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## Production of Castings by Patternless Process

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### Abstract

This paper deals with production of safety inlay for steam locomotive valve by the Patternless Process method. For the moulds creation was used moulding mixtures of II. generation, whereas binder was used a water glass. CNC miller was used for creation of mould cavity. Core was created also by milling into block made of moulding compound. In this article will be presented also making of 3D model, setting of milling tool paths and parameters for milling.

**Keywords:** Patternless process, Mould, CNC machining, Moulding mixture. Prototype casting

### 1. Introduction

Foundry industry is one of the most important sectors of the world industry. In this time are giving very high pretensions in particular on the speed and effectiveness of production with the highest pretensions for quality of castings, and with maintenance the highest possible effectiveness and productivity, and not least is considered over by ecological effects on the environment. Therefore are developed still new methods of production of castings.

After receiving a task to produce casting used as safety inlay for steam locomotive, we decided about the casting process. In consideration about production process was regarded several parameters such as castings cost, production rate and production of pattern equipment.

Because, we didn't have a pattern equipment, so it was decided to produce mould with using patternless process. This method significantly reduces time needed to produce the casting. In the production of a castings by the Patternless Process method, it is not needed pattern equipment, so we have eliminated the cost of production and storage facilities pattern equipment's. Therefore, the final cost price of one cast by this method is significantly lower and less time consuming than production

which using traditional methods of production castings. Fig. 1 shows the bronze casting of safety inlay for steam locomotive.



Fig. 1. Casting of safety inlay for steam locomotive

After decided the production method necessary on production of castings was decided about a type of moulding mixture. It was decided, that on the production of mould will be used moulding mixtures of II. generation, whereas binder was used a water glass.

As the opening material were used two types of silica sands from the Kerkosand company, the type SH 31 and type SH 34. As the binder was used 3% of water glass. The type of opening material SH 31 was used for better breathability and the type of opening material SH 34 was used for better quality surface of mould.

After measuring the old cast was created 3D model of shape, the entire structure including casting inlet system and core too. 3D model was created in the Solidworks system. Consequently were models save in the STEP format and opened in the Cut3D program, which is used for setting of milling tool paths and parameters for milling. The program generates The G-Code, that is loaded in the Mach3 Milling program, which control the milling itself.

After loading the G-Codes was milling the core and consequently parts of the moulds. Two half moulds and core are jointed together and to the creating mould is a liquid metal casts how to the mould created a traditional way.

The core and the parts of the mould were milling by the milling machine which was constructed in the Department of Technological Engineering, Faculty of Mechanical Engineering in the University in Žilina. The milling machine is shows in the Fig. 2.

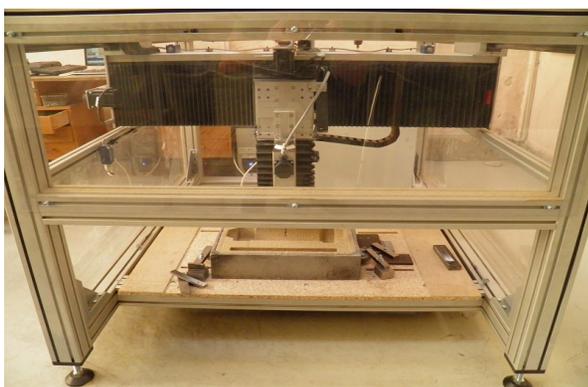


Fig. 2. Milling machine KTJ, SJF

Because was used two types of opening materials, every part of mould and the core was milling in three times.

The first time, dimensions of the core were reduced of 10 mm from either side. How the opening material was used silica sand SH 31 with dimensions  $D_{50}$  0,5 mm. After milling and hovered a moulding mixture was a cavity in a block moulding mixture filling a moulding mixture with opening material SH 34. Opening material SH 34 has dimensions  $D_{50}$  0,24 mm. This time was used correct dimensions and moulding cavity was milling by roughing machining and then by finishing machining.

Like that created parts of mould with more grained and more permeated materials, but the surface of cavity or surface of the core was create with better surface material.

## 2. Selection of moulding mixtures

Principle the method patternless process lies in fact that shape of the cast is milled into the block moulding mixtures without the use of pattern equipment.

The method of Patternless Process used moulding mixtures of II. generation, such as moulding mixtures with contains synthetic resins such as furans moulding mixtures, phenol formaldehyde moulding mixtures and etc.

How opening material were used a silica sands from Kerkosand Company, the type SH 31 and type Sh34. It are treated

mineral resources. Properties of opening materials are shown in the table 1.

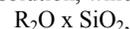
Table 1.

identification		SH 31	SH 34
AFS		30	57
$D_{50}$	[mm]	0,50	0,24
$SiO_2$	[%]	96,00	96,00
$Fe_2O_3$	[%]	0,18	0,18
$Al_2O_3$	[%]	1,8	1,8
Annealing loss	[%]	0,2	0,2
Sintering capacity	[°C]	>1300	>1300

In the production of moulds was used CT moulding compounds II. generation with water glass used as a binder. When moulding mixture was inserted into a frame, it was cured by  $CO_2$ .

The most widely used inorganic binder in the moulding mixtures II. Generation is a water glass.

Water glass is a compound of silica with salts of alkali metals in the form colloid water solution, which we can write how:



When R is sodium or calcium. Then we know the sodium or calcium water glass. In the casting is using the sodium water glass only.

The hardening of CT moulding mixtures being controlled by blowing – through a carbon dioxide to compress mixture of silica sand and water glass and the this moulding mixtures is quickly hardening.

The advantages of these compounds include the availability of materials, good price and easy preparation of moulding mixture. A high mechanical properties of the cured moulding mixtures allows the production of heavy and massive castings without lengthy drying.

## 3. Production of the core

After measuring the dimensions of the original cast was designed a mould joint and inflow proposed system, which was used for casing. Subsequently, was in the Solidworks was draught the core and a mould with the inlet system. The draught core is shown in the Fig. 3.

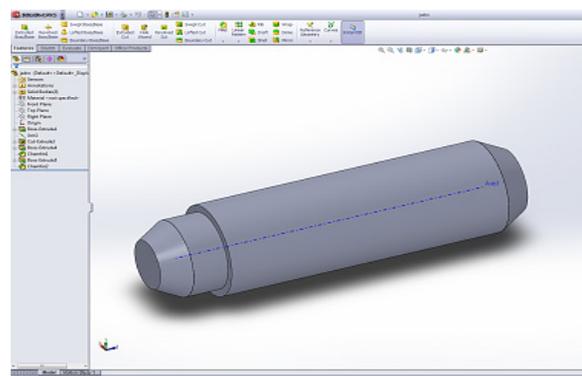


Fig. 3. The core draught in the Solidworks system

The core was save in the STEP format and then open in the Cut 3D program. Cut 3D is a dedicated toolpath engine for CNC machining 3D models that have been designed using a 3D CAD or graphic design products.



#### 4. Draught the core machining parameters

3D model are typically designed in any orientation and at any size. Cut 3D includes options for selecting what faces of the model to machine, mirroring, rotating and setting the required size in Inches or metric.

The maximum size a model can be machined is often limited by the available material thickness. Cut 3D includes options to scale a 3D model proportionally or each axis independently, allowing the Z thickness to be scaled for the material size.

3D menu is dividing to the several parts. In the first part of the menu is a determined orientates and size model and sides to machine too. We used millimeters, no inches.

We choose top side for milling from z axis. Length of the core is 350 mm and maximum diameter is 95 mm. The first menu Cut 3D program is shown in the Fig. 4.

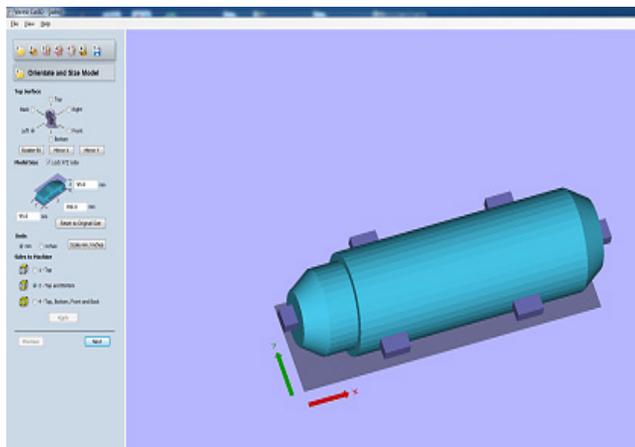


Fig. 4. First menu in the Cut 3D

In the second part of the menu are changed material sizes and there are choosing machining margins around model, depth of model below surface and cut plane position in model. The block of cured moulding mixture for produce the core had dimensions 515 x 255 millimeters and height was 116 millimeters.

We also choose the zero point, which is important for beginning and location of mould in the working area of milling machine. Machining margins around model, it's important for choose, that tool did not overcome the whole area of the mould frame.

Menu with material size and margins is shown in the Fig. 5.

Cut 3D include the function for add tabs also known as “bridges”, to hold the job in place when multi – sided machining into the material block. If we don't used the “bridges”, after finishing can the core fall from the block of moulding mixture.

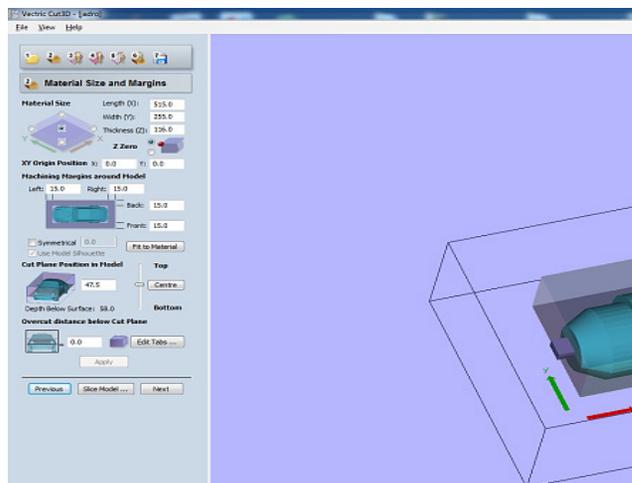


Fig. 5. Menu with material size and margins

In the following part of menu is select for roughing toolpath, cutting parameters, feeds and speeds and toolpath parameters. We can edit program and added new tools. By the selection progress was decided about roughing toolpath and then about finishing toolpath. In the FIG. 6 is shown roughing toolpath menu.

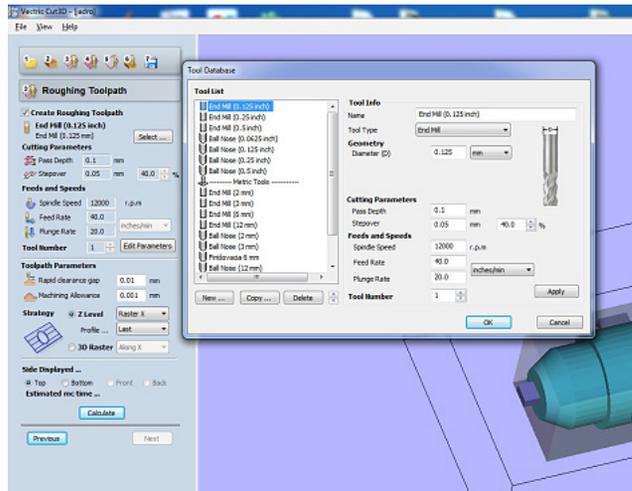


Fig. 6. Roughing toolpath menu

For roughing was used cutter with diameter 10 millimeters. Pass depth was 4 millimeters and stepover was 5 millimeters, therefore one half the diameter of cutter. Spindle speed was 12 000 rpm, feed rate was 40 mm / sec and plunge rate in the z axis was 20 mm / sec.

After entering all parameters, program automatically calculates the cutting tool paths. After roughing mode was settings the finishing mode.

How a tool was used cutter with ball head with diameter 8 millimeters, spindle speed was 10 000 rpm, feed rate was 40 mm/sec and plunge rate in the z axis was 20 mm / sec. Track mills were paralleled with y axis. The stepover was chooses 0,5 mm. Thereby was available high surface quality of the core. In the Fig. 7 is a detail in the finishing toolpaths.

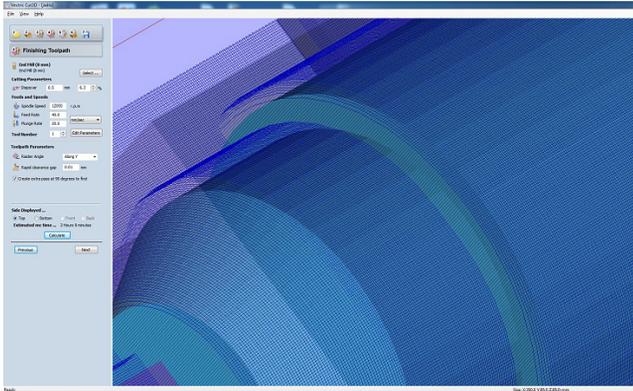


Fig. 7. Detail in the finishing toolpaths

The calculated toolpaths we can see in the next menu, how an interactive model, where is a shown all milling process, in the menu is shown finishing model, in our case it is the core, and the parts of the mould too. Program calculates the time required for the production of the model. Toolpaths were saved in the format G-Code for roughing process and finishing process.

Therefore was G – Code loaded in the program Mach 3Mill, which is connected with milling machine and which operate the milling. Animation toolpaths is shown in the Fig. 8.

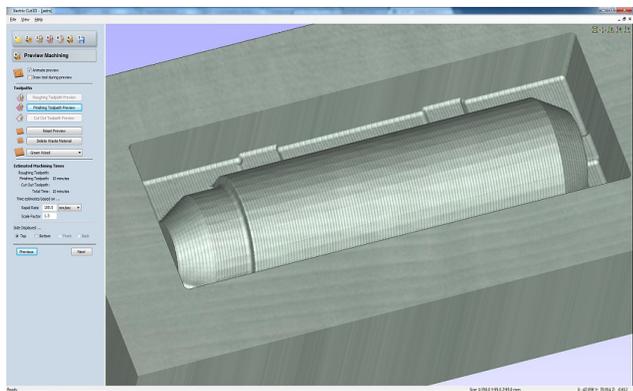


Fig. 8. Menu with Animation toolpaths

Mach 3 Mill software is a program package, which converts the computer on the very powerful control system. As a first step, we need to load G –Code. After loading the G –Code and putting the mould to the working area by milling machine, it's necessary to set a zero point by to pre- specified location in the program Cut 3D. Zero point can be set manually positioning.

After settings the zero point was launched program and started working. After roughing was loaded a new G –Code, which was used for finishing operation. In the Fig. 9 is shown menu Mach 3 Milling with loaded G –Code.

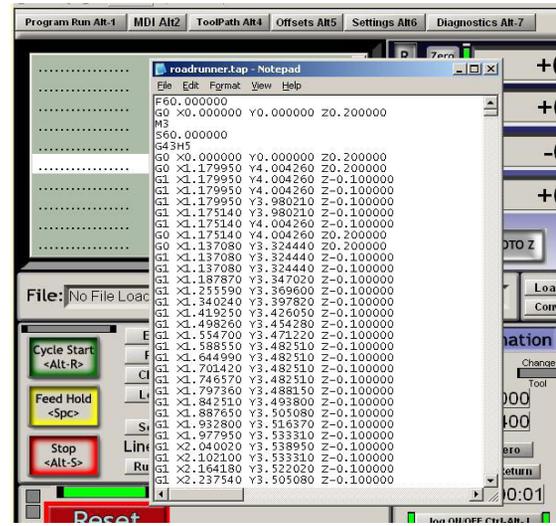


Fig. 9. Menu Mach 3 Milling with loaded G –Code

Cured block of moulding mixtures with opening material SH 31 was putting to the working area by milling machine which was created in the casting laboratory in the Department of technological Engineering. Moulding mixture was produced in wheeler mixer and after inserted into a frame, it was cured by CO<sub>2</sub>.

After milling one half of the core with smaller sizes was create cavity filled with moulding mixture with opening material SH 34 and the core was milling with the correct dimensions. Milling the core is shown in the Fig. 10.



Fig. 10. Milling the core, roughing

After roughing process was followed the finishing process. After milling one half the core, was the mould turned 180 degrees and repeat it. In the form were created the „bridges“, which holder core before falling down. In the Fig. 11 is finished core just before removing from the mould.



Fig. 11. Core just before removing from the mould

The core was after removed from the mould painted by protective varnish yet.

## 5. Production of the mould

After measuring the dimensions of the original cast was designed a mould joint and inflow proposed system, which was used for casing. In the Solidworks was draught the a mould with cavity mould and with the inlet system.

The core was save in the STEP format and then open in the Cut 3D program. Then were created tool paths and other parameters. The draught of the mould with core create in the Solidworks system is shown in the Fig. 12.

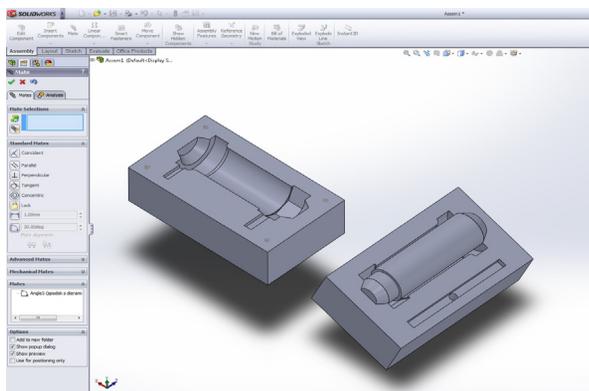


Fig. 12. Parts of mould with the core, create in Solidworks

## 6. Draught the mould machining parameters

Toolpaths parameters were settings like, the toolpaths parametres used for the production the core. In the first part of menu are settings at orientate and size of model. Mould was milling from top side. The length of the form was 400 mm, width was 220 mm and height was 120mm. In the Fig. 13 is shown the mould with calculated roughing toolpath.

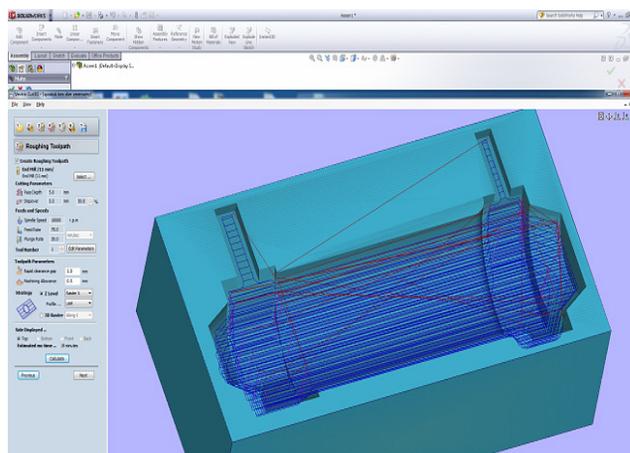


Fig. 13. Mould with roughing toolpaths

For roughing was used cutter with diameter 11 millimeters. Pass depth was 5 millimeters and stepover was 5,5 millimeters, therefore one half the diameter of cutter. Spindle speed was 10 000 rpm, feed rate was 70 mm / sec and plunge rate in the z axis was 30 mm / sec. Calculated time for roughing was 19 minutes.

After entering all parameters, program automatically calculates the cutting tool paths. After roughing mode was settings the finishing mode.

How a tool was used cutter with ball head with diameter 8 millimeters, spindle speed was 10 000 rpm, feed rate was 70 mm/sec and plunge rate in the z axis was 20 mm / sec. Track mills were paralleled with y axis. Calculated time for milling was 13 minutes. In the Fig. 14 is a detail calculated toolpaths.

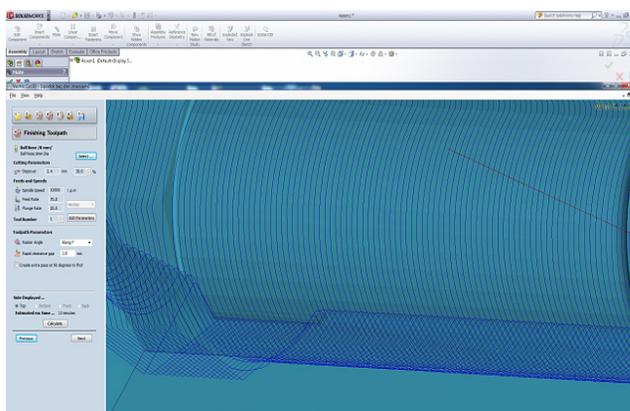


Fig. 14. Detail calculated toolpaths

Toolpaths were saved in the format G-Code for roughing process and finishing process for.

Therefore was G – Code loaded in the program Mach 3Mill, which is connected with milling machine and which operate the milling.

We used two CT moulding mixtures with water glass and opening materials SH 31 and SH 34 as how as in the production of the core. The first time, dimensions of the mould cavity were expanded of 10 mm from either side. How the opening material

was used silica sand SH 31. After milling and hovered a moulding mixtures was a cavity in a block moulding mixture filling a moulding mixture with opening material SH 34. This time was used correct dimensions and moulding cavity was milling by roughing machining and then by finishing machining.

After finishing process was one half of the mould removed from milling machine and in the same way was made the second part of the mould. To the bottom of the form has been included the core. The core in the mould is shown in the Fig. 15.



Fig. 15. One half the mould with include core

After milling of the top part the mould was finishing inlet system yet. All parts the mould are shown in the Fig. 16.



Fig. 16. All parts the mould

After jointed together two half moulds and to the creating mould is a liquid metal casts how to the mould created a traditional way.

## 7. Conclusions

This paper deals with production of safety inlay for steam locomotive valve by the Patternless Process method. For the moulds creation was used moulding mixtures of II. generation, where how a binder was used a water glass. How opening material were used two kinds silica sands from Kerkosand company, type SH 31 and type SH 34. The core and mould cavity were milling from the block of moulding mixture.

The paper deals with creating 3D models, creating toolpaths and milling parameters for milling the come and the moulds. How a first was produce the core and next was produce the bottom part and the top part the mould. The milling lasted only a few hours and the mould was ready for the casting.

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