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Research Article

ASSESSMENT OF THE MANUFACTURING POSSIBILITY OF THIN-WALLED ROBOTIC PORTALS FOR CONVEYANCE WORKPLACES

Peter Michalik[1], Jozef Dobranský[1], Leopold Hrabovský[2], Michal Petruš[3]

[1] Technical University of Kosice, Faculty of Manufacturing Technologies with seat in Presov, Bayerova 1, 08001, Slovakia, e-mail: peter.michalik@tuke.sk

[2] VŠB - Technical University of Ostrava, 17. listopadu 15/2172, 708 33 Ostrava - Poruba, Czech Republic, e-mail: leopold.hrabovsky@vsb.cz

[3] Milpoš 177, 082 71, Slovakia, e-mail: michal.petrus4@gmail.com

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ABSTRACT

The paper discusses evaluation of machining solutions for oversized thin-walled robotic portal component for conveyance workplaces. The following portal CNC machining centers have been selected. Firstly, a FSGC 300 “portal type” portal was proposed, with a 50000 mm “X” axis and Heidenhain control system, the second portal was a DMU 340 portal with the maximum axis “X” of 6000 mm and Siemens Sinumerik control system and the last portal was the VF-10 / 40 one, with the maximum axis “X” of 3048 mm and Fanuc control system. Further, the method of fixing a thin-walled robotic portal is designed and individual options are evaluated for their economy. The CAM software application used for programming the production was SolidWorks.

Keywords: robotic, thin walled, CNC machine center, CAM application.

INTRODUCTION

At present, machining is an integral part of the production of a wide range of products. The material is shaved off in a form of chips. The function of machining is to obtain a component of the required size and shape. The desired precision and quality is achieved by gradual removal of the material. The technology is implemented as the machine, tool, jig and workpiece. The technologies used to achieve the desired dimensions of the selected workpiece are milling, drilling, carried out in two steps of setting up the workpiece from different sides. The paper focuses on the problem related to machining thin-walled conveyance workplace segment of specific dimensions.

This is a small batch job work posing a problem of handling a limited component size [1]. The workpiece is designated for the robot portal. The input semi-finished product is a segment welded from aluminum alloy profiles. Machining properties of this material are not the best. It is not tough and causes the chips to stick to the tool. A measure for avoiding damage to the workpiece or tool is the choice of suitable tools with optimum cutting conditions [2, 3].

Studies and practice confirm better surface properties and its quality is achieved by increasing cutting parameters, such as cutting speed and feed rate [4]. Portal structures of robots can be made of castings or welded. Casting of aluminum-based load bearing structural elements of handling and measuring devices requires adherence to the desired parameters, path length, temperature, melt angle and wall mold temperature [5]. In the process of casting thin-walled structures, it is necessary to monitor the cooling process, i.e. the cooling curve. Mouralova et al. found key parameters of machine setup for the manufacture of high-precision components with the required surface quality for precision quality [6]. With welded structures, it is necessary to check the welds [7].

In case of chip machining of different structural elements on CNC machine tools, it is necessary to take into account the shapes of programmed tool paths, whether they are linear or circular, which affects the overall precision of the manufactured component. Conway et al. studied various tool tracks [8].

It is also necessary to monitor the extent of deformation in drilling, wriggling and boring chip operations. Ramesh et al. investigated machining of a composite [9]. The structure of chip-machined oversized thin-walled components should be checked for dimensional stability under changes in temperature. D'Aleo et al. designed of resistive temperature detector arrays on aluminium substrates [10, 20]. Computer models for determining internal stresses due to chip machining, welding or casting are more commonly use in research and practice. Strohmandl proposed a simulation of the reduction of defective products [11, 21]. Koszu at al. designed application FEM in the analysis in the construction of frame [12, 22].

DESIGN OF ALTERNATIVES

Different versions of three milling machine tools were selected for treatment of the thin-walled robotic portal for the conveyance workplace. The robotic portal model [13] is illustrated in Figure 1. It was created in Autodesk Inventor [14, 17, 19] with prescribed precision [15]. Thin-walled robotic portal was designed for pipe conveyor workplace [16, 18]. The material of the thin-walled robotic portal is Alloy 3,1645 EN AW-2007 aluminum, which should be taken into account at clamping, during which the portal

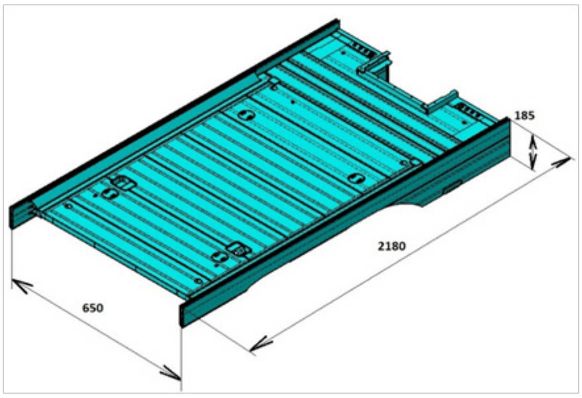

Fig. 1. Model of thin-walled robotic portal

Fig. 2. Optoelectronic workpiece probe

comes into contact with steel fasteners. In order to achieve desired production capacity, precision of the robotic portals and reasonable life of the cutting tools, the selected cutting conditions should be observed, the stiffness of the tools and the clamping jigs.

For machining itself, more zero points are required to be created in the program so that a minimal adjustment error is produced, which is also affected by the type of the applied optoelectronic measuring probe Figure 2. The total error will be minimal if zero points are placed directly in the center of the thin-walled robotic portal.

THE FIRST ALTERNATIVE CNC PORTAL MACHINING CENTER FSGC 300

The FSGC machining center offered is a machine with a portal structure Figure 3. It is equipped with a movable portal and base plates of cast iron for clamping the workpiece. These plates are a standardized design option for FSGC machines. The machine can be equipped with a special clamping device instead of cast plates or a combination of them. There is a wide range of accessories and equipment for machine tools to choose from. The heads, automated tool replacement, tool cooling, measuring probes and more. Precision is expressed in characteristic values according to the VDI / DGQ 3441standard, Table1. Modular structure of the machine allows a wide range of mounting dimensions for the FPPC machine. That is true for both, the width, but especially the length. For five-side machining, the machine can be equipped with a 2-axis head located in the structure or with continuously controlled indexing Figure 4 [23]. Table 1 shows the basic FSGC 300 parameters.

Table 1. Basic parameters of the FSGC 300 machine

Stroke of X-axis [mm]	4 000 – 50 000
Stroke of Y-axis [mm]	4 700
Stroke of Z-axis [mm]	1 500 (2 000)
Length of table [mm]	4 000 – 50 000
Width of table [mm]	3 000
Load of table [kg·m^2]	5 000
Distance between columns [mm]	4 300
Feeds X,Y,Z [mm]	2 500
Vertical spindle – mechanical	27 kW / 5000 rpm / 800 Nm / ISO50
Indexed head (machining of five sides)	30 kW / 5000 rpm / 800 Nm / ISO50
Continuously drive head (five-axis machining)	70 kW / 15000 rpm / 167 Nm / HSKA100

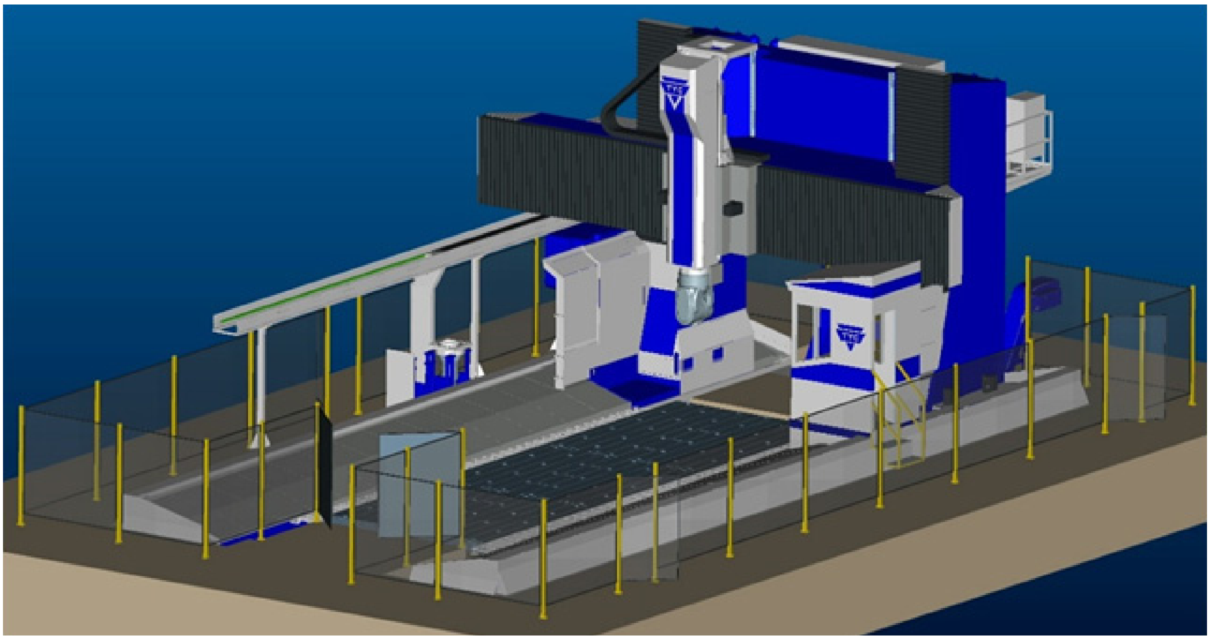

Fig. 3. Model milling portal machining center FSGC 300 [23]

Fig. 4. Milling portal machining center FSGC 300 [23]

THE SECOND ALTERNATIVE FIVE-AXIS CNC PORTAL CENTER DECKEL MAHO DMC 340 U

These five-axis machines with highly stable portal design offer maximum precision and greatest dynamics (Fig. 5). In addition to drilling and milling, the machine can also make the same settings. To maximize productivity, the DMC pallet changer allows for adjustments during machining. Large components may weigh up to 16 tons, they require large work area while leaving minimum trace. This concept is flexible, access to work area can be optimized, as can be the other processes. Their control system uses cycling cycles only, it de-

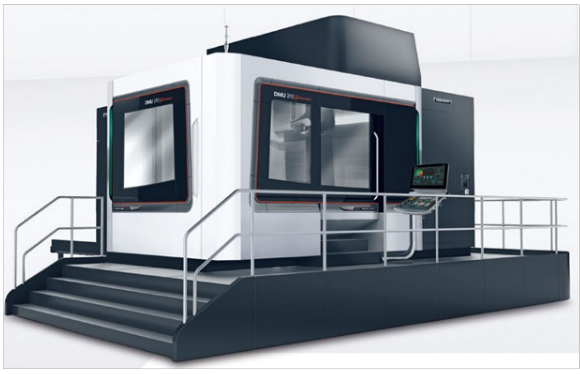

Fig. 5. Milling portal machining centre 5 axis CNC DECKEL MAHO DMC 340 U [25]

tects, controls and monitors scales, automatic speed setting based on component vibration, measurement cycles for laser measurement sensors [24].

It enables calibration of the measuring sensor in the work area and transmit the measured data to the control system. The series of portals shows maximum precision and temperature stability with standard positioning accuracy up to 10 μm. Comprehensive cooling delivers long-lasting precision (Fig. 6). Full cooling during machining ensures higher component precision. Positioning accuracy up to 8 μm with the possibility of packaging accuracy. Using the Celos control system offers a standard user interface for all new cutting-edge machines from DMG Mori. Celos Apps applications enable consistent management, documentation, and visualization of order, process, and machine data on a multi-touch monitor. They also simplify, standardize, and automate machine operation [18]. Table 2 shows the basic parameters of the DMC 340 U machine.

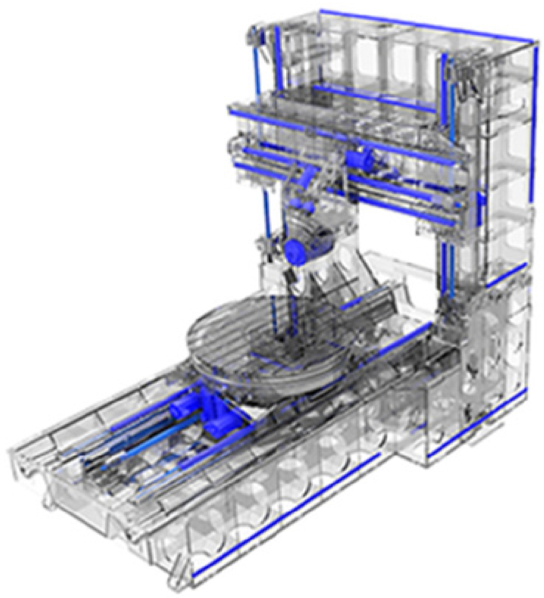

Fig. 6. The uncovered functional groups of 5 axis CNC portal center DECKEL MAHO DMC 340 U [24]

THE THIRD ALTERNATIVE MILLING 3-AXIS CENTER MLD - VF-10/40

All control systems of the vertical machining centers HAAS use a common concept of how they are to be operated. They are easy to use and program, so they require less training. Because of their compatibility, the existing programs can simply be reused, reducing total cost of ownership. 3D breakdown detection function HAAS Interference Control protects the machine, manufactured components and tools. The result is minimal downtime to protect expensive equipment and prevent damage to workpieces and machines. Hundreds of HAAS software features to improve intelligence, mobility, security, and productivity

Table 2. Basic parameters of the machine 5 axis CNC portal center DECKEL MAHO DMC 340 U

Max. X travels [mm]	3400
Max. Y travels [mm]	3400
Max. Z travels [mm]	1600
Max. table load [kg]	10000
Table length [mm]	2000
Table width [mm]	2500
High dynamics with feed speed [mm/min]	40000
Milling table with a torque [Nm]	10200
Power MASTER motor spindle with up to [Nm]	1000
Magazine with up to tools	234
B - axis with gear - driven spindle	8000 rpm, 52 kW, 1800 Nm torque

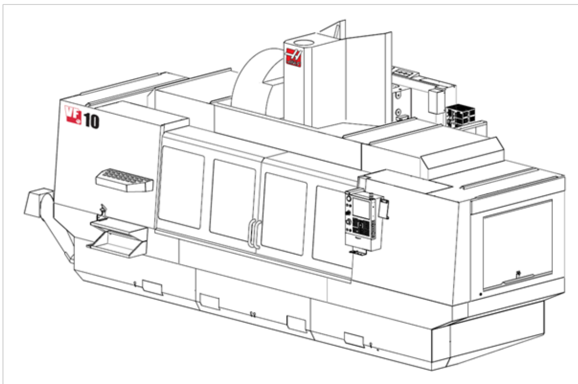

Fig. 7. The 3-axis milling center MLD–VF–10/40 [26]

enable the CNC control system to tailor the application perfectly and achieve greater efficiency. The three-axis CNC vertical center has an automatic screw with a chip, a programmable cooling nozzle, a color remote handle, 15 "color LCD monitor, USB port, key lock, power failure detection module, 1 GB program memory, a gallon (360 liters) system of flood cooling fluid, standard switch system, anchor kit that is highly recommended for installation (Fig. 7). Table 3 shows the basic MLD - VF machine parameters.

SOLUTION CLAMPING OF COMPONENT

The first step is to ensure the clamping of the blank (Fig. 8). The clamping is done by placing the workpiece on the CNC machining table's longitudinal table and by positioning other clamping elements. Using the available clamps, the workpiece is fastened, and its movement is prevented. A necessary step is using non-metallic plates to prevent the contact between metal and aluminum. The clamping should be done with available

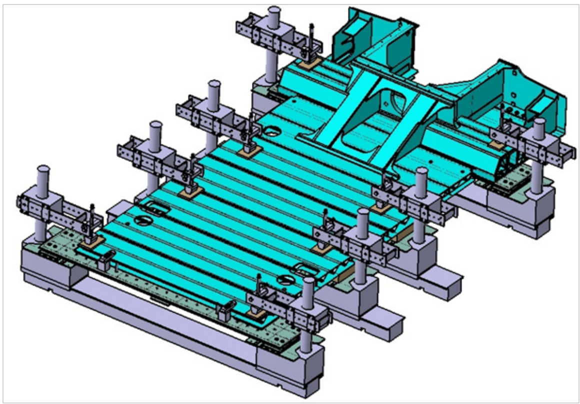

Fig. 8. Solution clamping of component

Figure 9. Available clamping elements

Table 3. Basic parameters of the machine 3 axis CNC MLD - VF-10/40

Max. X travels [mm]	3048
Max. Y travels [mm]	813
Max. Z travels [mm]	762
Max. table load [kg]	1814
Table length [mm]	3048
Table width [mm]	711
Max Tool Diameter [mm]	152
Max Tool Length [mm]	406
Vertical spindle – mechanical	22.4 kW / 8100 rpm / 339 Nm
Magazine with up to tools	24 + 1
Max Tool Weight [kg]	5.4

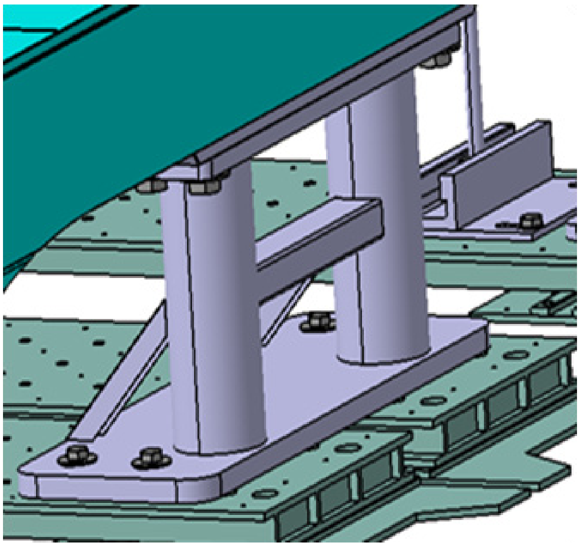

Fig. 10. Design of establishing and supporting a thin-walled robotic portal

clamping elements, which are generally used for other different blanks.

The clamping elements shown of Figure 9, consisting of a number of different shapes, stoppers, spacing pillars and a clamping screw.

The curved workpiece has a sufficient weight to prevent its movement. The problem of the structure itself lies in the fact that it is not a full material. There are undesirable vibrations and vibrations that need to be shortened. The chuck is a non-magnetic material and cannot be applied by an electromagnet. All clamping elements can only be applied to the longitudinal table to prevent movement and partially reduce the slope of the part. Stopping can be done by hand-screwed metric threaded pins. The installation of the thin-walled robotic portal will be secured by means of the screws and support pillars (Fig. 10).

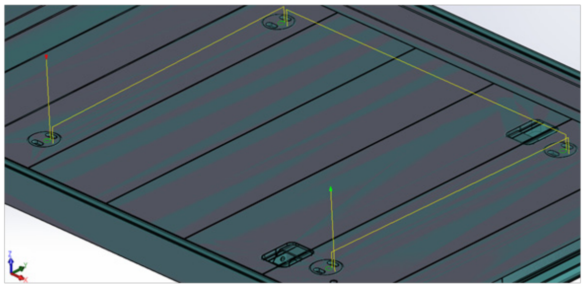

Fig. 11. Simulation machining of holes with the use of Autodesk Inventor HSM 2018

Before treating the holes, it is necessary to perform the simulation of the machining, as shown in Figure 11. All the parameters remain unchanged. Machining is performed using spiral ramping. Milling is performed only at the prescribed depth from the upper surface of the segment.

CAPACITIVE COMPARISON

The production time was 7.5 hours. The number of thin-walled robotic portals produced was 650. The coefficient of machine utilization 0.9, the coefficient of standard performance 0.9. Unique operation 7.5 hours (Table 4).

ECONOMIC COMPARISON

Based on the economic comparison, the most suitable alternative was chosen from among the produced thin-walled robotic portals for the conveyance workplaces. All advantages and disad-

Table 4. Capacitive comparison

	Cycle time (normal-hour)	Total time (normal-hour)	Required number of machines (number)
CNC portal center FSGC 300	0.1638	189.42	1.17090535
CNC portal center DECKEL MAHO DMC 340 U	0.1596	179.45	1.16860823
CNC center MLD - VF-10/40	0.3688	395.72	2.03560782

Table 5. Capacitive comparison

Machine	FSGC 300	DMC 340 U	MLD - VF-10/40
Cycle time (hour)	2.74	2.69	5.08
Number of pieces for turns (number)	2	2	1
Control system	Heidenhain	Sinumeric	Fanuc
Machine price (EUR)	650 000	1 000 000	140 000

vantages have been taken into account. Cost per work hour was EUR 32.00 (Table 5). Operating costs need to be taken into account.

CONCLUSIONS

Requirements for high quality and precision in the production of final assembled equipment are met by chip machining. Production of a thin-walled robotic portal needed to be designed. Individual manufacturing steps required a design of a suitable CNC machining center and the blank clamping procedure. During the manufacturing process, the applied cutting forces had to be eliminated to prevent tool and workpiece damage. The clamping proposed for individual operations will meet the requirements of desired precision, time sequence of steps and establishment of cutting conditions. In the practical part, a CAM application was developed and simulated by the NC program, which calculated, optimized tool paths and prevented possible collisions of working tools with clamping elements. Simulation of machining is systematically described by individual blocks of NC machining. Based on the economic calculations and types of control systems for the production of thin-walled robotic portal, the CNC portal machine tool center FSGC 300 is recommended.

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