Pressure casting die machining of the water pump body

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Abstract. In this paper the technological process of movable and immovable pressure casting die insert of water pump executed in one of motor industrial plant was presented. Machining processes of casting die elements were described in detail. Individual operations and the process of machining parameters selection were characterized. Machine applications were generated for the virtual 3D model of movable and immovable die insert in Mastercam application operating in Windows environment. An attempt at modification of technological process for selected HSM-applied milling operations (high-speed machining) in Mastercam was made. As the result of modifications it turned out that machining time of rough milling operation has been reduced by almost 49% for movable die insert and by 29% for immovable die insert, which means achieving considerable savings.
Key words: water pump, pressure casting die, technological process, machine tools, HSM, modification.

INTRODUCTION

The pressure casting die is a tool for making a pressure casting on a pressure die-casting machine. The basic components of the pressure casting die include: a movable and a fixed insert with a forming shape, a casing, slide blocks, servomotors and a cooling system. A technological process of making pump body inserts, as carried out in an automotive industry works is presented [8]. The pump body profile (Fig. 1, 2) was a complex profile, therefore the die inserts reproducing its shape had also a respectively complex construction. The repeatable production of such complicated shapes and, above all, the verification of the product as early as at the design stage, was only possible owing to the use of state-of-the-art CAD/CAM software applications [4, 6, 14]. They enabled the design of virtual 3D shapes and automatic generation of the machine codes of working for numerically controlled (NC) machine tools. The reduction of manufacturing costs was possible through the application of new manufacturing strategies, in particular the HSM working [5, 12, 13].

Fig. 1. Pump of water in section

a)

b)

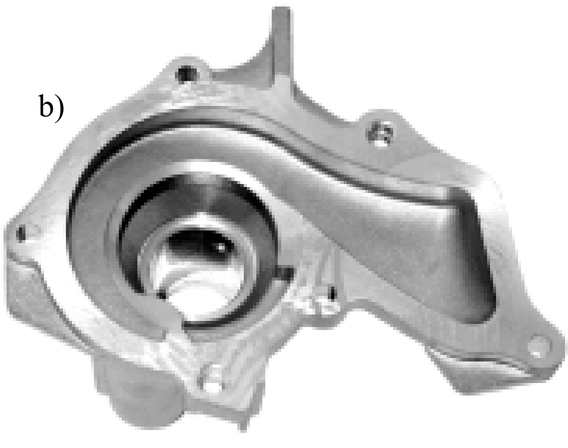

Fig. 2. Pump body: a) top view, b) bottom view

THE TECHNOLOGICAL PROCESS OF MAKING THE PRESSURE CASTING DIE

The technological process of making the pump body pressure casting die concerned the making of the inserts forming the casting shape on a pressure die-casting machine, i.e. the movable and the fixed insert.

The framework technological process of making the forming inserts was carried out in the following stages [8]:

– normalizing of the starting material,
– roughing on conventional machine tools (milling machines, drillers),
– stress relief annealing after the rough machining,
– pre-machining on NC machine tools,
– execution accuracy check no. 1,
– heat treatment – hardening,
– grinding of the forming shape and holes,
– finishing by milling on NC machine tools,
– spark machining of complex shapes,
– grinding, retouching, polishing and fitting of the inserts,
– execution accuracy check no. 2,
– testing of the die on the pressure die-casting machine,
– approval and authorization of the die for production,
– covering of the forming shape with a protective coating.

The basic stages of the technological process of making the pump body insert pressure casting dies were machining operations [2, 7].

ROUGING OF THE STARTING MATERIAL

The basic roughing operation was the milling of starting material bars of dimensions of 120 x 260 x 320 for the movable insert and 100 x 260 x 320 for the fixed insert, and the so called "skinning" of the profile, so that the least possible material allowance was left before the milling of the proper forming shape on the numerically controlled machine tools. The roughing was carried out on conventional machine tools.

The next operation was the making of holes in the starting material bars according to the insert working drawings. Drilling of holes was performed on a jig drilling machine to an accuracy of 0.01 mm (Fig. 3).

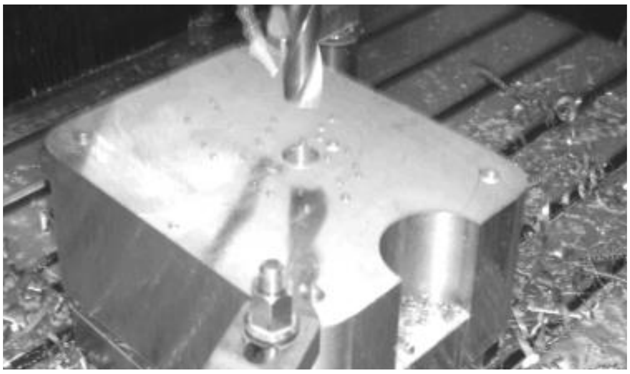

Fig. 3. Hole drilling in movable die insert on jig drilling machine

MACHINING OF THE MOVABLE INSERT

The generation of working machine programs required building virtual 3D models of movable and fixed insert shapes. The insert models were created in the Ideas application, and then were exported in the Parasolid format to the Mastercam program [14]. Milling machine programs and machining simulation were made in the Mastercam application running under the MS Windows environment.

The roughing on the NC milling machine was the pre-selection of the material from the movable insert forming shape region using a computer-generated program (Fig. 4).

Fig. 4. Rough milling of movable die insert shape

The rough milling program was generated for a ø25/R5 head the following parameters:

– axial travel Z = 1 mm,
– tool rotations n = 2200 rpm,
– working feed v_f = 880 mm/min.,
– sinking feed f_w = 100 mm/min.,
– allowance on the machined surface 0.3 mm.

The advantage of the CAD/CAM software application was the possibility of making machining simulation and verifying its correctness (Fig. 5).

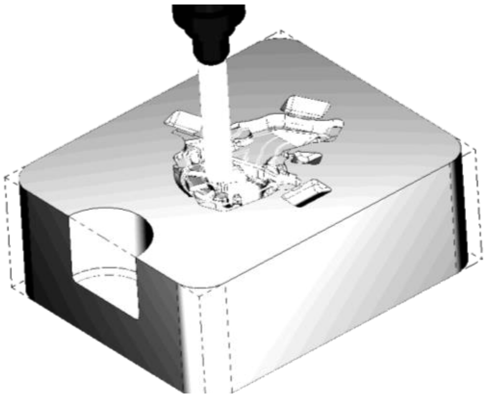

Fig. 5. Rough milling simulation in Mastercam

The finishing operation was the milling of the insert shape by the contouring methods, that is moving the mill along the contour by horizontal layers.

A program for the milling of the movable insert contour with a ø16/R1 mill was generated for the fixed parameters:

– travel in the Z axis = 0.3 mm,
– tool rotations n = 3000 rpm,
– working feed v_f = 1400 mm/min.,
– sinking feed f_w = 100 mm/min.

The Backplot function used within the Mastercam enables the visualization and evaluation of mill paths for the contouring program. The verification of the contouring machining was carried out, as, irrespective of the correctness of the mathematical surface description, an incorrect tool pass might have occurred, leading to material damage.

The subsequent finishing milling operation was contouring the movable insert profile with a ø12/R1 mill.

To obtain the final movable insert shape, a program for the linear finishing of the overflow basins of the pressure casting die was created. These are hollows of a specified shape serving for the collection of any access of liquid metal forced in under pressure in the casting process. As the basins had a radius-ended bottom, the most favourable in this case was to use a ø10/R5 ball end mill.

The final finishing milling operation was the formation of the movable insert profile with the ø4/R1 hob by the lining method. This made it possible to finally bring off the shape and obtain the proper surface quality. The contour milling provided little roughness of steep surface, while the linear finishing method was the most appropriate for horizontal surfaces or those with little inclination. After performing the linear finishing and making verification, a virtual shape of the movable insert of the pump body pressure casting die was obtained.

The obtained movable insert shape required additionally the removal of material from locations inaccessible to the mills. Therefore, the finishing of the shape on a high-speed milling machine (a ø3 mill; n=20000 rpm) and spark machining of the rib shape, performed after heat treatment by hardening, was necessary (Fig. 6).

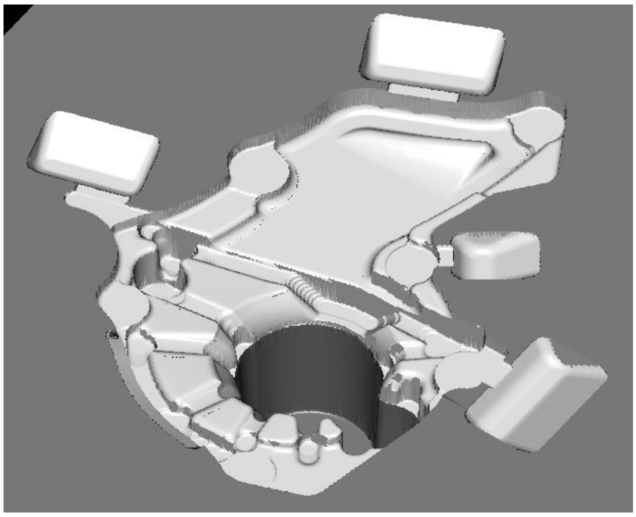

Fig. 6. Virtual view of movable die insert

MACHINING OF THE FIXED INSERT

The machining of the fixed insert was similar to that of the movable insert. The only differences resulted from a different forming shape [8].

The roughing on an NC milling machine was pre-milling of the shape using a computer-generated contouring program for a ø25/R5 mill.

The finishing working was made up of three operations of milling the insert shape by the contouring method using a ø12/R1, ø8/R1 and a ø6/R1 mills. An additional finishing milling operation was the formation of the insert profile with the ø6/R1 mill by the lining method.

After completion of the finishing milling operation and making final verification, a virtual model of the fixed insert shape was obtained (Fig. 7).

The obtained insert shape required additionally the spark machining of three recesses on the conical surface, to be made after heat treatment by hardening.

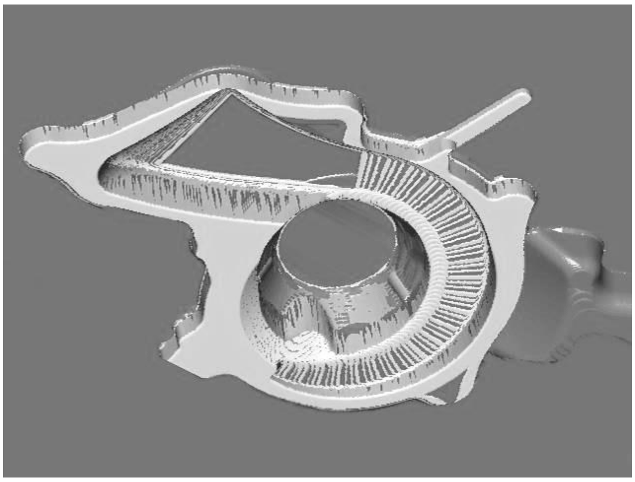

Fig. 7. Virtual view of fixed die insert

HSM WORKING AND DIE INSERT FEED OPTIMIZATION

When modifying the technological process of making die inserts, the HSM milling strategy with variable feed values available within the Mastercam was used [14]. The program offered a possibility of shortening the milling time from about ten to several tens percent through the automatic modification of machining parameters. The high-speed feed (High-feed) module dynamically varied (optimized) the feed during milling. The result was a reduction of the machining time without any deterioration in the surface quality and an extension of the tool working lifetime.

Instead of applying a constant value of the feed, the program computed its optimal magnitude for different tool positions, while taking into account two criteria [12]:

1) The tool motion path criterion. The program automatically modified the feed by increasing it, if the tool path was close to a rectilinear one, or decreasing it in the case of a change in tool movement direction, approaching to arcs or corners, etc.
2) The current section of the layer machined. The program dynamically considered any variation in the thickness of the layer being machined. For small allowances, the feed was automatically increased and, inversely, increasing allowance resulted in a reduction of the feed.

The generation and application of machining programs with a dynamically variable feed required the machine tool to be equipped with a system for the infinitely variable adjustment of advance movement speed so as not to induce excessive vibrations of the machine. The control system provided the reading in of particular programme blocks to the memory in real time. The modern tools with replaceable plates were adapted to meet the requirements for efficient HSM machining [1, 3, 15].

A modification to the technological process of machining roughing of pressure casting die inserts on NC machine tools was made.

The result of this modification [9, 10, 11] was a reduction of the machine time of machining operations by approx. 49% for the movable insert and 29% for the fixed insert.

Real model of movable die insert and real view of fixed die insert after machining is shown in Fig. 8 and 9.

Fig. 8. Real model of movable die insert after machining

Fig. 9. Real view of fixed die insert after machining

CONCLUSION

Modern NC machine tools, properly selected cutting tools, implemented CAD/CAM systems and the HSM (high-speed machining) technology all enabled a considerable reduction of the machine time of selected machining operations. The savings were the greater, the larger were the series of parts machined and higher cutting speeds and feeds.

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