CNC MACHINING OF CAVITY BLOCKS

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Téma práce: **CNC Machining of cavity blocks**

Zásady pro vypracování:

1.Elaborate a literary survey of CNC machining

2.Design a given part in 3D

3.Set up a program for CNC machining of the given part

4.Put machining of the cavity block into effect

Rozsah práce:

Rozsah příloh:

Forma zpracování bakalářské práce: **tištěná/elektronická**

Seznam odborné literatury:

Recommended by supervisor

Vedouci bakalářské práce: **Ing. Martina Malachová**
Ústav výrobního inženýrství

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ABSTRACT

Bachelor thesis is focused on the numerical control machines. It contains basic information about the computer-aided manufacturing and CNC machines, their control and basic information about programs for their control.

The practical part of this thesis is focused on the manufacturing of cavity block for turncock. Cavity block was designed in the Solid Edge 20 programme and then machined in the EdgeCam programme. Also NC code for CNC mill machine was generated. All the necessary technical drawing documentation is enclosed.

Keywords: Solid Edge, EdgeCam, CNC machine

ABSTRAKT

Bakalárska práca je zameraná na oblasť číslicovo riadených strojov. Práca obsahuje základné informácie o číslicovo riadených strojov, ich vývoj, ovládanie a programovanie.

Praktická časť tejto práce sa zabývá výrobou dutiny formy pre guľový kohút. Dutina formy bola navrhnutá v programe Solid Edge 20 a obrábaná pomocou programu EdgeCam. Taktiež bol vygenerovaný NC kód pre CNC frézku. Práca obsahuje aj výkresovú dokumentáciu.

Kľúčová slová: Solid Edge, EdgeCam, CNC stroj

ACKNOWLEDGEMENT

I would like to thank to my supervisor Ing. Martina Malachová for her help, support, comments and guidance without which this work would not exist.

I declare that I have worked on this thesis independently, using only sources listed in the bibliography.

In Zlin, 28th May 2008

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Signature

INTRODUCTION

Computer numerical control is among the fastest-growing fields in manufacturing today. CNC stands for computer numerical control and has been around since the early 1970s prior to this, it was called NC. If people, will be working in manufacturing, it is likely that they will be dealing with CNC on a regular basic.

In the NC systems used machine tools can be broadly classified as

- Convention numerical control
- Computer numerical control

In the convention numerical control system the entire data input and data handling process including control functions are determined only by the constant or fixed circuit inter-connections of decision elements and storage devices.

Computer numerical control system a dedicated stored programme. Computer is used to perform all the basic NC functions as pervade control programme stored in the memory of the computer called Executive programme that machine control data comes direct from the computer memory and not from the continuously read tape.

Today, CNC machines are found almost everywhere, from small job shops in rural communities to companies in large urban areas. Truly, there is hardly a facet of manufacturing that is not in some way touched by what these innovative machine tools can do. Everyone involved in the manufacturing environment should be well aware of what is possible with these sophisticated machine tools.

The design engineer, for example, must possess enough knowledge of CNC to perfect dimensioning and tolerance technique for workpiece to be machined on CNC machines. Tool engineer must understand CNC in order to design fixtures and cutting tools for use with CNC machines. Quality control people should understand the CNC machine tools used within their company in order to plan quality control and statistical process control accordingly.

I. THEORETICAL PART

1 DEFINITION OF NUMERIC CONTROL MACHINE

A Numerical Control (NC) and a Computerized Numerical Control (CNC) system perform the same task that is manipulation of data for a part machining. A control system contains logical instructions that process data.

The NC system uses fixed logical functions those are built-in permanently wired within the control unit. These functions can not be changed by a programmer or a machine operator because they have fixed wiring of the control logic. All required changes must be made away from control, usually in an office environment. [7]

The CNC system uses internal micro processor. This computer contains memory registers storing variety of routines that are capable of manipulating logical functions. The programmer or the machine operator can change the program on control itself with instantaneous result. This flexibility is the greatest advantage of the CNC machine. The CNC programs and the logical functions (for example software instructions) are saved on special computer chips. [7]

Information used in the CNC machines can be divided into:

- Geometry – determined measurements of components or distance between holes; it describes motion of the tool to semi finished product.
- Technology – describes regulation functions that machine does in separate steps, e.g. feedrate, spindle rotation, etc.
- Contour – it is information about aid functions, e.g. on, off coolant control.

1.1 History

NC technology as is known today emerged in the mid 20th century. It can be traced to the year of 1952 the U.S. Air Force, and is connected with John Parsons and the Massachusetts Institute of Technology in Cambridge, MA, USA. It was not applied in production manufacturing until the early 1960s. The real boom of CNC came around 1972; a decade later affordable micro computers were introduced. The NC machines can be divided into 5 developing generation groups. (See 1.4.1) [6]

1.2 Basic Terminology

NC (Numerical Control) – a technique of controlling a machine or process by using numbers, letters, and symbols. [4]

CNC (Computerized Numerical Control) – machines which consist of memory registers; they are controlled by computer. [4]

DNC (Direct Numerical Control) – machines controlled by a central computer. [1]

CAD (Computer Aided Design) – uses graphics-oriented computer software for designing and drafting applications. [5]

CAM (Computer Aided Manufacturing) – means is the use of computer to assist in various phases of manufacturing. [5]

CAE (Computer Aided Engineering) – uses graphics-oriented computer software for engineering and drafting applications involving mathematical analysis. [1]

CAP (Computer Aided Production) - computer support for technological preparation. [1]

CAPP (Computer Aided Process Planning) – use of computer for process planning. [1]

1.3 Accuracy and Repeatability of CNC Machine

A major benefit of modern CNC machines is a high degree of accuracy and repeatability. A part program is saved on the disk, tape or stored in the computer's memory. The given program can be used again and again. The high accuracy and repeatability of CNC machines allow continuous production of the high-quality parts. [8]

1.4 Types of CNC Machines

The CNC machines can be divided into six categories (Fig.1). In addition to that, various combinations can be made, e.g. uni professional CNC milling and serial kinematics for HSC shaping. Uni professional CNC machine uses only one type of operation (milling, turning, drilling and edging). Nowadays, uni professional machine with automatic tools change and a workpiece can be seen. It is usually a simple machine centre where dominant operations are done according to uni professional NC machine. The main advantaged is its lower price. This machine is built according to the needs of a customer. If the machines have automatic tools and workpiece change, we speak about a machine centre. The machine centre is understood as a kind of CNC machine which can work automatically (automatic cycles, change of tools and workpieces, it also consists of diagnostic and measure equipment). [6]

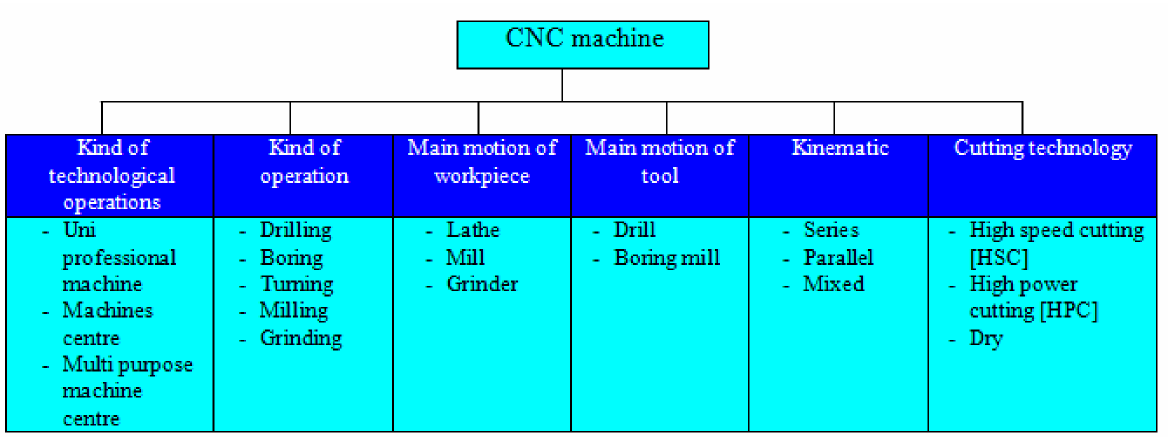

Fig. 1 Division of CNC machines

1.4.1 Division of NC Machines

NC machines can be divided into the following groups:

- **Machines of the first generation** - They were based on conventional machine and suitable for NC control system. These machines are not used anymore because they do not have features characteristic for NC machines. [6]
- **Machines of the second generation** - They were specially built for numerical control and worn tools are changed manually. [6]
- **Machines of the third generation** - The most important feature of these machines is the fact that they are used in the automatic manufacturing centre, the products and tools are changed automatically as well. On the other hand, worn tools are changed manually. [6]
- **Machines of the fourth generation -** They are characterized by automatic change of worn tools. Concerning operations, such as change of the tools and the products, and manipulation with chips, they are fully automatic. [6]
- **Machines of the fifth generation** - Following operations are used: Compensation of motion errors and measuring of the product during cutting by motion sensors.

1.5 Storing Devices

An interface is usually an electronic device designed to communicate with the computer of the CNC unit.

1.5.1 Punched Tape

Punched tape is the oldest media for storing programs. The tape is made of a good quality reinforced paper. Paper tape is generally available in black color. Other tape materials are used, such as Mylar which is a paper tape sandwiched between two layers of plastic. The plastic makes the tape stronger, which is an important factor when the tape is to be used constantly. Aluminum or metal tapes are also available and they are used only for critical jobs and long programs. [7]

1.5.2 Magnetic Tape

In the late 1950s some NC machine control units (MCUs) used 25mm magnetic tape to store data. This tape was similar to what was used to record music and conversation, but was of a higher quality. It was not used for any length of time because interference from nearby electrical equipment such as transformers and other shop equipment had a tendency to erase or scramble some of the information on the tape. Today magnetic tape has better shielding from outside electrical interference, and 6mm tape in a cassette is used for some CNC applications (Fig.2) [10]

1.5.3 Zip Drive

Zip disk that can hold up to 100 MB of data. The drive is included with software that can catalog the disks and lock the files for security. A new 250 MB version of the Zip drive, introduced in 1998, can also read and write the 100 MB Zip cartridge. (Fig.2) [10]

1.5.4 CD-ROM (Compact Disc Read Only Memory)

A compact disk format has digital data carved into them with a laser. Standard CDs can very quickly record or retrieve up to 650 MB of data, or about 250,000 pages of text. (Fig.2)[10]

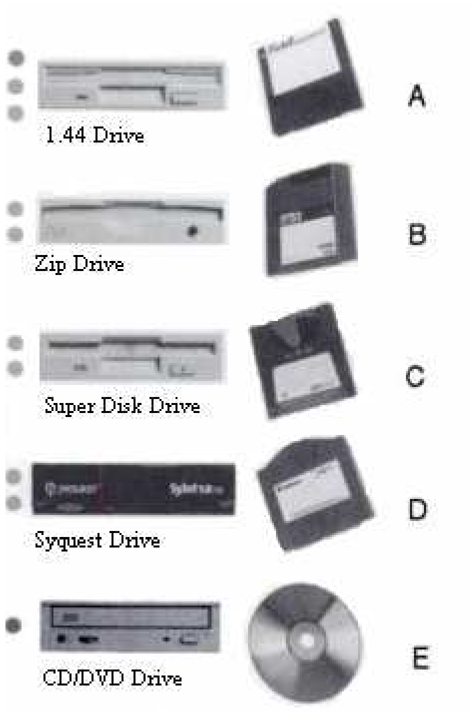

Fig. 2 The drives and input media

1.6 Advantages of CNC Machine

It is important to know which areas will benefit from being machined by CNC machine and where a conventional way of machining is better to use. Individual users will experience different levels of actual improvement depending on the product manufactured on-site, the CNC machine used, the setup methods, complexity of fixturing, quality of cutting tool and engineering design, experience level of the workforce, and individual attitudes. [7]

1.6.1 Setup Time Reduction

In many cases, setup time can be reduced for CNC machine, sometimes quite dramatically. Setup time is unproductive, but necessary - it is a part of the overhead costs of doing business. Keep the setup time to a minimum should be of the primary considerations of the programmer and the operator. [7]

1.6.2 Lead Time Reduction

Lead time for the first run is usually longer; it is virtually zero for any subsequent run. If engineering change of the part design requires the program to be modified, it can be done quickly and thus lead time is reduced. [7]

1.6.3 Contouring of Complex Shape

The CNC lathes and machining centers are capable of contouring variety of shapes. Many CNC users acquired their machines only to be able to handle complex parts. Complex shapes such as molds can be manufactured without additional expenses of making and model of tracing. [11]

1.6.4 Increase in Cutting Time and Productivity

The CNC machining is under control of computer. The small volume of manual work is restricted to the setup, loading and unloading part. The main benefit of consistent cutting time is for repetitive work, where the production scheduling and work allocation to the individual machine tools can be done very accurately. [12]

2 TECHNOLOGICAL PREPARATION OF MANUFACTURING

Production sequence must be deeply considered when CNC machined. Right option of technology is the basic precondition for good work and economical use of machines.

2.1 Stages of Product Preparation

2.1.1 Choice of Material

A production engineer decides which parts are available for CNC machining with consideration of their shapes, required accuracy and demands for additional conventional machining. He also determines suitable machine tool. Economy is the basic indicator of the given workpiece transformation into component basic.

Technological Sequence:

The production engineer creates technological sequence containing preliminary operations, basic operation of CNC machine and finalization. It is necessary to distinguish surface area for workpiece gripping and decide the special cutting tools that will be used. These decisions are done in cooperation with the programmer. Then tool setter adds schematic representation. Department of technological preparation implements construction of clamps and tools.

Control Program:

It consists of:

- Choice of gripping method – it is necessary to ensure firm and secure keep of workpiece, especially when force during machining is maximal and workpiece deformation is minimal. Gripping does not block the approach of the tools to the machine surface as well as of other operations such as measuring, cooling, and chip remove.
- Creation a technological sequence for CNC machine.
- Draw of the product for subsequence programming. It is based on the working drawing of the part. Stop surface, reference point coordinate as well as other important points are marked off.

- List of tools:
    - Tool type, its position in magazine, automatic or manual tools change
    - Tools specification, type of holder
    - Tools correction, description of work
    - Determination of cutting conditions
    - Comments important for manufacturing
- List of coordinate system – used for better orientation and program blocks control
- Program list entry – all data must be transferred into a numerical form; every section of manufacturing must be defined by single block. Tools tracks, end point coordinate, point of tool exchange and all technological information must be determined.
- Machine control of the program – the programmer and the machine operator must be present. Suitability of the tools, cutting conditions and workpiece gripping are also controlled. When everything is all right, the programmer creates the final version of the program, documentation and records retention.

2.2 Machining Simulation

The latest in the development of CNC is Deneb's Virtual NC, a superior interactive 3D simulation setting that allows a person to visualize and analyze the operation of a machine tool, its CNC controller, and the material-removal process. It allows a user to improve the quality of CNC programs, eliminate tool and machine crashes due to program errors, and produce the most efficient machining process. [12]

A few of the advantages of Virtual NC are:

- **Rapid Modeling** – Attachments, tool changers, fixtures, etc., can be added to produce a realistic manufacturing process.
- **Training –** New operators can be trained without damaging the machine or tooling.
- **Collision Avoidance –** Virtual NC automatically detects near misses and collisions, and stops the cycle, at the same time noting the program block in which correction is needed.

- **Cycle Information –** Material removal and machining data can be continuously monitored.
- **Concurrent Engineering –** Manufacturing engineers and programmers can evaluate the machine controller and the machining process without taking up valuable machine time or risking damage to the machine.

3 PROGRAMMING OF CNC MACHINE

Programming of the CNC machine can be done in 2 possible ways:

- online system, direct at CNC machine, workshop programming
- offline programming.

3.1 Coordinate System

The CNC machining is used right–handed, rectangular (Cartesian) coordinate system with the axes X, Y and Z. International movements can be worked as A, B, C and they correspondent with X, Y, Z axes. Axe Z is parallel with headstock, where the positive motion is out of workpiece to tool. Cartesian coordinate system is important for machines, tools motions are done according to commands. Coordinate system can be rotated or moved with (Fig.3). [8]

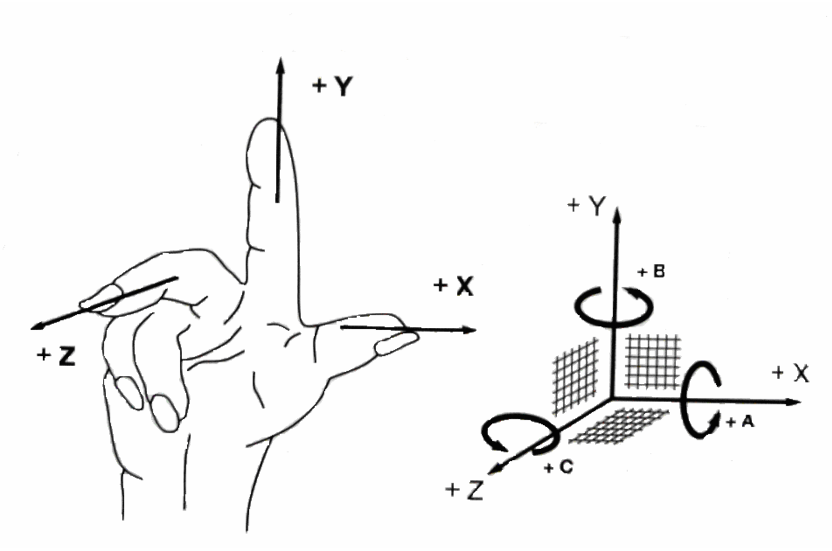

Fig. 3 Cartesian coordinate system

3.2 Reference Point

Reference point is activated after a turn. The machine coordinate system has zero point which must be right assessed. [8]

M – Machine Zero Point: It is established by the producer. It is a basic point for all next coordinate systems and reference point at machine. Turning machine has zero point at a spindle axis. Milling machine has zero point at outer point on the milling table in the both axes (usually from worker’s point of view it is left, front).

W – Workpiece Zero Point: The programmer set it up, according to existing functions, in the necessary place on the workpiece.

It can be done as follows:

- Moving of coordinate system – function G54 to G59 (absolute, incremental) from machine zero point.
- Indication of tool position function – tool is defined by point coordinate system.

Programmer sets up zero point which is depended on the machine.

R – Machine Reference Point: It is established by the producer. Mechanical and computation part of the machine can be activated by reference point. After turn on machine it is prepared for strict measurement. Possible errors are prevented by use of reference point. It is realized by mechanical way (according to switch). [Fig.4]

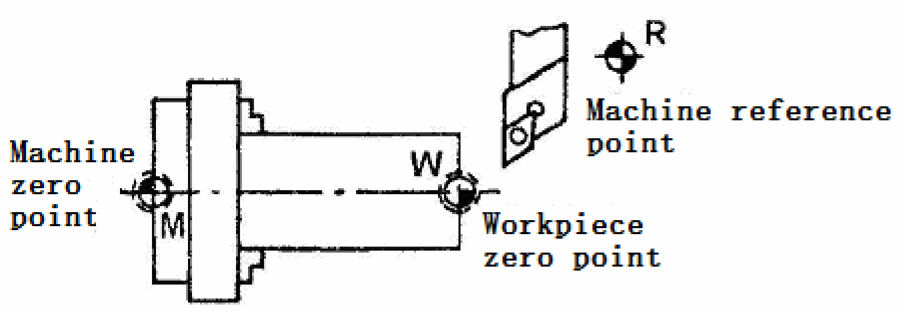

Fig. 4 Basic machine and tool points

3.3 CNC Code

Cartesian coordinate system is used for machining CNC program.

- **Absolute programming** – All dimensions are measured from origin point. Origin point is the program reference points also known as program zero point. The machine actual motion is difference between current absolute position of the tool and the previous absolute position.

The main advantage of absolute programming is easy modification by the programmer or the CNC operator. Change of one dimension does not affect any other dimensions in the program (Fig.5). [7]

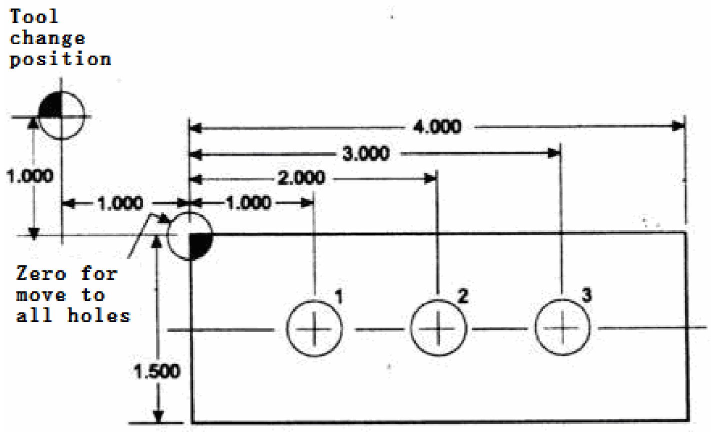

Fig. 5 Absolute programming

- **Incremental programming (relative)** – all program dimensions are measured as separate distances to specified direction. The actual machine motion is the specified along each axis, with the direction indicated.

The main advantage of incremental programming is its portability between individual sections of the program. It is mostly used when developing subprograms or repeating an equal distance (Fig.6). [7]

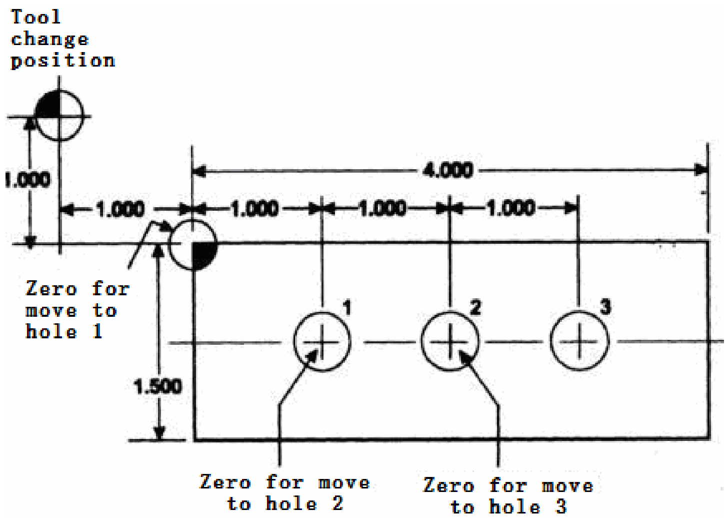

Fig. 6 Incremental programming

- **Combinations in a single block** – On many Fanus controls, the absolute and incremental modes can be combined in single program blocks for special programming purpose. [8]

3.4 CNC Program

Each line in the CNC program is called a block. In the terminology established above, the block is defined as a single instruction process by the CNC system.

Sequence block, program block is normally one hand written line in the program copy, or line typed in the text editor and terminated by the enter key. This line can contain one or more program words – words that result in the definition of single instruction on the CNC machine. Program instruction may contain a combination of preparatory commands, coordinate words, tool functions and commands, position registration, etc. Program consists of a series of blocks necessary to complete certain machining process. [8]

Main advantages of the following program structure are:

- Program shape, instructions and syntax rules must be kept. As a result, possible errors can be found.
- Structure program enables easy orientation in program
- Structure program enables better changes.

The overall program length will always depend on the total number of the blocks and their size.

The block consists of the followings signs and words:

- N – Block Number – every block must begin with a number. The block number is on the front of each block program and consist address N and the number.
- G – Preparatory Commands – this address has one and only objective – that it is to preset, to prepare the control system to certain desire condition, to a certain mode or a state of operation.
- X, Y, Z – Axis Motion Commands – they are determined on the finish position points

- F – Feed Function – it is a number which has 4 or 6 decimal places. It is determined on the feed working motion in mm/min.
- S – Speed Function – it is number which has 4 or 6 decimal place. It is determined on the speed of spindle in rev/min.
- T – Tool Functions – it determines the tool which is used.
- M – Auxiliary Functions – an able us to control machine functions such as spindle rotation, spindle orientation, coolant selection, tool changing and indexing table. [8]

Modern CNC machines do not have exactly established words in the blocks. (Fig.7)

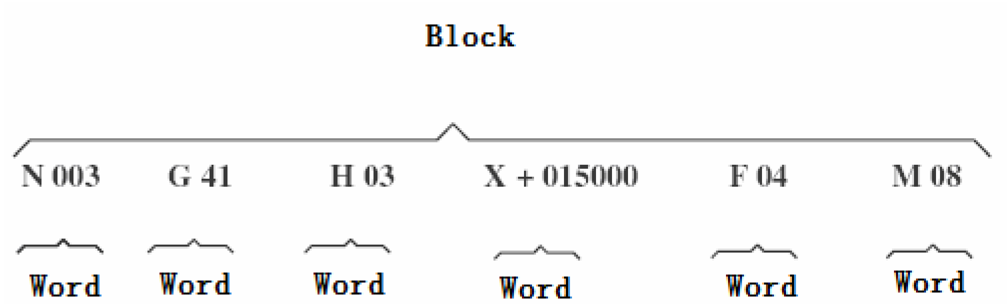

Fig. 7 CNC program structure (block)

4 CUTTING TOOLS

4.1 Cutting Tool Materials

High productivity and minimum costs are required in machining on the CNC machine. Cutting tools must suit the demands for high cutting power, high persistent against mechanical and temperature efforts. Tools with replaceable edge made of cemented carbide, coated slate are used. [8]

Most frequently used materials:

- High Speed Steel
- Cemented Carbide
- Ceramics
- Diamond

4.1.1 High Speed Steel

Tools made of high speed steel must be used in suitable environment (cutting coolant). It is mostly used for manufacturing. They are easily machinable. Very well is used cemented carbide. Cutting tips are on the body tool soldering or mechanic fixed. It can be used replaceable cutting tip for all tools. Disadvantage is more expensive chucking equipment and organization servicing. [8]

4.1.2 Cemented Carbide

As the name implies, cemented carbide is a tool-material made up hard of carbide particles, cemented together by a binder. It was an advantageous combination of properties for metal cutting and along with high speed steel, has dominated metal cutting performed at higher cutting speeds. [2]

Cemented carbide is a powder metallurgical product made from a number of different carbides in a binder. These carbides are very hard and those of tungsten carbide (WC), titanium carbide (TiC), tantalum carbide (TaC), niobium carbide (NbC) are the main ones. The binder is mostly cobalt (Co). In addition, the carbides are solvabled in each other and can form the cemented carbide without a separate metal binder. The hard particles vary in size between 1 – 10 microns and usually make up between 60 – 95 % in volume share of the material. [3]

Cemented carbides vary considerably as far as properties are concerned, some are much harder than others and some are tougher. The carious grades that are established for inserts are mainly determined by:

- Type and size of hard particles
- Type and proportion of binder
- Manufacturing techniques
- Quality [2]

The manufacture of cemented carbide takes place in the following main stages:

- Powder production
- Pressing of compacts
- Sintering
- Insert treatment
- Coating [3]

With cemented carbides, coated and uncoated, being responsible for most of the metal removed in machine shops, and with the broad ranges of applications and work piece materials, there have been a lot of different grades developed. These have descriptions from manufacturers but need a classification system for users to relate them to operations, conditions and materials. [1]

The ISO classifications of cemented carbides aim to provide a code and chart from which users can begin to select grades.

The ISO classification is a mere starter when considering tooling up for an application.

The ISO classification is divided into 3 areas:

- Blue P – representing machining of long chipping materials such as steel, cast steel, stainless steel and malleable iron.
- Yellow M – representing machining of more demanding materials such as austenitic stainless steel, heat resistant materials, manganese steel, alloyed cast – iron, etc.

- Red K – representing machining of short chipping materials such as cast iron, hardened steel and non–ferrous materials such as aluminium, plastics, etc.

Within each main area there are numbers indicating the varying demands of machining from roughing to finishing. [3]

4.1.3 Ceramics

Ceramic cutting tools are hard with high-hot-hardness, and do not react with the workpiece materials. They have long tool-lives and can machine at high cutting speeds. Very high metal removal rates are achieved in the right application. [3]

There are 2 basic types of ceramics:

- Aluminium-oxid based (Al_2O_3)
- Silicon-nitride based (Si_3N_4)

4.1.3.1 Aluminum-Oxide (alumina)

Based ceramics are divided into:

- A-pure
- B-mixed
- C-reinforced

Pure:

The pure oxide based ceramics has relatively low strength, toughness values as well as low thermal conductivity. These are obviously not the best values to have in metal cutting and are the reasons why cutting edge fracture occurs if conditions are not right. The addition of small amounts of zirconium oxide to the composition significantly improves the properties of the pure ceramic. The mechanism that the zirconia grades offer means improved toughness. Durability, dentist and uniformity of grain sizes are important factors as are the various amounts of added zirconia to suit the application area. Any porosity will deteriorate tool performance. [3]

Mixed:

The mixed, aluminum-oxide based ceramic material has better thermal shock resistance through the addition of a metal phase. This type is less sensitive to cracking through improved thermal conductivity. The improvement is relative and toughness achieved can not be compared to that of cemented carbides. [3]

Reinforced:

This ceramic is a relatively new development. This type is also called whisker-reinforced ceramics, from that of the single crystal fibre called a whisker. These whiskers are only about one micron in diameter with a length of more than twenty microns. They are very strong and made of silicon carbide. [3]

4.1.3.2 Silicon Nitride

The silicon nitride based ceramics is a completely different material and is better than aluminum-oxide based ceramics in standing up to thermal shocks and as regards toughness. It is the number one choice for machining grey cast-iron with very high removal rates. Cast-iron is relatively easy to machine but does make demands on the tool material when being machined at high removal rates and speeds: high hot-hardness, strength, toughness and resistance to thermal shock as well as chemical stability.

The successful application of ceramics depends a lot on the match between the operation types, machining conditions, workpiece material, machine tool performance, general stability, the method by which machining is performed and the cutting edge preparation, especially as regards strengthening chamfers, and presentation to the cut. [9]

4.1.4 Polycrystalline Diamond

The hardest material known is the natural monocrystalline diamond and synthetic polycrystalline diamond (PCD) is almost as hard. Its considerable hardness enables it to stand up to very abrasive wear – it is used to dress grinding wheels, for instance. Fine diamond crystals are bonded during sintering under high temperature and pressure. The crystals are randomly orientated to eliminate any direction for crack propagation. This results in hardness and wear resistance uniformly high in all direction.

The small polycrystalline diamond cutting edges are bonded to cemented carbide inserts which add strength and shock resistance. Tool-life can be many times longer than cemented carbide – up to one hundred times.

However, draw-back for this seemingly perfect cutting material is:

- cutting zone temperatures must not exceed 600 degrees C,
- can not be used for ferrous applications due to affinity,
- nor for tough, high-tensile workpiece materials.

Because of the very brittle nature of polycrystalline diamond, very stable conditions, rigid tools and machines and high speeds are necessary for machining with polycrystalline diamond. Cutting fluids can be used, generally for cooling. Finishing and semi-finishing in turning and boring are typical operations. For face milling, polycrystalline diamond tipped inserts can be used as ordinary or wiper inserts in special seats. Lighter feeds, lower depth of cut and avoidance of interrupted cuts and shocks are important. [9]

4.2 Tool Offset

For every part, the programmer must consider the step-by-step operations required to machine the part. At the same time, a list of cutting tools used for each operation must be included. This tool list must include the type of each cutting tool, its diameter, and length. Since a wide variety of cutting tool of various lengths and diameters are generally used for machining a part, it is important to be able to compensate for the differences in their diameters and length to ensure that the part will be machined accurately. This compensation involves working with offsets so that the machine control unit knows exactly how to adjust for differences in tool diameters and lengths.

All forms of compensation work with offsets. CNC offsets can be thought of as memories on an electronic calculator. If the calculator has memories, a constant value can be stored into each memory and used whenever required for a calculation. The need to enter the same number over and over again when it is required is thus avoided. [10]

4.2.1 Tool Length Offset

Tool length offset (TLO) allows tools of various lengths to be used with a common datum, as shown in (Fig.8), without having to alter the program. Setting commences with tool T01, which is 'touched' onto the work surface or a setting or a block depending upon the Z-axis datum height, and the Z-axes readout is set to zero. The master tool is now T01. Each subsequent tool is then 'touched' onto the Z-axes datum and its Z-axis readout is noted. Using this information, a Z-axis offset is then applied to each tool in turn to compensate for differences in length compared with T01. The tool-length offsets are recorded in the memory of the machine's computer under the tool number file. Each time a tool is called up by its T code, the correct length offset will be automatically applied. If this parameter changes for a particular tool (the tool is reground), the offset can be reset and no change has to be made to the program.

The application of tool-length offsets to turning tools is shown in (Fig.9). In this case it can be seen that offsets are required in the X- and the Z-axes relative to a common datum. Usually a number of different tools are located in the lathe turret and each tool will require its own offsets since each tool protrudes by a different distance. The offset for any one tool becomes operative as soon as that tool is called into the program by its T number. [12]

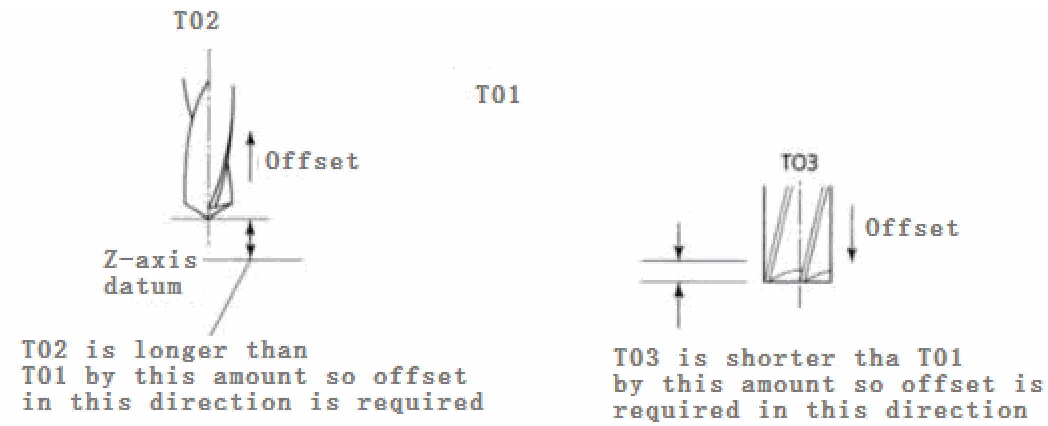

Fig. 8 Tool lengths offset milling

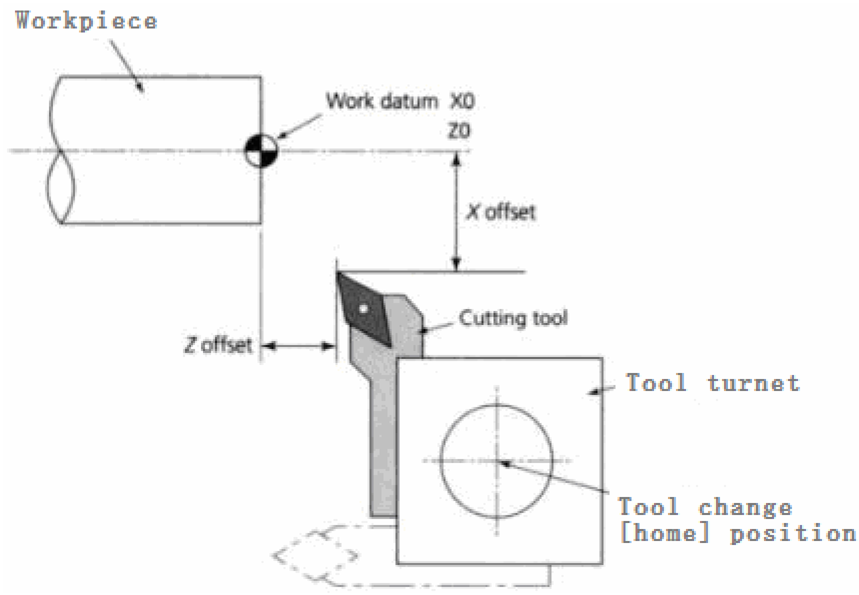

Fig. 9 Tool length offset turning

4.2.2 Tool Radius Offset

Like tool-length offsets, cutter-diameter compensation (milling) and tool-nose radius compensation (turning) are also facilities provided to aid programming. Not only do these facilities allow tools of different sizes to be interchanged without alternation to the program, they simplify the writing of the program. The tool can be assumed to travel round the profile being machined and allowance for the actual diameter of the cutter is automatically made by the controller. Furthermore, the programmer when programming for turning on the lathe, can assume the tools have a sharp nose. In this instance the controller automatically compensates for the nose radius of the tool. [12]

Cutter-diameter compensation for milling machines is controlled by the following preparatory codes:

G41 compensates – cutter to the left of the work-piece (Fig.10a)

G42 compensates – cutter to the right of the work-piece (Fig.10b)

G40 compensation cancelled

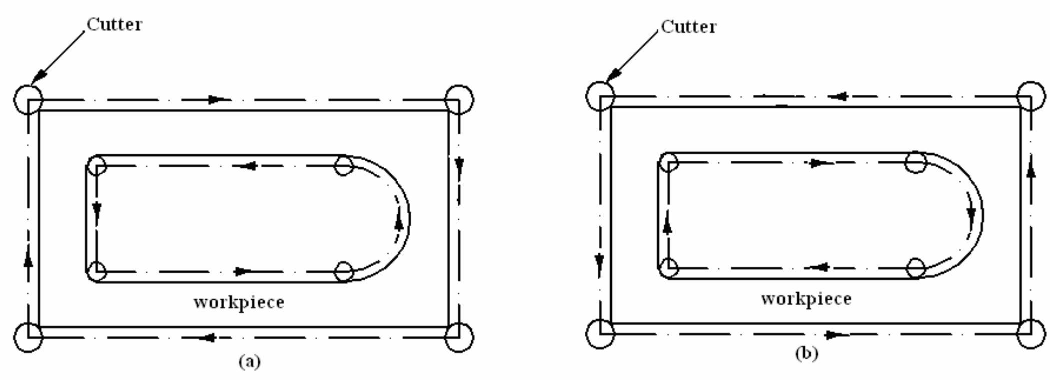

Fig. 10 Milling cutter diameter compensation: (a) to the left; (b) to the right

At first sight the 'handing' of the compensation is a little difficult to interpret. Consider Fig.10a Start at any point and face in the direction of the cutter travel by following the arrows. It can be seen that the path of the cutter is allowed to the left of the surface being machined. Similarly, in Fig. 10b the path of the cutter is always to the right of the surface being machined. The path of the cutter traverse is determined by whether up-cut or down-cut (climb) milling techniques are used.

4.3 Chucking of Workpiece and Tools

4.3.1 Chucking of Workpiece

In manual operations, a chuck, a collect or a special fixture mounted on the headstock of a lathe normally opens and closes when the CNC operator presses a foot pedal. For safety reasons, a chuck that is rotating can not be opened because it is protected by a special safety interlock. Another important feature of chucks is that the terms open and close depend on the method of chucking – external or internal (Fig.11). Note that the terms opened or closed are relative to the setting of a toggle switch or a key switch, found on the machine itself, usually marked chucking closed – that has two settings – in and out.

On most CNC lathes the pressure is controlled by an adjustable valve, usually in the tailstock area. Once the chuck pressure has been set, it is not changed very often. However, there are jobs that require the chucking pressure to be increased (tighter grip) or decreased (looser grip) frequently, usually within the same operation. A very few CNC lathe manufacturers offer a programmable chucking pressure. [7]

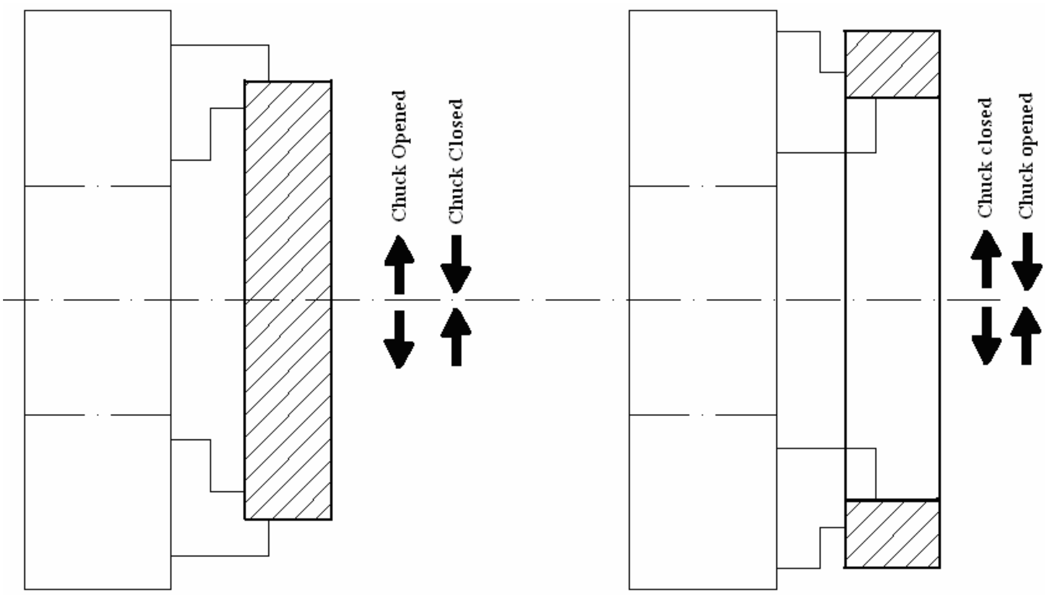

Fig. 11 Part gripping – external and internal applications

Most chucks have three jaws, spaced 120° apart (Fig.12). The jaws may be hard (usually serrated for better grip) or soft (normally bored by the CNC operator to suit the work diameter). Only soft jaws can be modified.

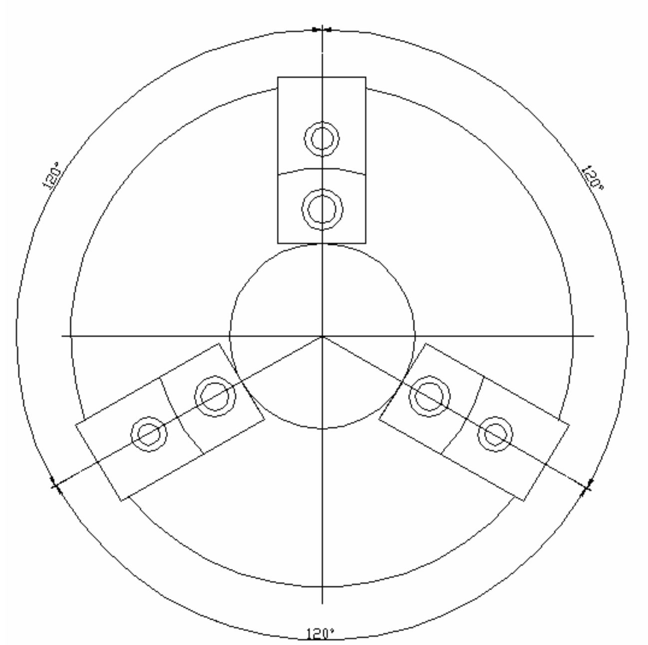

Fig. 12 Three-jaw grip CNC lathe

Soft jaws are designed to be bored and the ability to do that is one of the basic skills a CNC operator must have. There are various techniques to bore soft jaws. Fig.13 shows three versions – one correctly bored jaw and two incorrectly bored jaws. In both incorrect versions, the grip, the concentricity, or both, may suffer.

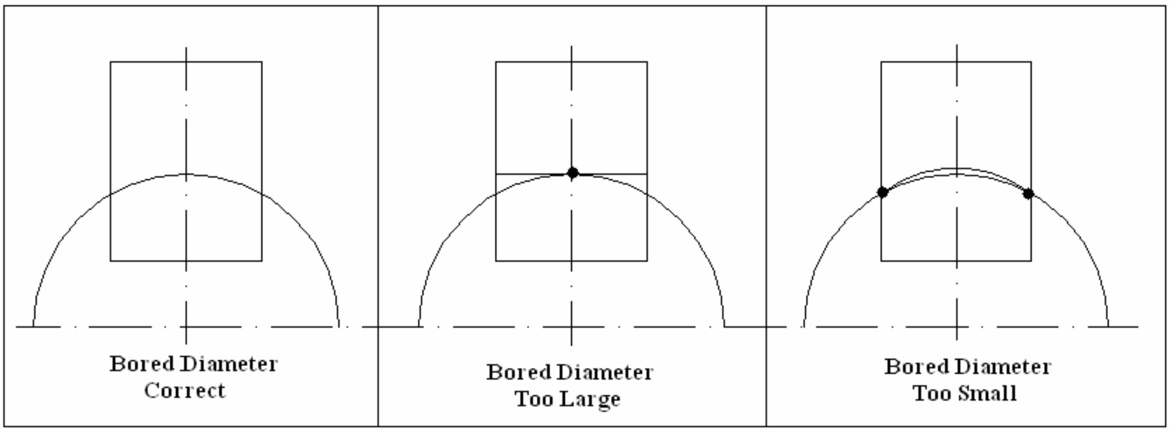

Fig. 13 Soft jaws diameter bored correctly (left) and incorrectly

4.3.2 Chucking of Tools

Tooling has a direct impact on the productivity of CNC machines. This is true of both work-holding tools and cutting tools. Good chucking can ensure that workpiece is held with the rigidity required for machining. Additionally, the proper use of fixtures can minimize tool changes if multiple workpiece is held. Similarly, cutting tools have a direct relationship to machining time. The better tooling the faster machining can take place. Cutting tool maintenance can also be kept to a minimum if the proper cutting tools are used. All of this means that tooling must be considered an essential core element of the CNC environment. Keep in mind that CNC machine tool technology and cutting tool technology are constantly leapfrogging one another. The machine tool builder designs a CNC machine that can withstand all that today’s cutting tools can do. Tomorrow, next week, or next year, a tooling manufacturer will develop a new grade of cutting tool that improves on current technology. It is then the machine tool builder’s turn once again to catch up. [6]

Though it can almost be a full-time job, one must strive to keep track of changes in tooling technology.

5 CAVITY BLOCK

5.1 Preform Design

One of the most important aspects of the closed-die forging process is the design of preforms to achieve adequate metal distribution. With proper preform design, defect-free metal flow and complete die fill can be achieved in the final forging operation and metal losses into flash can be minimized. The determination of the preform configuration is an especially difficult task and art in itself requiring skills achieved only with years of experience. In attempting to develop quantitative and objective engineering guidelines for preform design, one must have a thorough understanding of metal flow. Metal flow during forging can be considered to take place in two basic modes: extrusion and upsetting. In most forgings, the geometry of the part is such that both modes of flow occur simultaneously. In the study of metal flow for designing the preform, it is very useful to consider various cross sections of a forging at which the flow is approximately in one plane. The surface connecting the centers of the planes of flow is the neutral surface of the forging. The neutral surface can be thought of as the surface on which all movement of metal is parallel to the direction of die motion. Thus, metal flows away from the neutral surface, in a direction perpendicular to die motion. It is common practice in designing a preform to consider planes of metal flow, that is, selected cross sections of the forging, and to design the preform configuration for each cross section based on metal flow. The basic design guidelines are given below.

First, the area of each cross section along the length of the preform must be equal to the area of the finished cross section augmented by the area necessary for flash. Thus, the initial stock distribution is obtained by determining the areas of cross section along the main axis of the forging.

Second, all the concave radii of the preform should be larger than the radii of the forged part. Finally, whenever practical, the dimension of the preform should be larger than those of the finished part in the forging direction so that metal flow is mostly of the upsetting type rather than of the extrusion type. During the finishing operation the material then will be squeezed laterally toward the die cavity without additional shear at the die material interface. Such conditions minimize friction and forging load and reduce wear along the die surfaces. [13]

5.2 Multiple-Part Dies

Forging of more than one part in a single die is desirable under certain conditions, including:

- Costs for forging without multiple-part dies are prohibitively high because machine time is long and the proportion of metal lost to flash, sprues, and tonghold is high.
- Production requirements are large.
- Parting face of the die is uneven, and a balance of forces is needed to avoid incorporating a counterlock in the die.
- The forging is so small that it cannot be produced economically in the equipment available.

There are conditions, however, under which it is not practical to consider making more than one forging in a single die. These include:

- The parts are too large to be made in multiples in the available equipment.
- The parts are too large to be handled more than one at a time.
- Production requirements are not sufficient to make full use of the life of a multiple-part die.

The above conditions generally cannot be considered singly, because there are many applications for which labor and machine costs, along with savings in metal, may or may not offset the cost of multiple-part dies.

Forgings that are best suited to production in multiple-part dies are those that can be arranged in pairs or other multiples in such a way that the forging forces are balanced. A forging in which the distribution of stock is uneven from one end to another, such as a connecting rod, is an example. When forged singly in a hammer, parts of this type require several blows in fuller and roller impressions, but when forged in multiples, they can be nested, grain flow permitting, to eliminate some of the blows required and to improve the production rate. A second example is a forging that, production singly, must be made in dies having a single plane of lock. When such parts are forged in multiples in alternating position, the force imparted by the opposing planes of lock can be balanced.

Forging of uniform section can be made either singly or in multiples. For making such forgings, multiple-part dies are used mainly to reduce per-piece forging costs or to increase the rate of production.

An advantage of multiple-part dies in that by more fully using the machine capacity and operator time they allow a reduction in forging piece costs, even though a larger-capacity forging hammer or press may be required or the machine cycle time may be longer.

The flash allowance for a part made in a multiple-part die is generally less than for a part made in a single-part die. [13]

II. PRACTICAL PART

6 SOFTWARE

6.1 Solid Edge

Solid Edge is a 3D CAD parametric feature solid modelling software. It runs on Microsoft Windows and provides solid modelling, assembly modelling and simulation of functionality.

Part Modelling **-** The modelling process begins with a basic feature which can be created by a linear, revolved, lofted. Each subsequent feature is based on the previous feature. When being modified, the model is rolled back to the point where the feature was created so that the user is not allowed to apply constraints to geometry that does not exist yet. The drawback is the fact that the user does not see how a modification will interact with the subsequent features.

Direct Modelling **-** The direct modelling of the features allows the user to change model geometry/topology of which the user does not have access to the parametric data. This is particularly useful for working with imported models.

Assembly Modelling - An assembly is composed of individual parts connected by binding constraints. Solid Edge supports large assemblies (over 100,000 parts).

Draft - A draft file consists of a 3D model projected to one or more 2D views of the part or assembly file.

6.2 EdgeCam

EdgeCam is a computer aided manufacturing (CAM) program developed by Planit. EdgeCam specialises in solid based machining. It has support for direct translation of Solidworks solid files, as well as files from other widely used CAD systems, such as Inventor, Solid Edge, Pro/ENGINEER, Pro/DESKTOP, UGS NX and CATIA.

EdgeCam is a complete computer aided manufacturing software solution for production machining, and mould and die applications. It has an extensive range of 2-5 axis milling, turning and mill/turn strategies, seamless computer aided design integration and it is sophistication for automation tools.

Supportive solutions for more productive and profitable machine shop are supplied. These include toolpath simulation, a wizard approach to post processing, a comprehensive tooling database, intuitive and flexible machine tool communications.

EdgeCam covered the production machine shop with a wide range of flexible milling cycles. Efficiency of machining is maximized on simple and complex prismatic parts as well as those incorporating sculptured surface geometry. EdgeCam includes prismatic machining combined with powerful 3D solid and surface machining strategies.

EdgeCam Turning includes functionality for a wide range of machine tools, including 2-axis lathes, multi-turret configurations, sub-spindle turning centers and milling/turning machines. On a milling/turning machine, C-, Y- and B-axis milling and drilling take place within the same program as the turning to provide a fully integrated and associative programming solution.

EdgeCam produces advanced roughing and finishing turning cycles, together with support for facing, boring and drilling.

6.3 Product Description

Turncock was produced in a large lot-production in the Slovarm Company. The product was designed in the EdgeCam programme. The main parts of turncock were made from brass and handle from aluminium alloy covered by plastic. Gaskets were from non-stick material, which resists working temperature and working pressure. It works as a stop valve to distribute drinkable and industrial water of 110°C and working pressure of 1.6MPa. It can be used for air pressure up to 2MPa. It was manufactured with two-arm handle and one-arm handle.

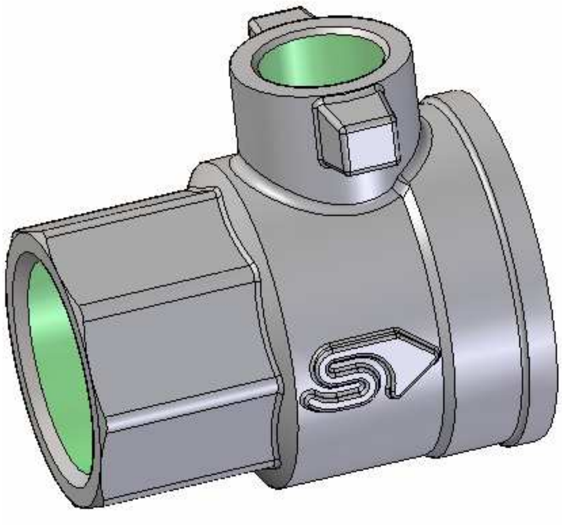

Fig. 14 Turncock (product)

6.4 Matrix and Plunger

Cavity block was designed and manufactured in the Slovarm Company for a forging machine.

6.4.1 Material

Matrix is made out of manganese steel 19541.3, which has very good mechanical qualities (hardness, toughness, hardenability and dimensional stability). Chrome-manganese steel was chosen for impression die.

Chrome-manganese steel contains: 0.32%C, 3%Cr, 4.8%Mn, 0.5%V. It has good warm strength, resistance to tempering, good heat conductivity and can be water-cooled. It is used for overused parts of extrusion presses, cavity blocks and overused tools for high casting. It is spheroidized a temperature of around 750 – 800° C, cooled in the furnace. It is hardened a temperature of around 1020 – 1050° C and it is cooled in an oil or in a quenching bath a temperature of around 500 - 550° C and it is hardness 52 HRC and it is tempered on the 52 HRC by about 560° C.

6.4.2 Designed at Solid Edge Programme

Cavity block for the forging machine was designed in the Solid Edge programme. Sizes of matrix were done according to size of forging machine. Design documentation is in the appendix.

Solid Part option was chosen after had opened the Solid Edge programme (fig. 15).

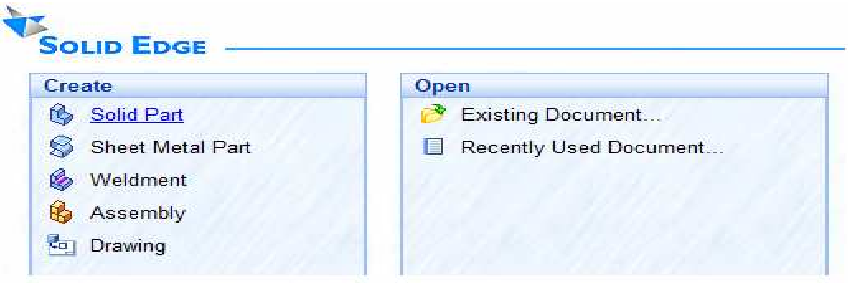

Fig. 15 Possibilities of construction

As the first operation was used Protrusion operation (fig. 16), where plane was selected for creation a feature. Profile was protruded on the required size (fig. 17) and every side of the block were chamfered.

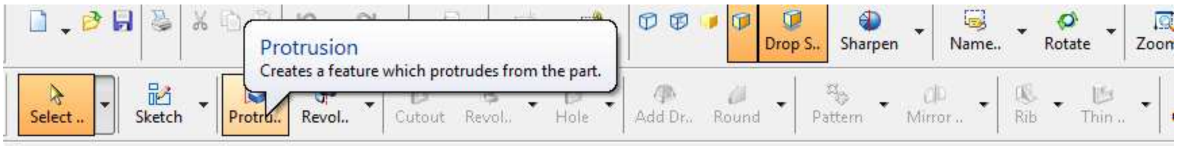

Fig. 16 Basic panel for modelling

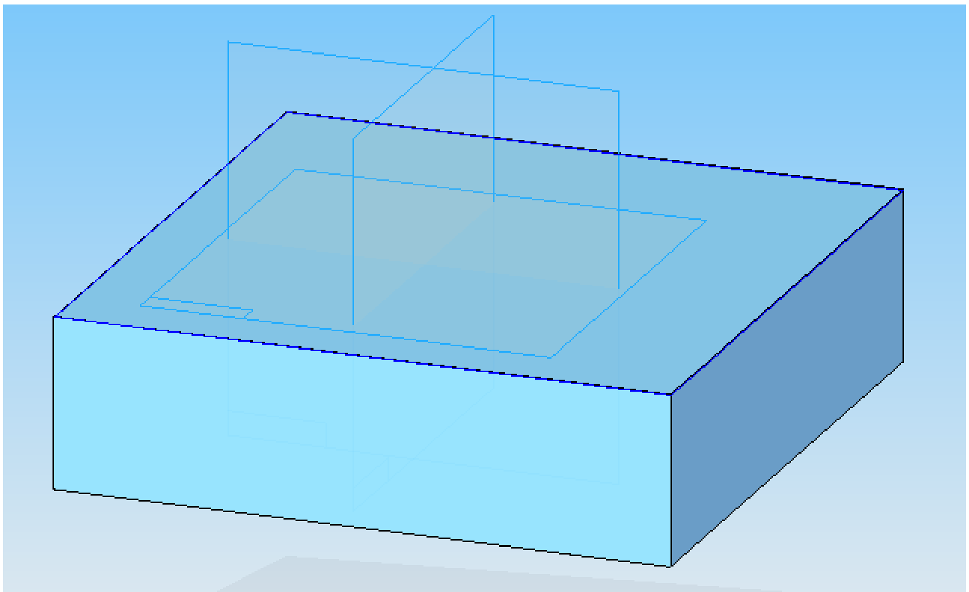

Fig. 17 Side of protrusion

Cutout operation was chosen for creating the holes (fig. 18). As first were made 4 holes with size Ø20mm (for the adjusting pin). After creating the place for gripping (fig. 19) the Hole operation was used (fig. 20). 4 holes with threads were created (fig. 19) and edges of holes were chamfered.

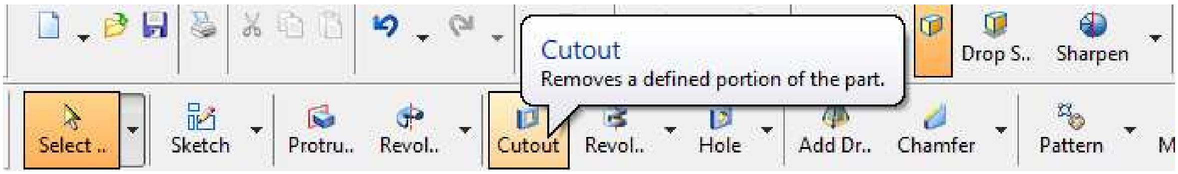

Fig. 18 Cutout operation

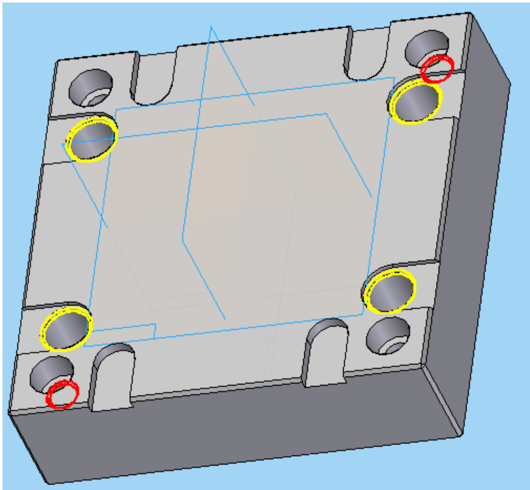

Fig. 19 Holes

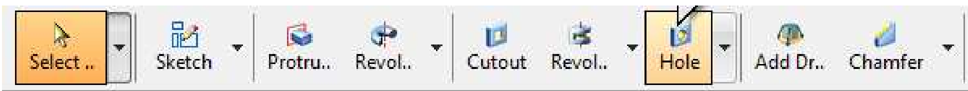

Fig. 20 Hole operation

New coordinate system was added (fig. 21) and Part-Copy operation was applied to add turncock into the block and then Boolean operation (fig. 22) was used for the imprint turncock into the cavity block (fig. 23).

Fig. 21 Coordinate system operation

Fig. 22 Boolean operation

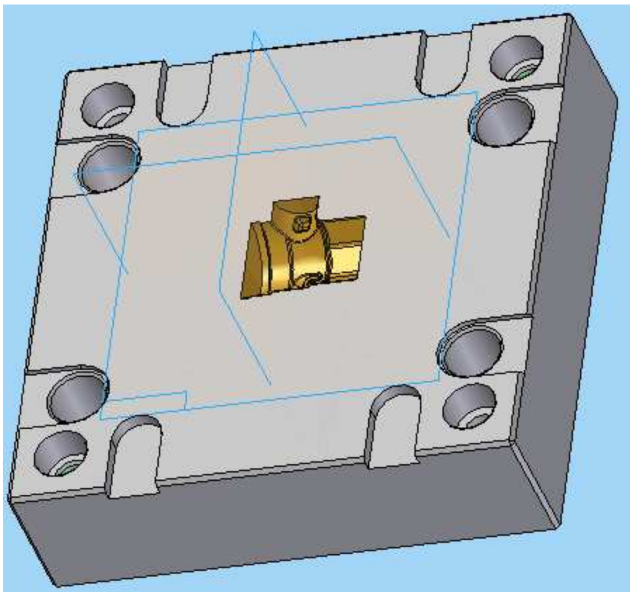

Fig. 23 Turncock imprint

For the designed cores was chosen the Revolted Cutout operation (fig. 24) and the ending of cores were chamfered (fig. 25).

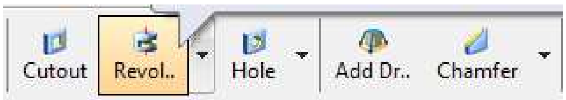

Fig. 24 Revolting operation

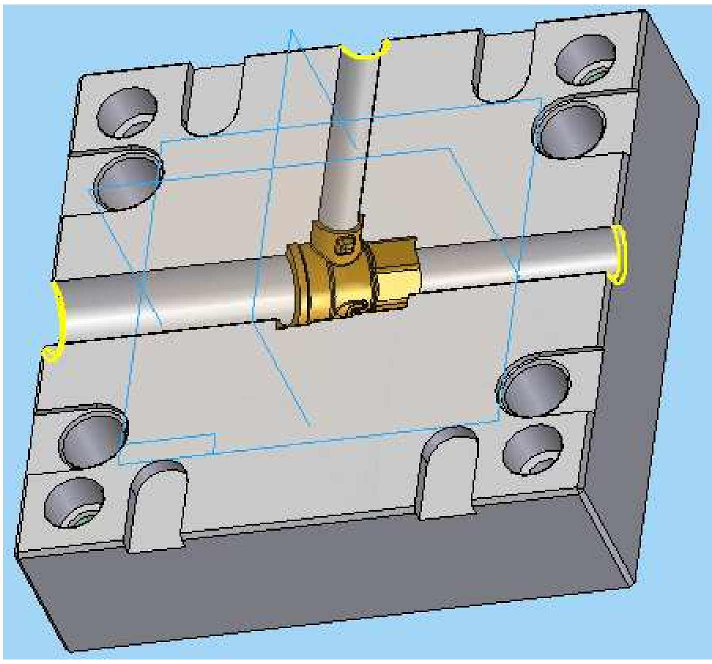

Fig. 25 Cavity block with cores

The Cutout operation was employed for the creating veining mortise and inner edges of the veining mortise were round (fig. 26).

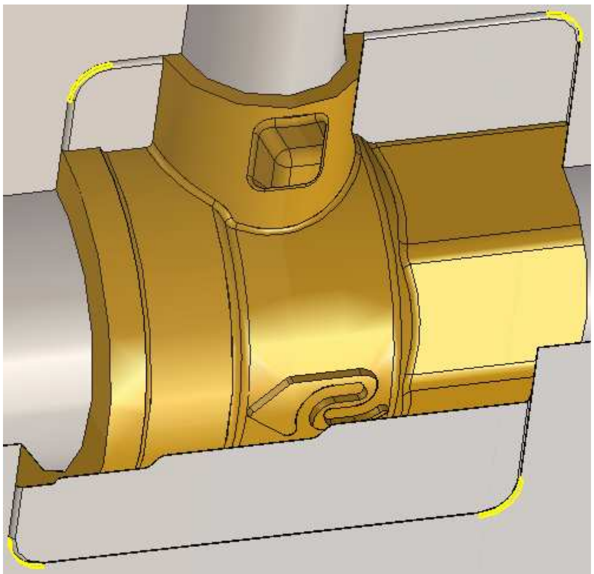

Fig. 26 Veining mortise

The Cutout operation was picked for design the ejectors (fig.27) and the holes were chamfered.

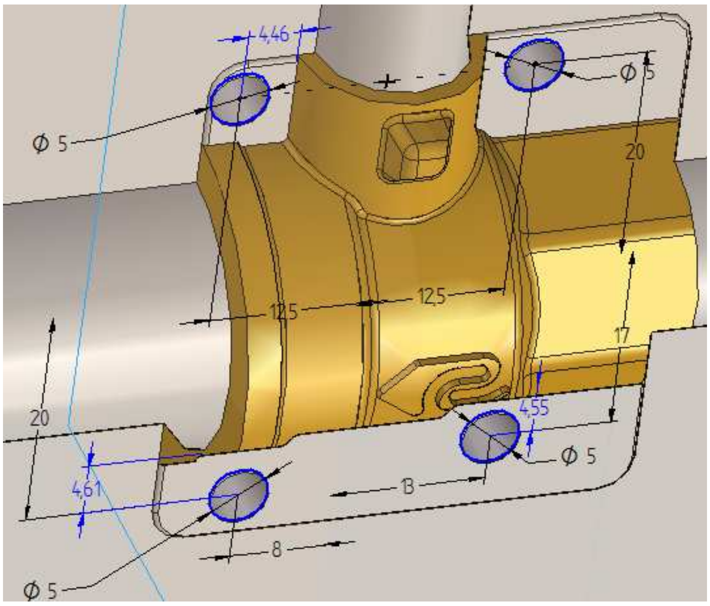

Fig. 27 Ejectors

The same way was used for the manufacturing plunger (fig. 28).

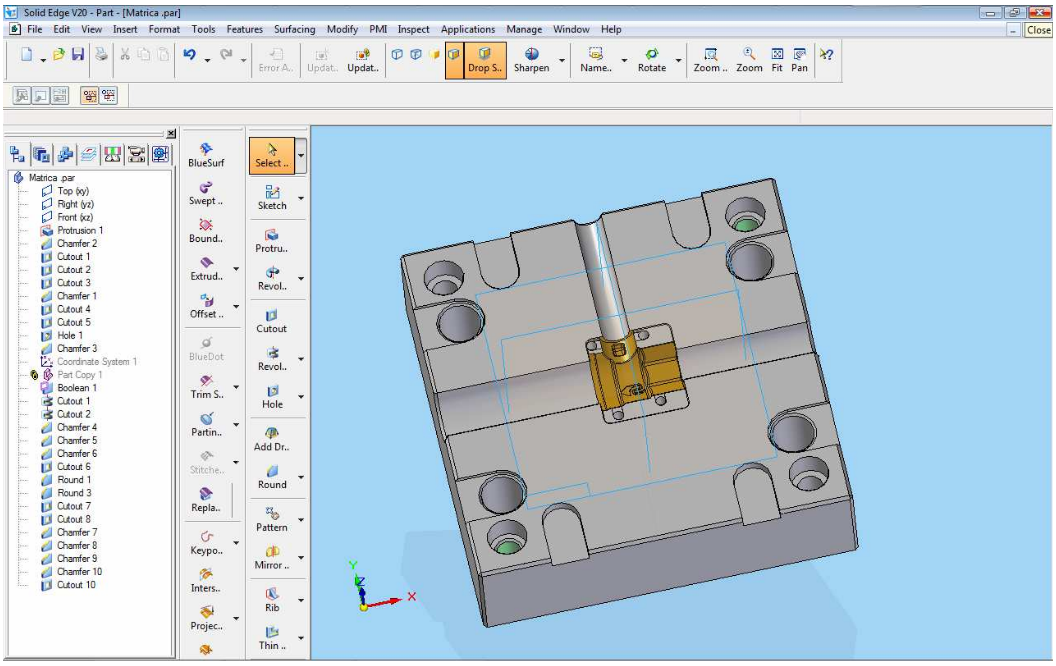

Fig. 28 Final matrix

6.4.3 Programming at EdgeCam

The matrix was imported into the EdgeCam programme as the model (fig. 29).

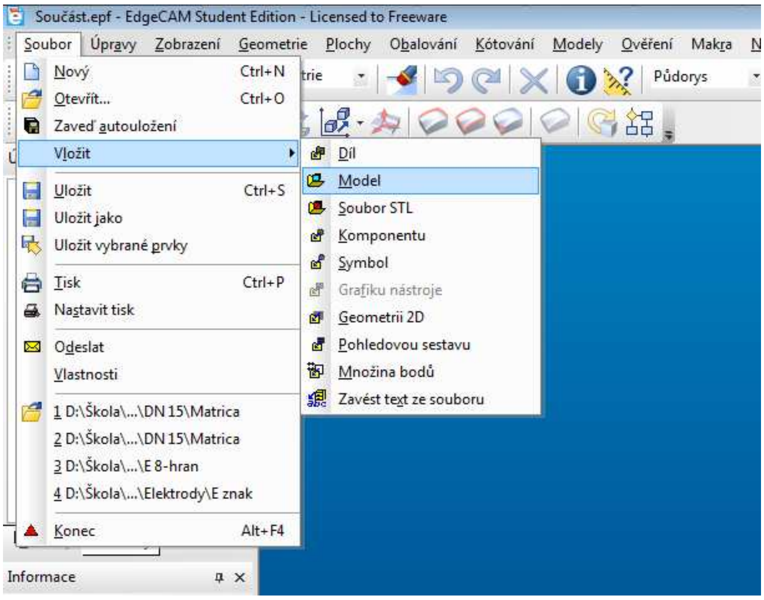

Fig. 29 EdgeCam programme

The manufacturing lines (Z-line) were set up. Manufacturing lines had different colours, which helped with orientation (fig. 30).

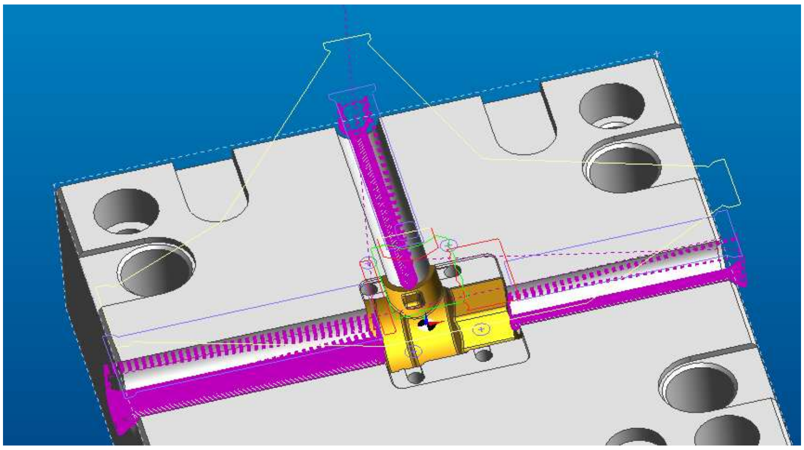

Fig. 30 Manufacturing lines

6.4.3.1 Roughing Cycle

First, cores and cavity of turncock were manufactured. The plane cutter was used for the roughing operation. Roughing operation was established for removing the biggest part of material (fig. 31).

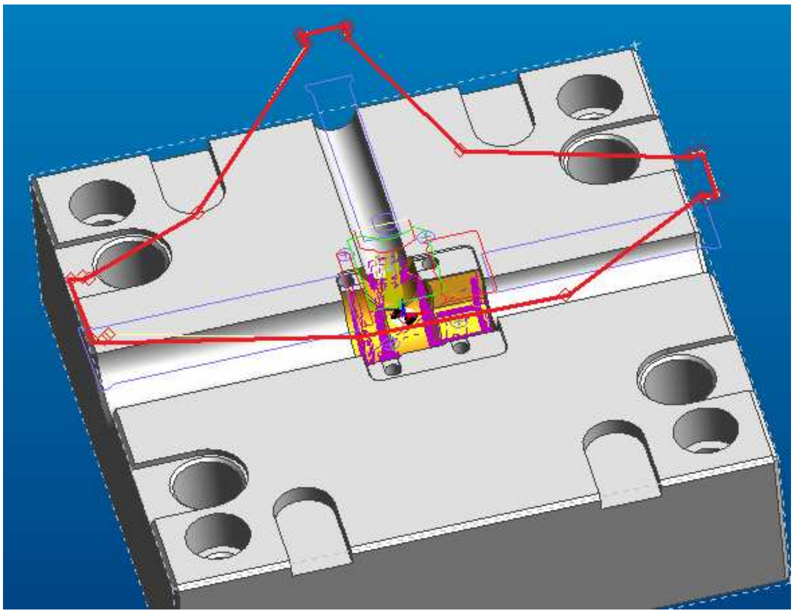

Fig. 31 Roughing operation

In the roughing tab were set up manufacturing parameters. All parameters for the manufacturing are in the table 1.

Table 1 Roughing cycle

Tool	*Plain milling cutter 12 r2.5*
Feed (mm/min)	*2400*
Infeed (mm/min)	*3000*
Speed (rev/min)	*4000*
Offset (mm)	*0.2*
Clearance (mm)	*5*
Depth (mm)	*-16*
Cut increment (mm)	*0.3*
Time (sec)	*560*

6.4.3.2 Rest Roughing Cycle

It was continued in the same way as for the roughing operation. All parameters for the manufacturing are in the table. 2.

Table 2 Rest roughing cycle

Tool	*Plain milling cutter 12 r2.5*
Feed (mm/min)	*960*
Infeed (mm/min)	*2000*
Speed (rev/min)	*5000*
Offset (mm)	*0*
Clearance (mm)	*5*
Depth (mm)	*-16*
Cut increment (mm)	*0.25*
Time (sec)	*625*

6.4.3.3 Finishing Cycle

The cores were manufactured and then the cavity of turncock was manufactured (fig. 32). Ball cutter was used for the finishing operation. Cutting parameters are in the table 3. Small pieces of material were removed.

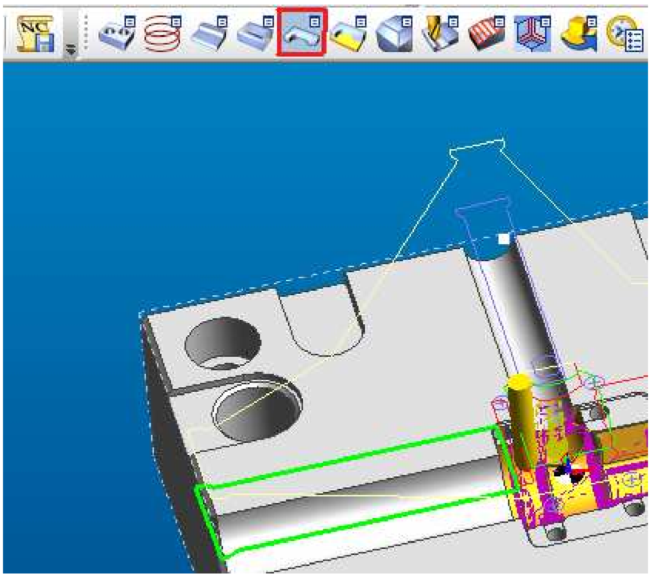

Fig. 32 Finishing operation

Table 3 Cores and turncock parameters

Operation	*Cores parameters*	*Turncock parameters*
Tool	*Ball cutter 10*	*Ball cutter 6*
Feed (mm/min)	*1500*	*600*
Infeed (mm/min)	*3000*	*3000*
Speed (rev/min)	*4700*	*5500*
Offset (mm)	*0.2*	*0.15*
Level (mm)	*-5*	*-3.4*
Clearance (mm)	*5*	*5*
Depth (mm)	*-7*	*-13*
Cut increment (mm)	*0.2*	*0.2*
Time (sec)	*495*	*1020*

6.4.3.4 Flat Land Finishing Cycle

Flat Land Finishing operation was selected to reach the flat surface. The manufacturing line was picked out (fig. 33) and parameters for the cutting were set up (table 4).

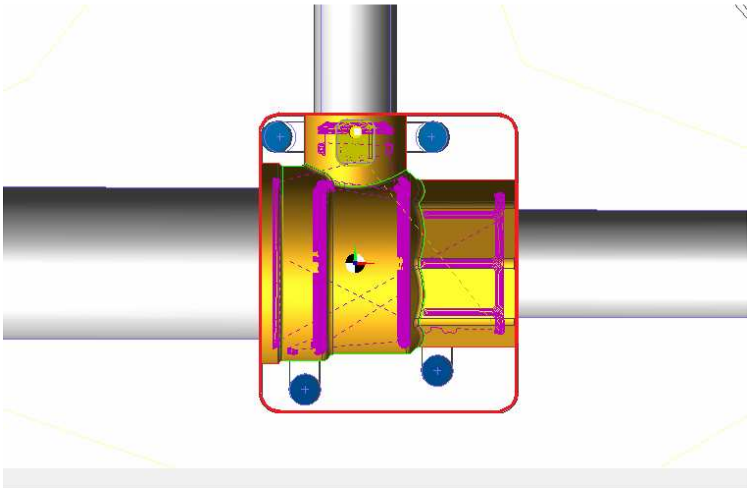

Fig. 33 Flat manufacturing line

Table 4 Flat land parameters

Tool	*Plain milling cutter 4 r0.4*
Feed (mm/min)	*400*
Infeed (mm/min)	*3000*
Speed (rev/min)	*6000*
Offset (mm)	*0*
Level (mm)	*-0.1*
Clearance (mm)	*5*
Depth (mm)	*-0.7*
Cut increment (mm)	*0*
Time (sec)	*70*

6.4.3.5 Roughing Operation for Tetrahedron

Roughing operation was chosen for the manufacturing of tetrahedron (fig. 34). Geometry line was selected and manufacturing parameters were set up (table 5).

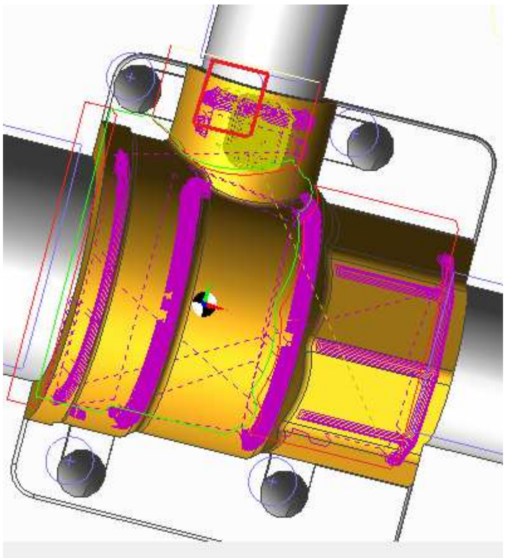

Fig. 34 Tetrahedron

Table 5 Roughing operation

Tool	*Ball cutter 4*
Feed (mm/min)	*600*
Infeed (mm/min)	*3000*
Speed (rev/min)	*5500*
Offset (mm)	*0.1*
Level (mm)	*-5*
Clearance (mm)	*5*
Depth (mm)	*-10*
Cut increment (mm)	*0.25*
Time (sec)	*100*

6.4.3.6 Finishing Operation for Tetrahedron

It was continued in the same way as in section 1.3.3.5. All parameters for the cutting are in the table 6.

Table 6 Finishing operation

Tool	*Ball cutter 4*
Feed (mm/min)	*600*
Infeed (mm/min)	*3000*
Speed (rev/min)	*5500*
Offset (mm)	*0*
Level (mm)	*0*
Clearance (mm)	*5*
Depth (mm)	*-13*
Cut increment (mm)	*0.15*
Time (sec)	*60*

6.4.3.7 Finishing Operation for Cores after Heat-Treatment

Finishing operation was elected for the manufacturing cores (fig. 35). After heat treatment, cores were manufactured to reach finally accuracy. For the manufacturing cores were used two tools (ball cutter 12 for the cores Ø24 and Ø17 and ball cutter 8 for the core Ø13). All manufacturing parameters are in the table 7. Finally, NC code was generated for a CNC milling.

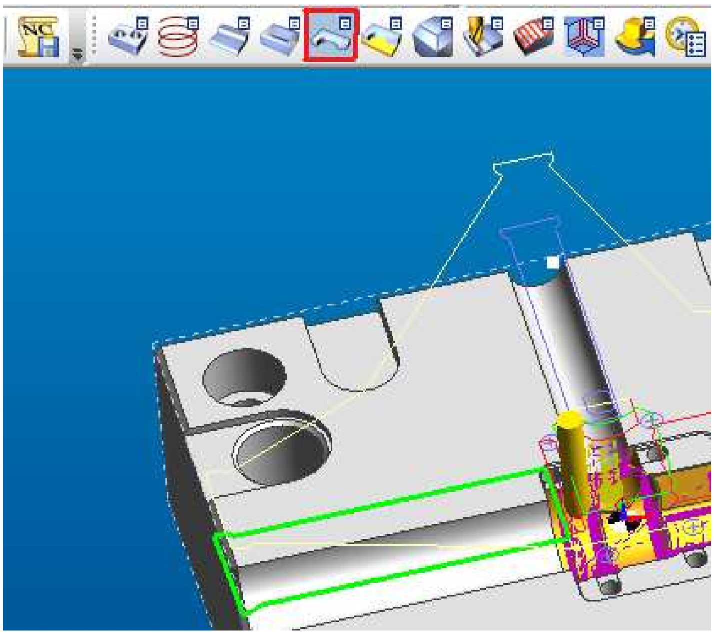

Fig. 35 Finishing operation for cores

Table 7 Cores manufacturing parameters

Tool	Ball cutter 12	Ball cutter 8
Feed (mm/min)	1000	1000
Infeed (mm/min)	3000	3000
Speed (rev/min)	2600	2600
Offset (mm)	0	0
Level (mm)	-6	-4
Clearance (mm)	5	5
Depth (mm)	-10	-10
Cut increment (mm)	0.12	0.1
Time (sec)	771	255

6.5 Heat Treatment of Cavity Block

Cavity block was heated to the quenching temperature of 1070° C and then cooled in a salt bath, where the hardness of 55 HRC was reached. Product was tempered at about 560° C on the hardness 51 HRC.

6.6 Cores

The cores were manufactured in the three sizes KR17x101.3 mm, KR13x103.4 mm, KR24 x125mm and were automatically added into the closing cavity block. They were manufactured from the tool steel 19541. The cores were polished for exactness 10 and they were hardened on the 50 HRC.

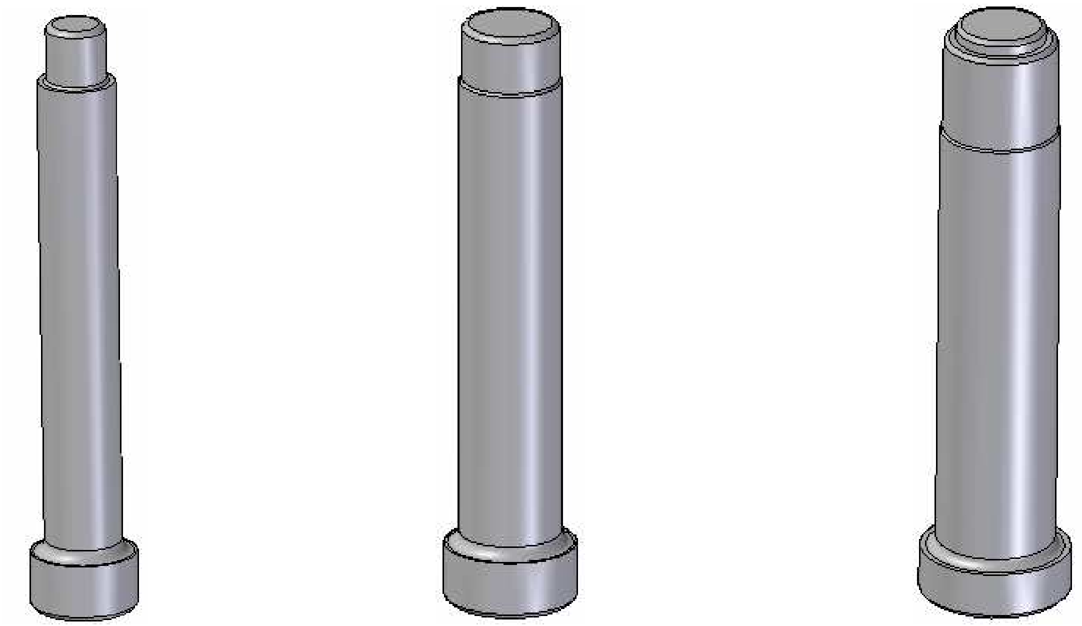

Fig. 36 Cores

6.7 Manufacturing of Electrodes

6.7.1 Material

The electrodes were made out of 99.99% Cu. Electrodes were used for electro-erosion machining. Copper was selected for very good electro-conducting properties. Electrodes were used for the accuracy of cavity block.

6.7.2 Manufacturing

Electrodes were manufacturing in five sizes. On the first electrode was company symbol, which was hollowed out into matrix. On the second electrode there was the number of a product, which was hollowed out into plunger. Other three electrodes were used to reached the finally accuracy.

The electrodes were designed in the Solid Edge programme and manufactured in the EdgeCam programme.

The roughing operation was applied for removing the biggest part of material and next was chosen finishing operation. For the roughing and finishing operations was selected plain cutter. Manufacturing parameters are in the table 8 for the octahedron electrode, for the 31.8 electrode are parameters in the table 9, for the symbol electrode are parameters in the table 10 and number electrode are in the table 11. Finally, NC code for the CNC milling machine was generated.

Table 8 Manufacturing of octahedron electrode

Operation	*Roughing*	*Finishing*
Tool	*Plain cutter 6 r0.6*	*Plain cutter 6 r1.5*
Feed (mm/min)	*1200*	*1200*
Infeed (mm/min)	*3000*	*3000*
Speed (rev/min)	*6000*	*6000*
Offset (mm)	*0.2*	*0*
Level (mm)	*5*	*5*
Clearance (mm)	*0*	*0*
Depth (mm)	*-16.3*	*-16.3*
Cut increment (mm)	*0.15*	*0.15*

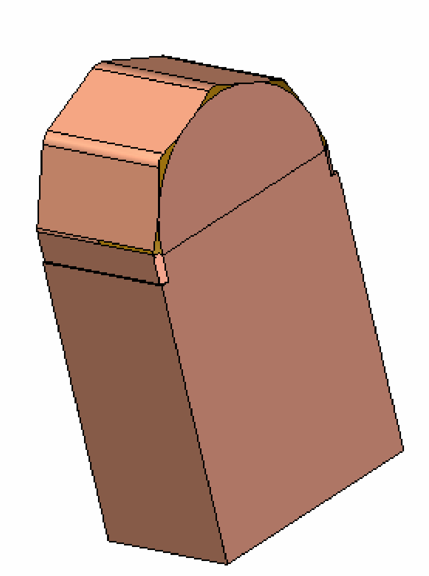

Fig. 37 Octahedron electrode

Table 9 Manufacturing parameters for 31.8 electrode

Operation	*Roughing*	*Finishing*	
Tool	*Plain cutter 6 r0.6*	*Plain cutter 6 r1.5*	*Ball cutter1*
Feed (mm/min)	*1200*	*1200*	*200*
Infeed (mm/min)	*3000*	*3000*	*3000*
Speed (rev/min)	*6000*	*6000*	*6000*
Offset (mm)	*0.2*	*0*	*0*
Level (mm)	*5*	*5*	*5*
Clearance (mm)	*0*	*0*	*0*
Depth (mm)	*-17.9*	*-17.9*	*-17.9*
Cut increment (mm)	*0.2*	*0.15*	*0.03*

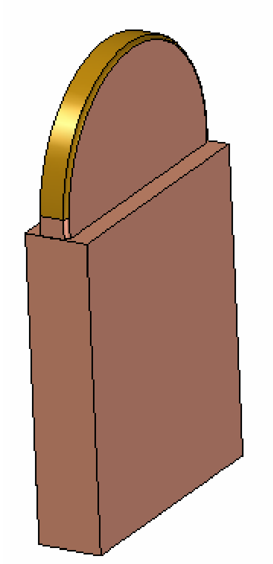

Fig. 38 Electrode 31.8

Table 10 Manufacturing parameters for the symbol electrode

Operation	Roughing	Finishing
Tool	Plain cutter 2 r0.15	Plain cutter 1 r0.01
Feed (mm/min)	600	180
Infeed (mm/min)	3000	3000
Speed (rev/min)	6000	7000
Offset (mm)	0.1	0
Level (mm)	5	5
Clearance (mm)	0	0
Depth (mm)	-1.5	-1.3
Cut increment (mm)	0.1	0.1

Table 11 Manufacturing parameters for the word electrode

Operation	*Roughing*	*Finishing*
Tool	*Plain cutter 1 r0.01*	*Plain cutter 0.4 r0.04*
Feed (mm/min)	*180*	*90*
Infeed (mm/min)	*200*	*100*
Speed (rev/min)	*7000*	*7000*
Offset (mm)	*0.1*	*0*
Level (mm)	*5*	*5*
Clearance (mm)	*0*	*0*
Depth (mm)	*-1.8*	*-1.7*
Cut increment (mm)	*0.1*	*0.03*

6.8 Work Flow

- Matrix and plunger were designed in the Solid Edge programme
- Matrix and plunger were programmed at the EdgeCam programme
- Stock size 180x180x50mm with holes was gripped on the CNC machine
- Stock was manufactured on the required shape
- Cavity block was heat treatment
- Cores were manufactured for the required accuracy again
- On the cavity were used electrode for the required accuracy

6.9 CNC Machine

Producer of this milling machine is Kovosvit MAS. Milling machine MCV 500 is CNC milling machine determined to mill steel materials, iron, nonferrous metal and plastics materials. The maximum machining place is in X-axis 500mm, Y-axis 500mm and Z-axis 500mm, maximum feed rate is 500 mm/min, accuracy is 0.02mm, maximum speed is from

20 to 10 000 rev/min. Engine output is 7.5 kW. Maximum weight of the table is 400kg. Machine is equipped with two cooling level. Twenty tools can be gripped into the toolbox.

Fig. 39 MCV 500 milling machine

CONCLUSION

The aim of this thesis was to search and handle with information about computer numerically control machine (CNC), programming and projecting of cavity block for the CNC milling machine.

History of CNC machines was written in the theoretical part, definition and advantage of CNC machines, communicate tapes and which kind of tool material can be used for CNC manufacturing. Simulation and programming of CNC machines were also described.

The cavity block was projected and manufactured in the practical part. Cavity block and electrodes were drawn at the Solid Edge programme. Then it was imported into the Edge-Cam programme, where cavity block and electrodes were manufactured and NC code for the CNC milling machine was generated. Cavity block and cores were hardened and tempered on the hardness of 51 HRC. Cavity block was grinded and polished on Ra 0.8 and accuracy of IT8. Electrodes were used for the finishing accuracy of cavity block; the sign of company and the number of product were imprinted into the cavity block. Kovosvit MAS MCV 500 machine was chosen for the manufacturing cavity block and electrodes. Cores were manufactured on the lathe milling.

Appendix contains drawing documents of cavity block, cores, electrodes, part drawing and NC code of cavity blocks and electrodes.

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LIST OF SYMBOLS AND ABBREVIATIONS

CC Cemented Carbide

CAD Computer Aided Design

CAE Computer Aided Engineering

CAM Computer Aided Manufacturing

CAP Computer Aided Production

CAPP Computer Aided Process Planning

DNC Direct Numerical Control

NC Numerical Control

TLO Tool Length Offset

LIST OF PICTURES

LIST OF TABLES

APPENDIX

P1: Matrix

P2: Plunger

P3: Turncock

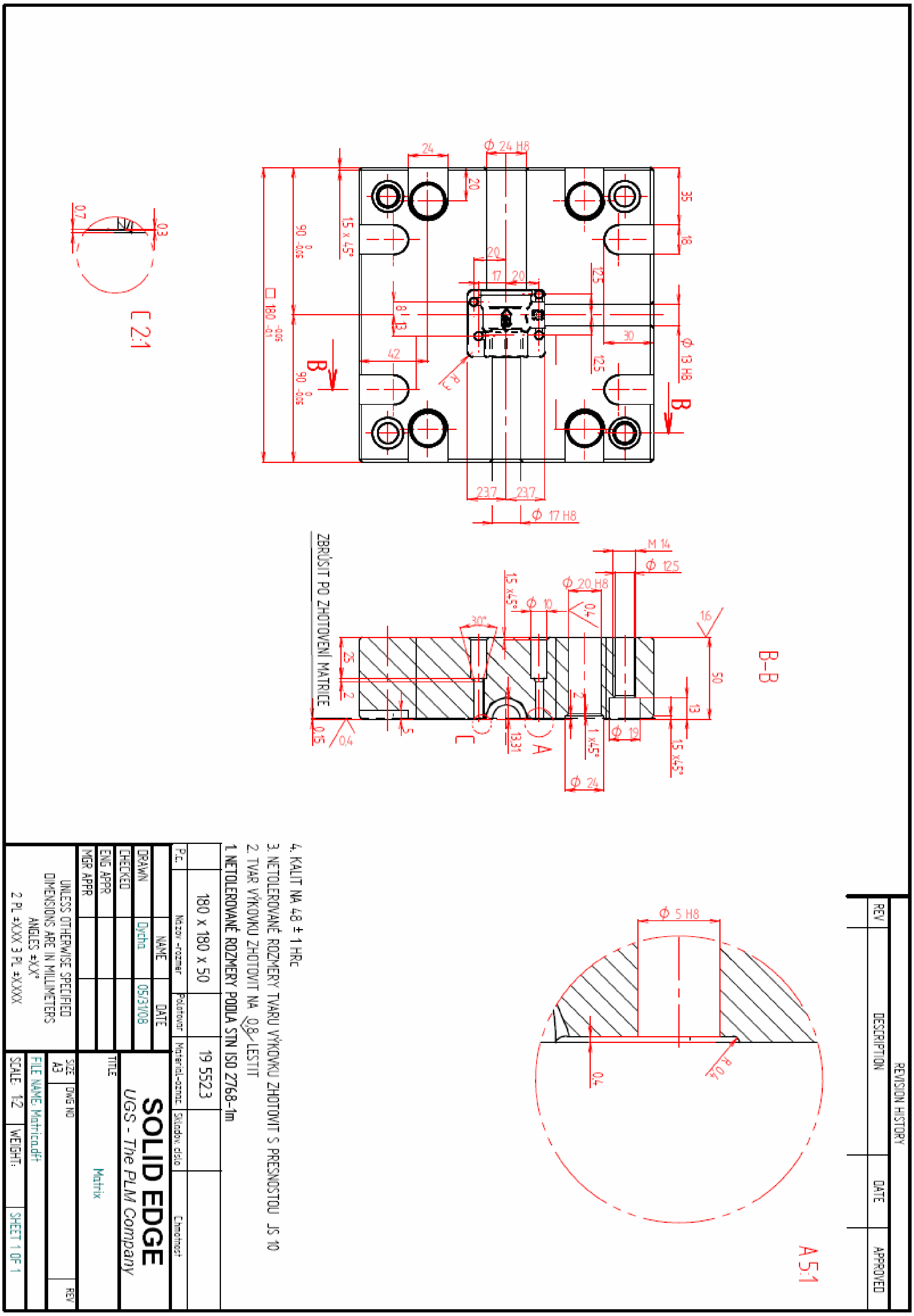
P4: Electrodes

P5: Cores

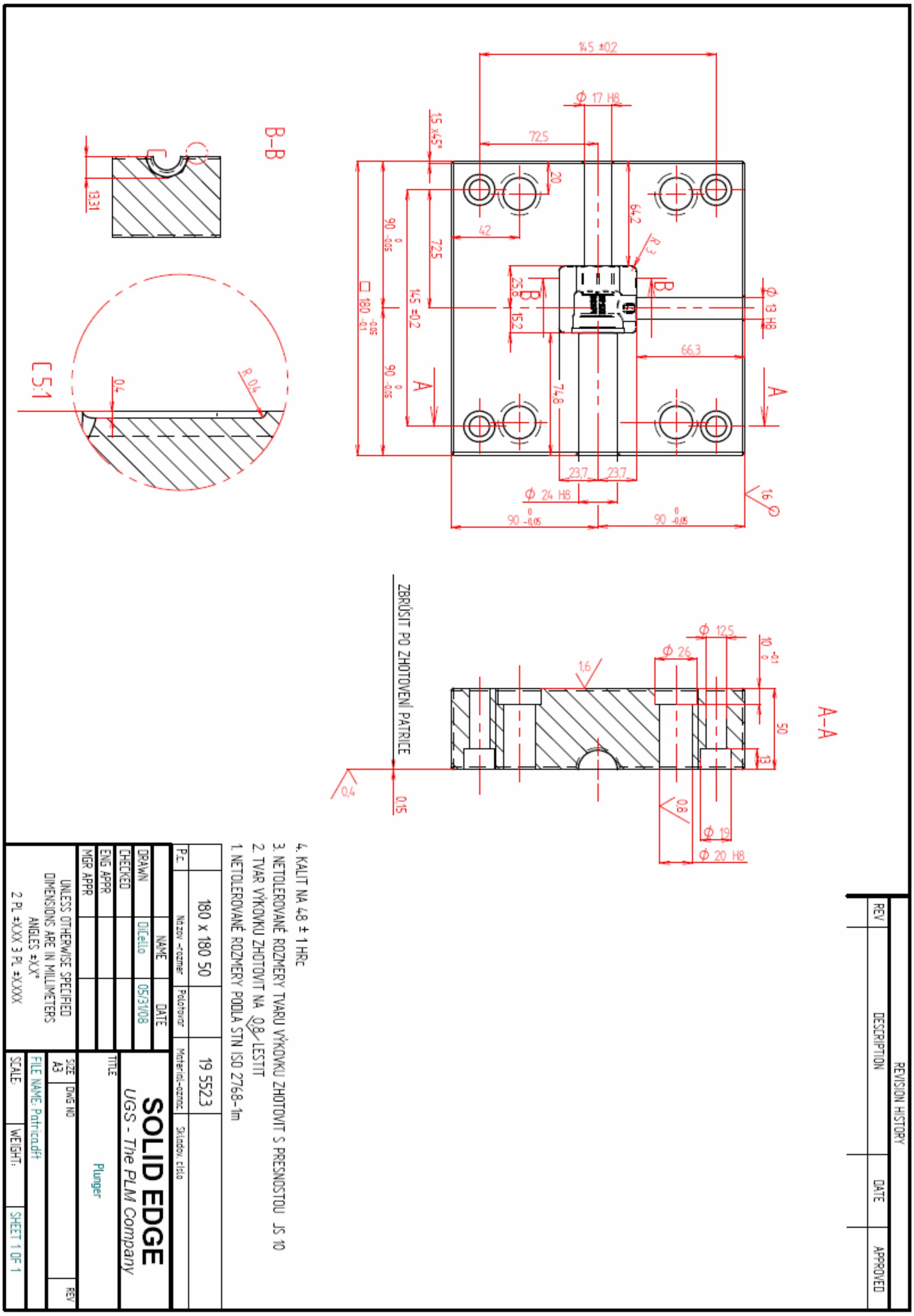
P6: CD disk contents:

- Model of cavity block and drawing documentation at Solid Edge programme
- NC code for CNC milling machine

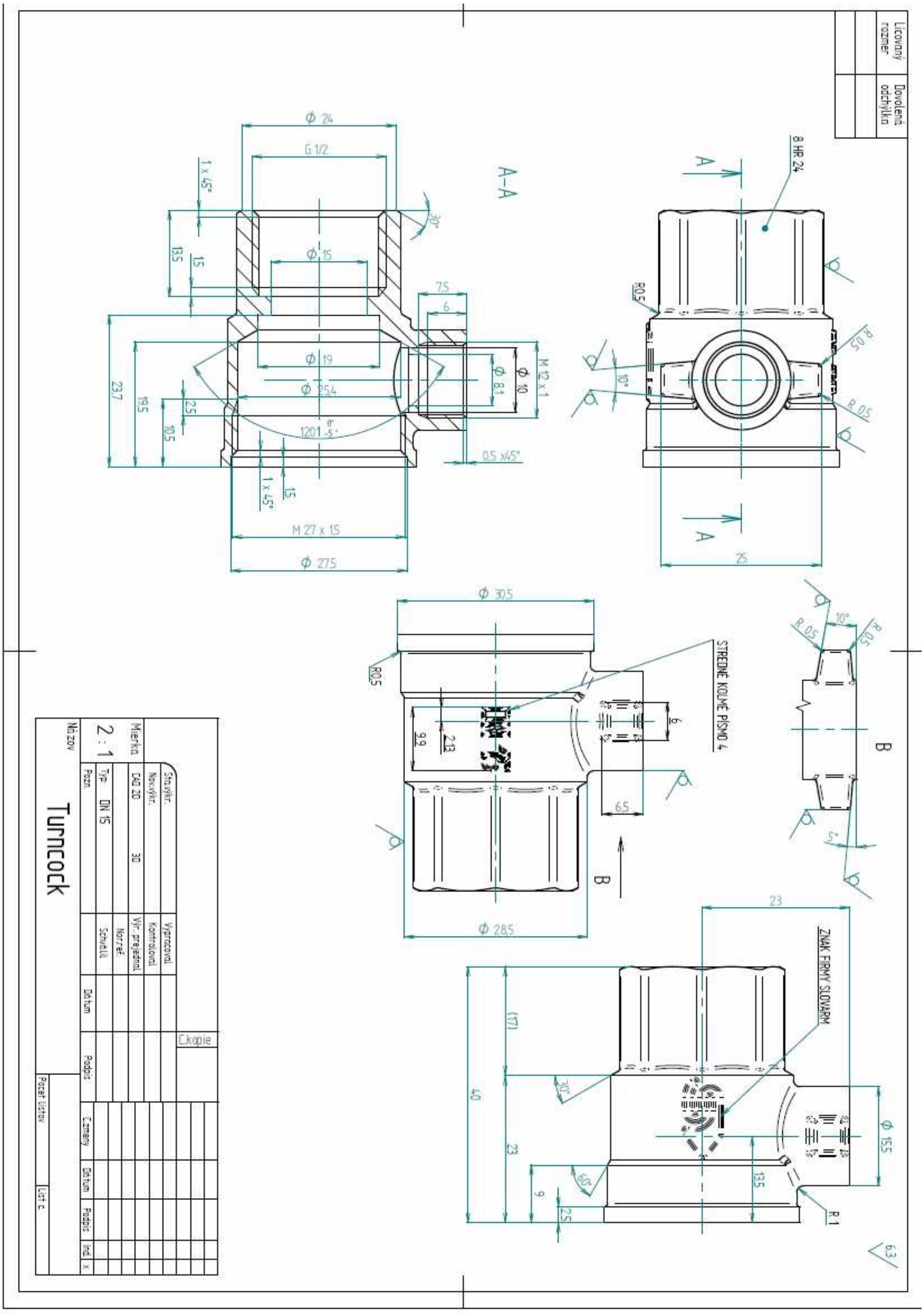
APPENDIX 1: MATRIX



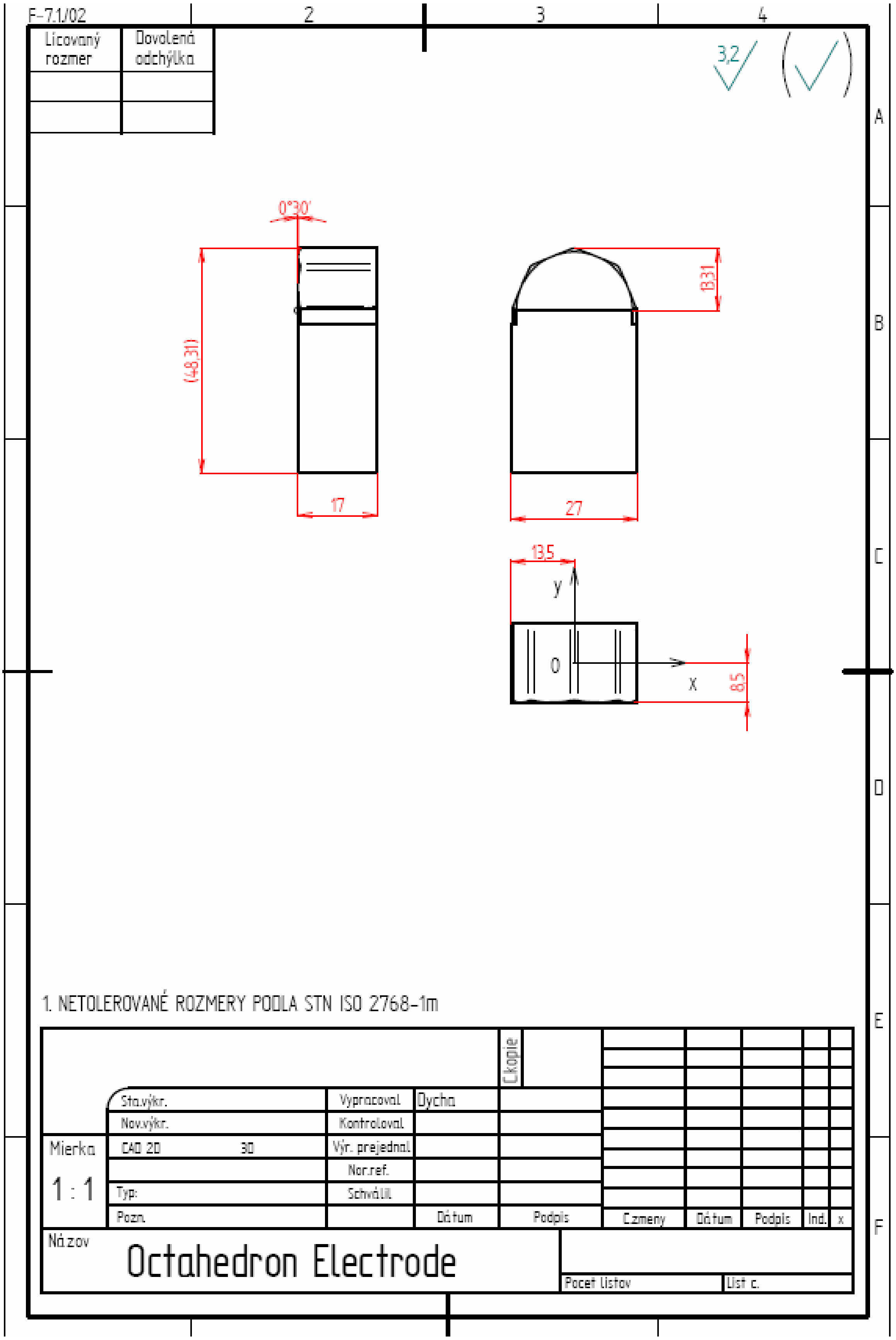
APPENDIX 2: PLUNGER

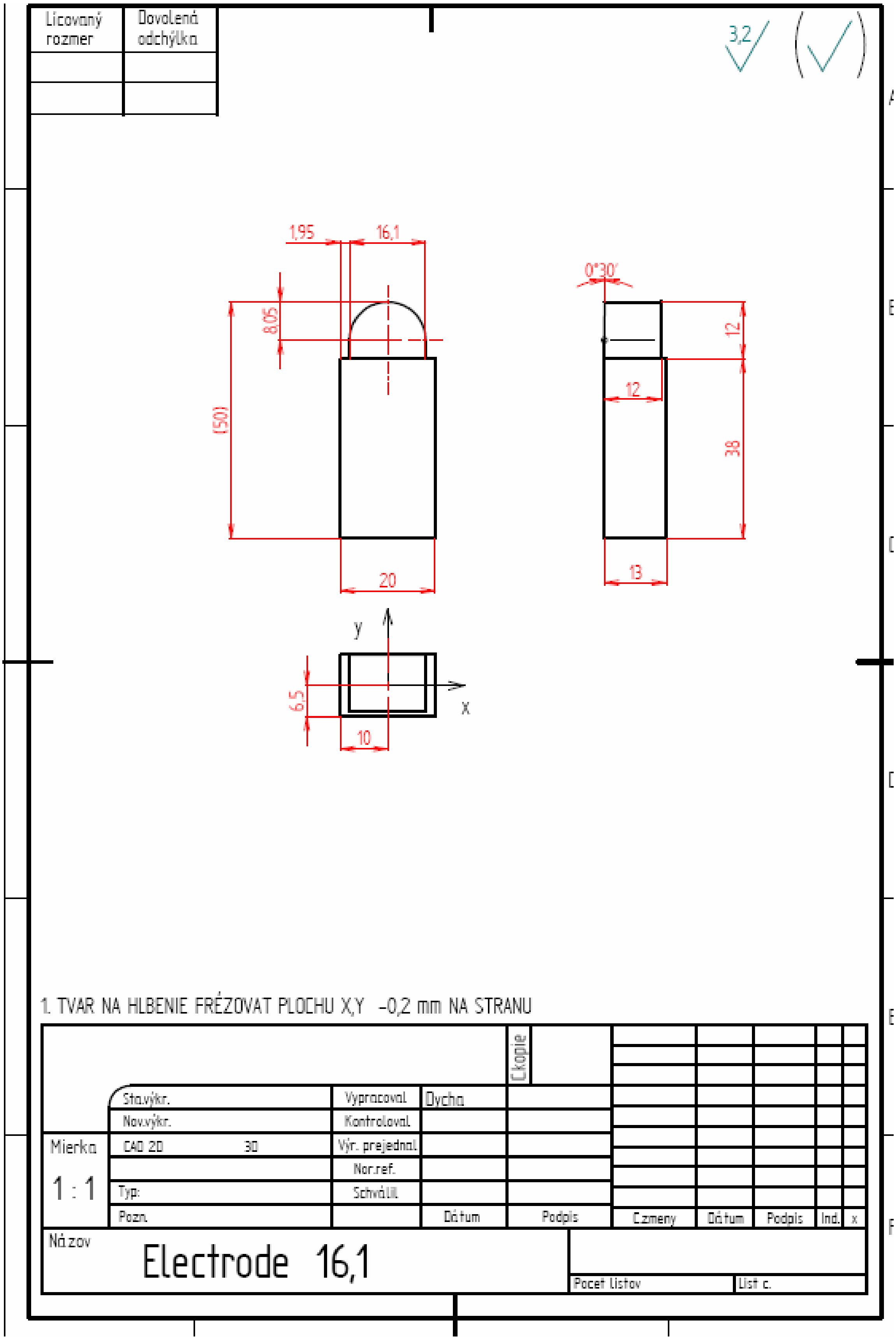


APPENDIX 3: TURNCOCK



APPENDIX 4: ELECTRODES

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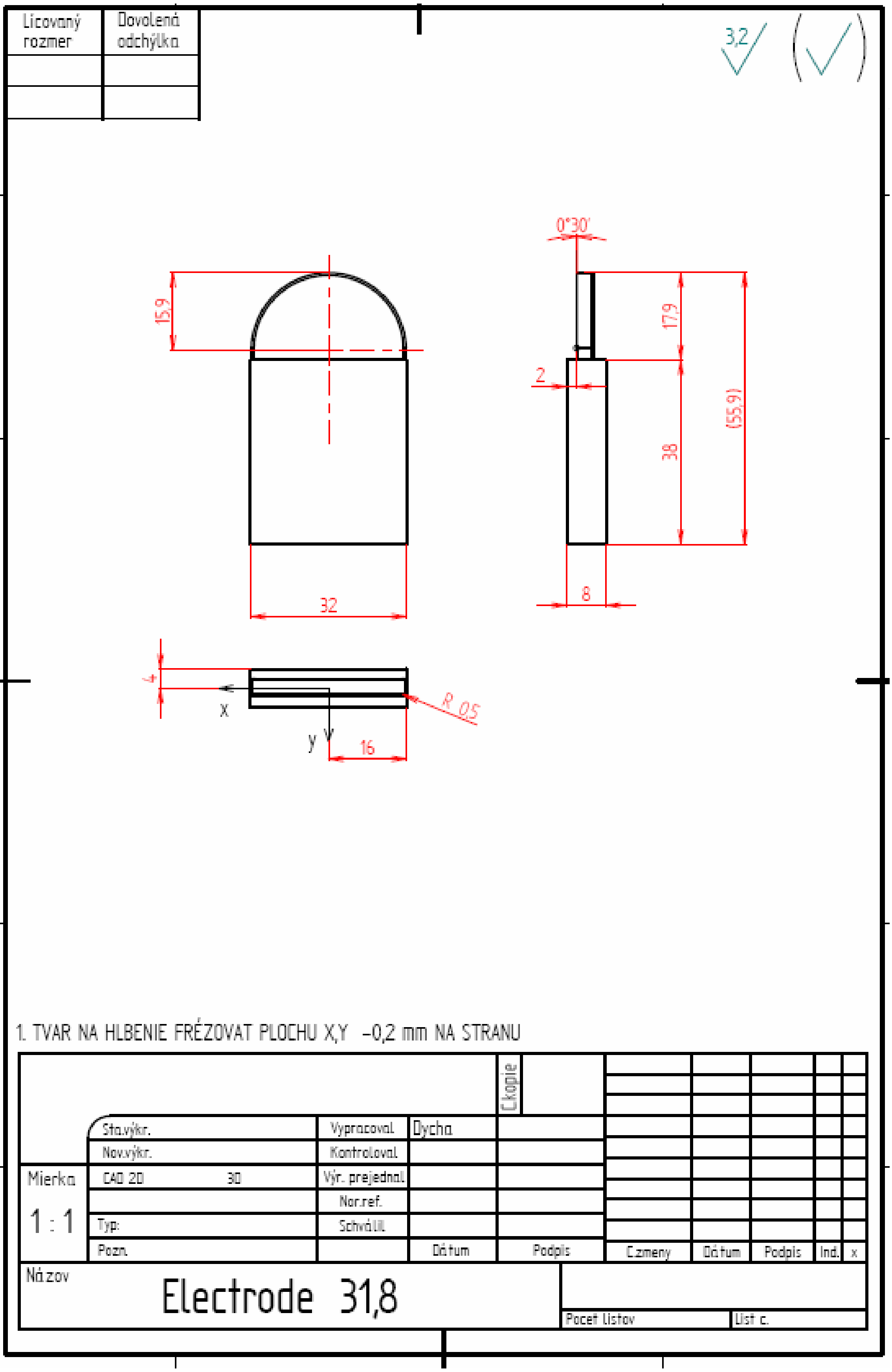
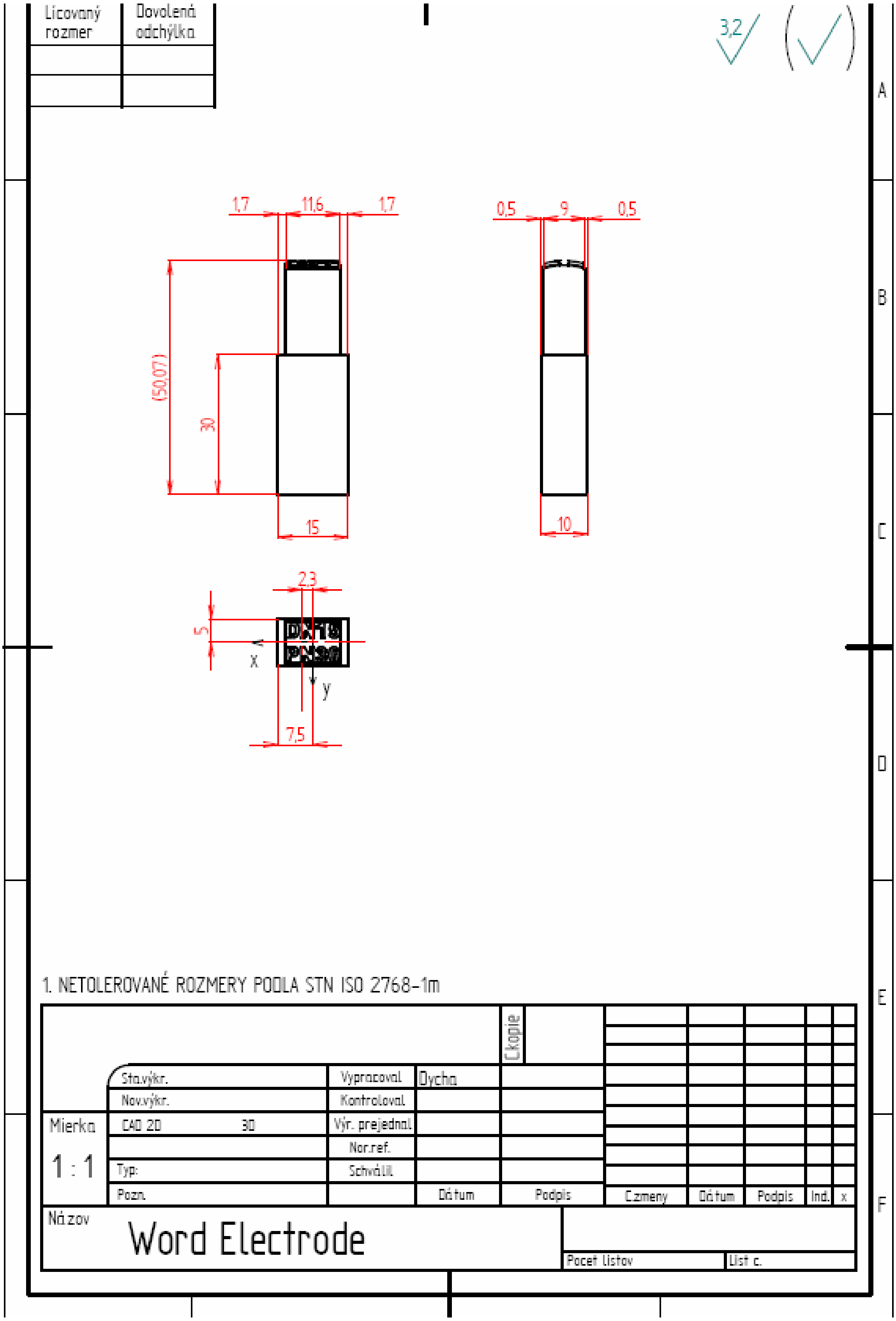
Dovolená odchýlka
3,2
1,95
16,1
0°30'
8,05
(50)
12
12
38
20
13
y
x
6,5
10
1. TVAR NA HLBENIE FRÉZOVAT PLOCHU X,Y -0,2 mm NA STRANU
Ckopie
Sta.výkr.
Nov.výkr.
CAD 2D
3D
Typ:
Pozn.
Vypracoval
Dycha
Kontroloval
Výr. prejednal
Nor.ref.
Schválil
Dátum
Podpis
Czmeny
Dátum
Podpis
Ind.
x
Mierka
1 : 1
Názov
Electrode 16,1
Pocet listov
List c.



Lícovaný rozmer
Dovolená odchýlka
3,2
0°30'
15,9
17,9
2
38
(55,9)
32
8
4
x
y
16
R 0,5
1. TVAR NA HLBENIE FRÉZOVAT PLOCHU X,Y -0,2 mm NA STRANU
Ckopie
Sta.výkr.
Nov.výkr.
CAD 2D
3D
Typ:
Pozn.
Vypracoval
Dycha
Kontroloval
Výr. prejednal
Nor.ref.
Schválil
Dátum
Podpis
Čzmeny
Dátum
Podpis
Ind.
x
Mierka
1 : 1
Názov
Electrode 31,8
Pocet listov
List c.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Dovolená odchýlka
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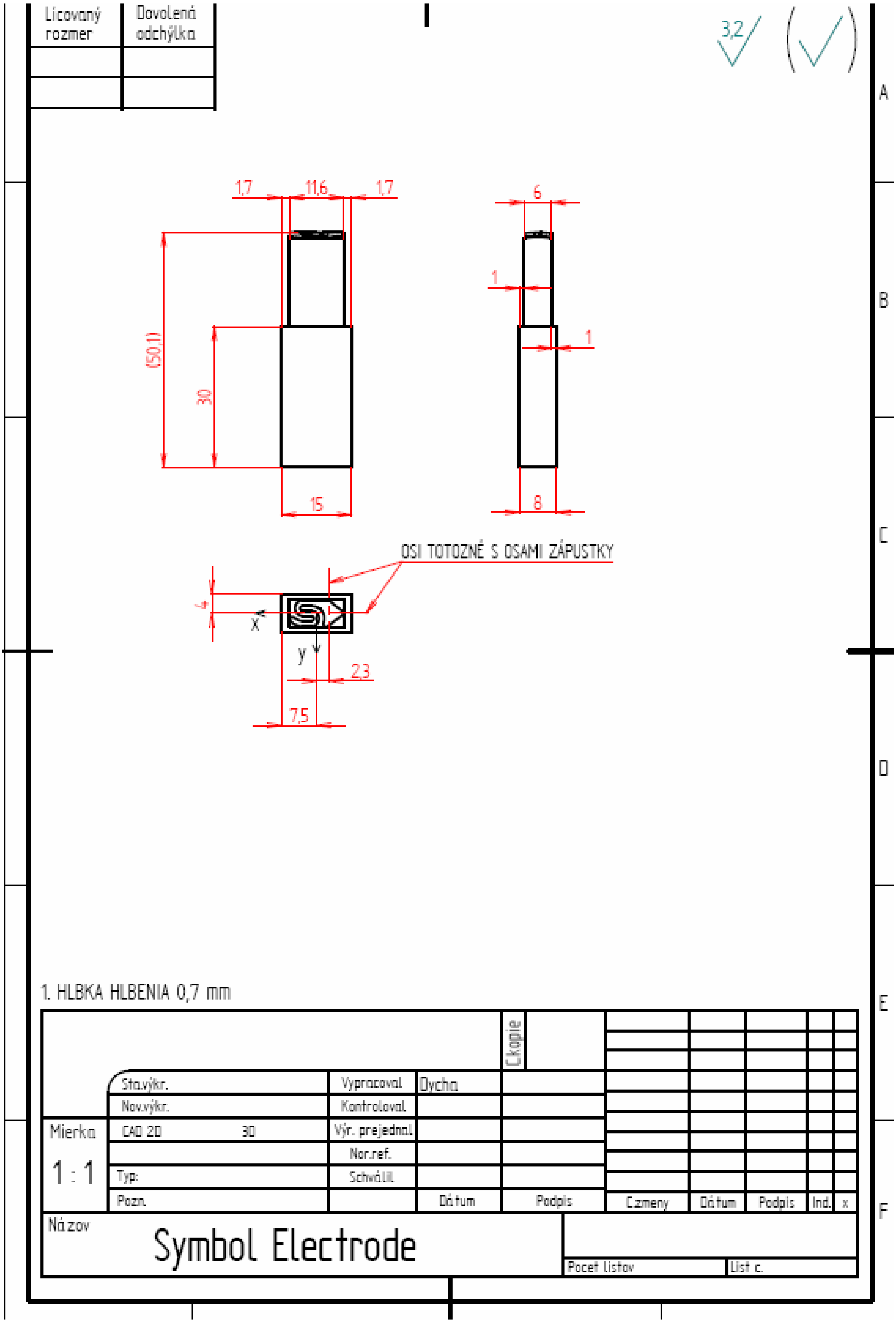
1,7
11,6
1,7
0,5
9
0,5
(50,07)
30
15
10
2,3
5
x
y
7,5
A
B
C
D
E
F
1. NETOLEROVANÉ ROZMERY PODĽA STN ISO 2768-1m
Ckopie
Sta.výkr.
Nov.výkr.
CAD 2D
30
Typ:
Pozn.
Vypracoval
Dycha
Kontroloval
Výr. prejednal
Nor.ref.
Schválil
Dátum
Podpis
Cmeny
Dátum
Podpis
Ind.
x
Mierka
1 : 1
Názov
Word Electrode
Pocet listov
List c.



Lícovaný rozmer
Dovolená odchýlka
3,2
1,7
11,6
1,7
6
1
1
(50,1)
30
15
8
OSI TOTOZNÉ S OSAMI ZÁPUSTKY
4
x
y
2,3
7,5
A
B
C
D
E
F
1. HLBKA HLBENIA 0,7 mm
Ckopie
Sta.výkr.
Nov.výkr.
CAD 2D
30
Typ:
Pozn.
Vypracoval
Dycha
Kontroloval
Výr. prejednal
Nor.ref.
Schválil
Dátum
Podpis
Czmeny
Dátum
Podpis
Ind.
x
Mierka
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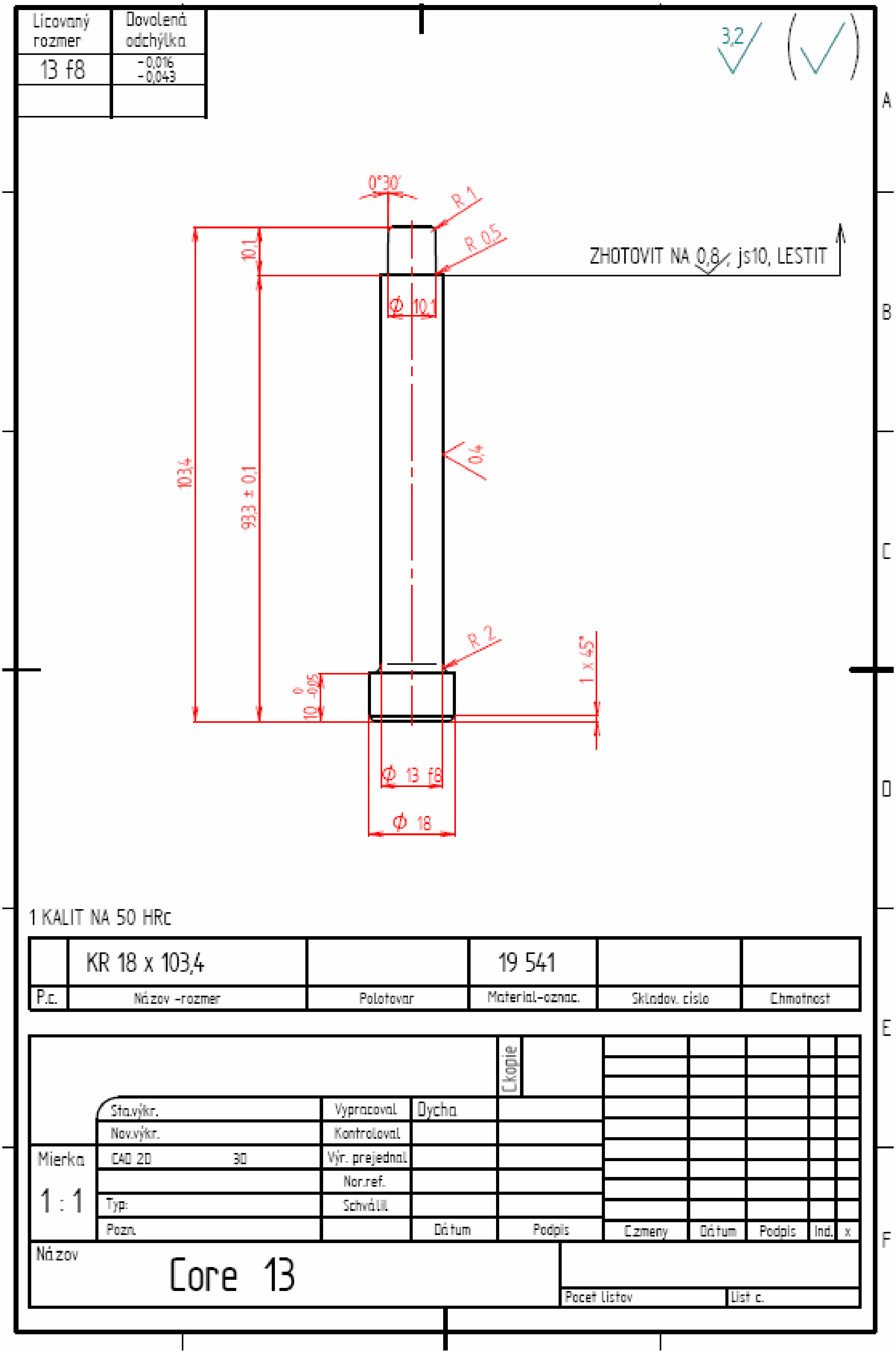
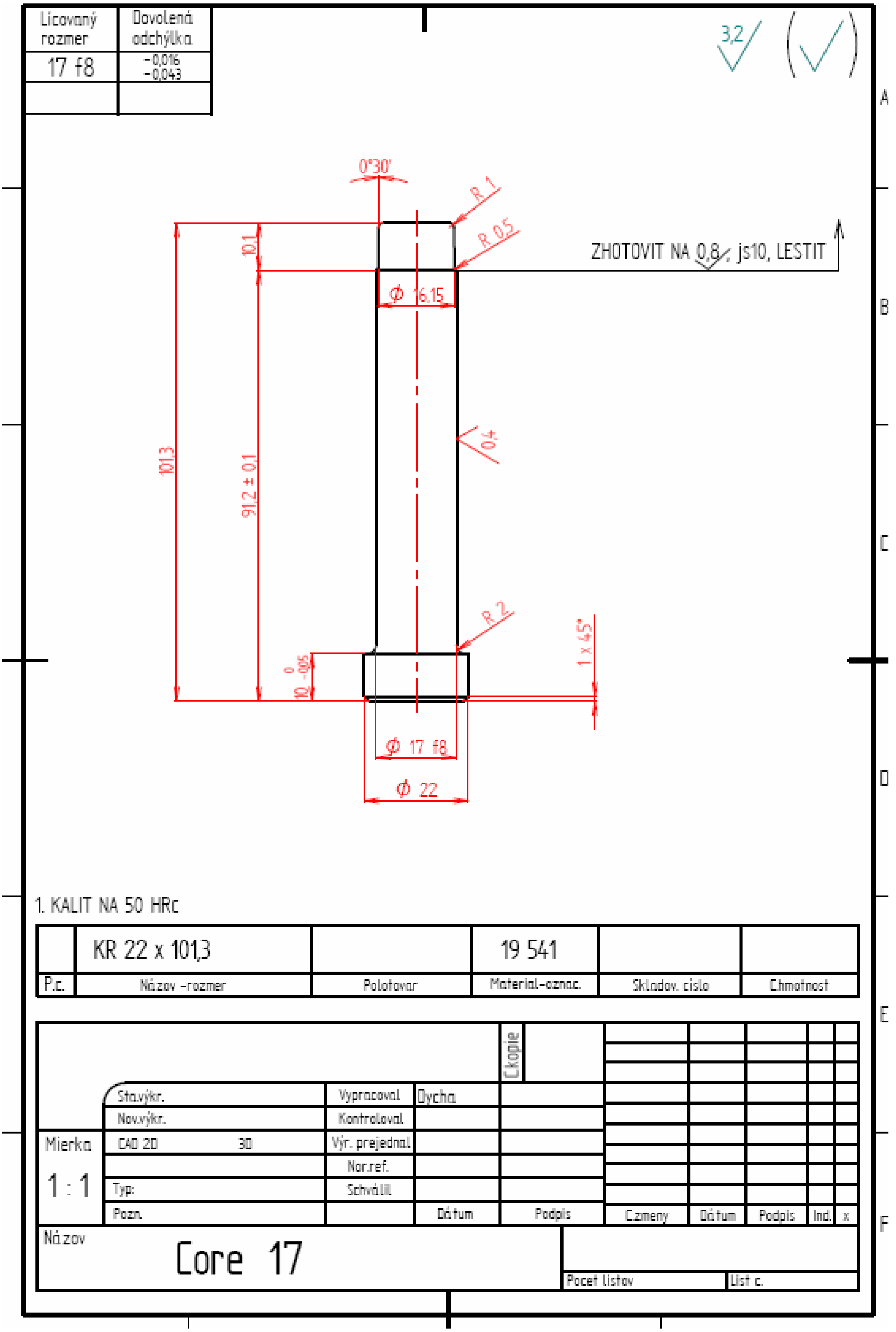
Názov
Symbol Electrode
Pocet listov
List c.

APPENDIX 5: CORES





Lícovaný rozmer
Dovolená odchýlka
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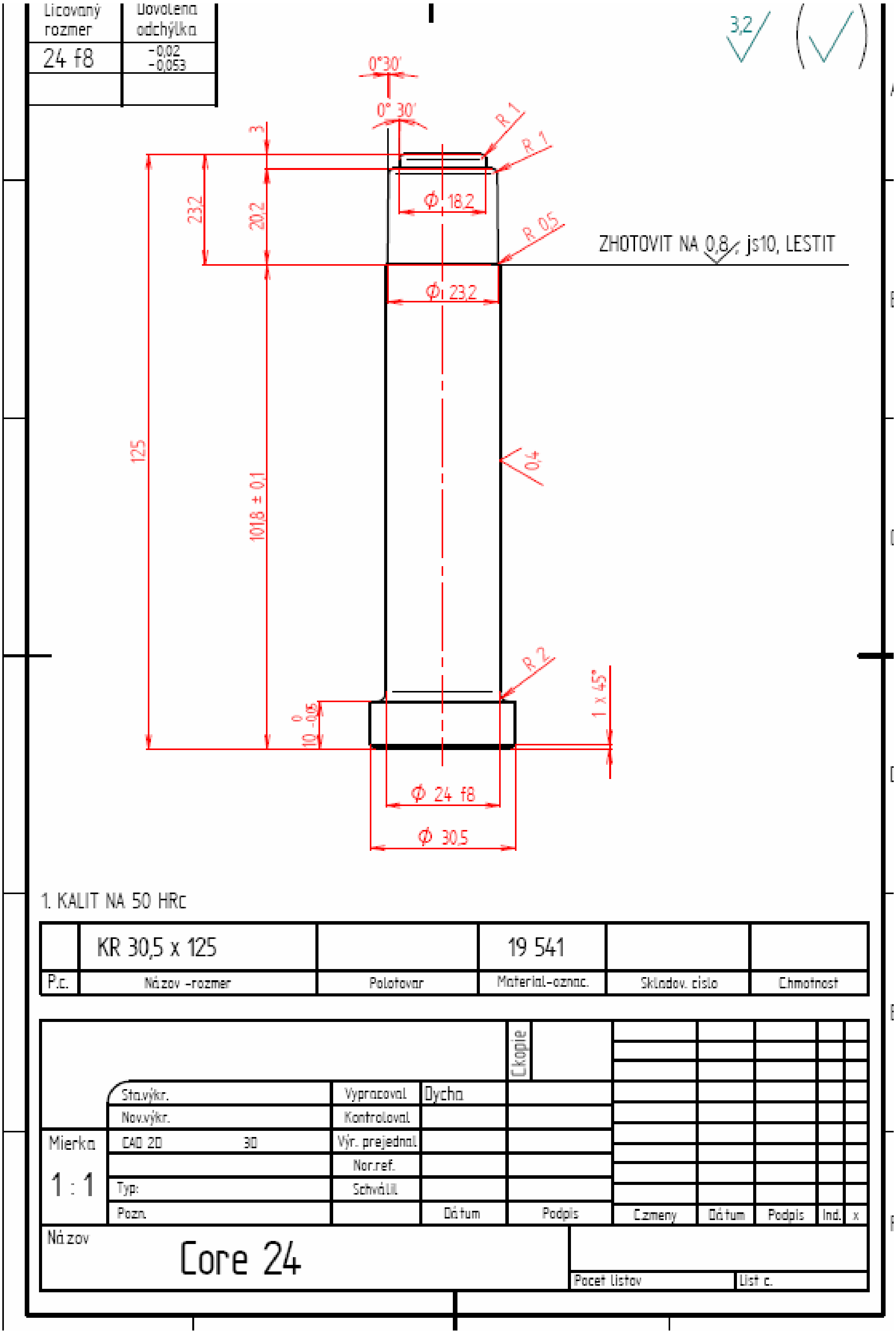
-0,016
-0,043
3,2
0°30'
R 1
R 0,5
ZHOTOVIT NA 0,8, js10, LESTIT
10,1
Φ 16,15
101,3
91,2 ± 0,1
0,4
R 2
1 x 45°
Φ 17 f8
Φ 22
1. KALIT NA 50 HRc
KR 22 x 101,3
19 541
P.c.
Názov -rozmer
Polotovar
Materiál-označ.
Skladov. číslo
Chmotnosť
Ckopie
Sta.výkr.
Nov.výkr.
CAD 2D
3D
Vypracoval
Dycha
Kontroloval
Výr. prejednal
Nor.ref.
Schválil
Mierka
1 : 1
Typ:
Pozn.
Dátum
Podpis
Czmeny
Dátum
Podpis
Ind.
x
Názov
Core 17
Počet listov
List č.
A
B
C
D
E
F


Licovaný rozmer
Dovolená odchýlka
24 f8
-0,02
-0,053
3,2
0°30'
0° 30'
R 1
R 1
3
23,2
20,2
Φ 18,2
R 0,5
ZHOTOVIT NA 0,8, js10, LESTIT
Φ 23,2
125
101,8 ± 0,1
0,4
R 2
1 x 45°
10 -0,05
Φ 24 f8
Φ 30,5
1. KALIT NA 50 HRc
KR 30,5 x 125
19 541
P.c.
Názov -rozmer
Polotovar
Materiál-oznac.
Skladov. cislo
Hmotnost
Ckopie
Sta.výkr.
Nov.výkr.
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Podpis
Zmeny
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Mierka
1 : 1
Názov
Core 24
Pocet listov
List c.