet clumping	

M codes

Code	Function	Explanation
M25	Counter	At each M25 Workpiece counter count's 1 piece.Pressing switch button can stop counting pieces
M30	End of Program and go back to initial position	Determines last block of program, it depend on button CONTINUOUS, if it's ON it goes back to the beginning of program and the process starts again.
M35	Workpiece collector forward	Shift Workpiece catcher box forward
M36	Workpiece collector to the back	Shift Workpiece catcher to the back
M98	Call sub-program	M98 P0030001 call three times (first three numbers for P) program 01 (next four numbers) sub-program must be terminated by function M99 sub-program can be called for maximum 999times
M99	Finish sub-program	Finish sub-program and go back to main program.
M161	Position 1 of tool post head	Carry out after rotating secondary tool post head to the position 1
M162	Position 2 of tool post head	Carry out after rotating secondary tool post head to the position 2
M163	Position 3 of tool post head	Carry out after rotating secondary tool post head to the position 3
M190	Waiting command	This M function synchronize operation of secondary tool post head (B axis) with operation of main toolpost head (X, Z axis)
M198	Sub Program Storage	M198 R0000 .R is program title.
M213	Start workpiece conveyer	Start moving workpiece conveyer
M215	Stop workpiece conveyer	Stop moving workpiece conveyer

Other codes

Code	Function	Explanation
J83	Drill a deep hole	J83 B… R… Q… F… B End of deep drilling R Position of start point of drilling Q Depth of the hole F feed [mm/rot]
P	Program call out for sub routines	
F	Feed rate [mm/rot]	
S	Main Spindle Speed [rpm	
U	Secondary axis parallel to x axis	
T	Tool Selection—tool number	
Z	Z motion dimension- Spindle Axis Direction Movement	
X	X motion dimension- Left to right movement, Diameters in turning	
R	R Arc radius for G02, G03 Programming	
Q	Peck depth for pecking drill cycle	

Table 2.7.2.3

Program: 001

„A''	HOLDER	CUTTING TOOL
T0101	PCLNR	CNMG 120408-TF
T0202	TGDR 2020 3M	TGMF 302
T0303	GHDR 20-3	GIP 3.00E-0.20
T0404	GHDR 20-3	GIP 1.96-0.15
T0505	SER 2020 K16	16 ER 1.5 ISO
T0606	PICCO 16.D3-5	PICCOR050.5-20
T0707	DGFH 32-3 DO-GRIP	DGR 3102J-6D

WORK SHIFT	SHIFT VALUE	Z156.000

AUX„B''

T71	CHAMDRILL	DCM 160-048-20A	IDI 160-CG
T72	VRT d5.3		
T73	VRT d5.8		

SPACESAVER: **70 [mm]**

Table 2.5.1

List 1
Lists 3

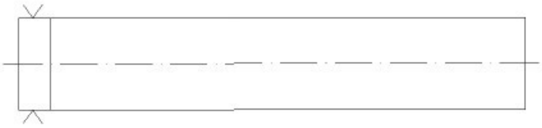
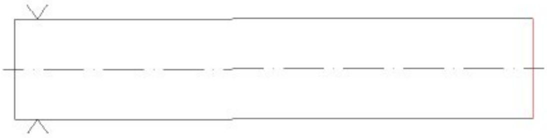
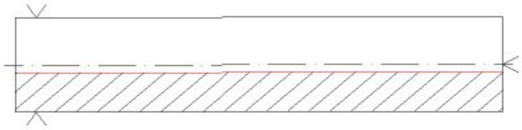
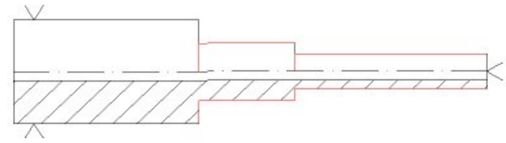
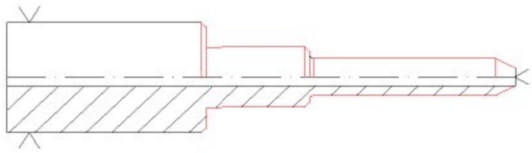
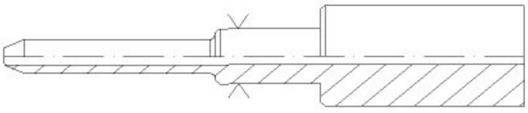
Opr. No.	Section	Sketch	Description	Tools
1 HACK-SAW PR 15	1		Cut semi-part Diameter 12 mm Length 51.8 mm	saw-blade 300 x 25 x 1,5
2 S 32	1a		Clamp on 48mm Cut face (level) h=3mm Rough cutting	Soft jaws
	1b		h=0.5 Finishing cut	
	2		Drill a hole ∅ 2mm depth 49mm	Drill ∅ 2mm
	3a		Remove material ∅7.2 mm length 31.2 mm,rough cutting	CNMG 120408-TF
	3b		∅4.6 mm length 20.7 mm, rough cutting	
	3c		Turn shape (finishing) ∅6.6 mm length 31.5 mm,	CNMG 120408-TF
	3d		∅4 mm length 21 mm make radius R0.5,R0.2 and chamfer 0.5x45° 2x	
S 32	1		Re-clamp workpiece on backstop 24 mm	

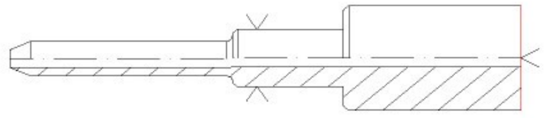
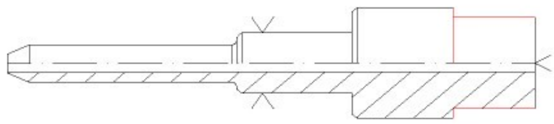
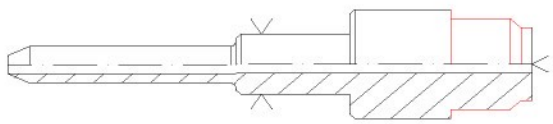
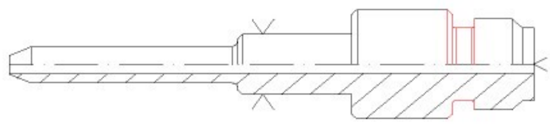
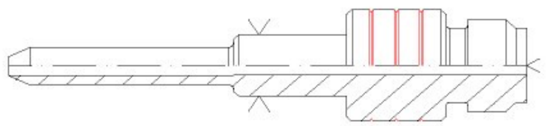
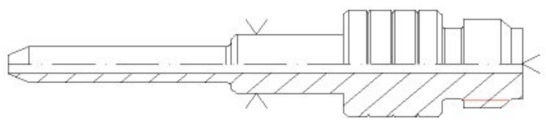
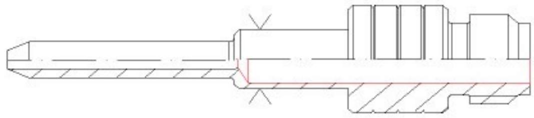
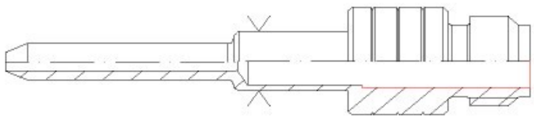
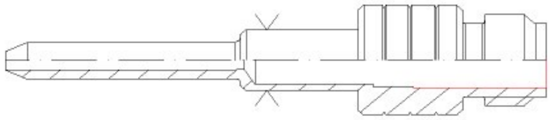
Table 2.5.1				List 2 Lists 3
Opr. No.	**Section**	**Sketch**	**Description**	**Tools**
	2a		Cut face (level) h=3 mm rough cutting	CNMG 120408-TF
	2b		h=0.5 mm finishing cut	
	3a		Remove material ∅10.6 x 7.2 mm, rough cutting	CNMG 120408-TF
	3b		Finishing cut ∅10mm length 7.5 mm,	
	4		cut edge 1x45^{o}	GIP 1.96-0.15 groove
	5		Turn groove ∅8mm Cut edge 0.5x45^{o} Finishing	GIP 1.96-0.15
	6		Turn groove ∅11.4mm Finishing	16 ER 1.5 ISO
	7		Turn thread M10 length 5.5 mm Finishing	16 ER 1.5 ISO

Table 2.5.1				List 3
				Lists 3
Opr. No.	**Section**	**Sketch**	**Description**	**Tools**
	8a		Bore ∅5.3 x 26 mm Finishing	Drill ∅ 5.3 mm ČSN 221125
	8b		Bore ∅5.85 x 15.5 mm Finishing	16 ER 1.5 ISO
	8c		Bore ∅6.1 x 11.9 mm Finishing	16 ER 1.5 ISO