MATEC Web of Conferences **94**, 01003 (2017) DOI: 10.1051/matecconf/20179401003
CoSME'16

Design of equipment for training machine tools

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Abstract. The article proposes multiple devices designed to be used with training machine tools EMCO Concept series. Design was focused to enchant educational potential of training machine tools located in the laboratory of CNC programing, department of automation and production systems, Faculty of mechanical engineering, University of Zilina. The described device allows monitoring of machine tool, to measure tool offset and dimension, to use alternative ways of clamping, and to create video of machining.

1 Introduction

Constant improvement development and application of results of research affects our lives, whether it takes place in industry, training, or education. Implementation of progressive modern technologies to education process is essential for sustaining competitiveness of educational institutions and graduates. Even implementation of seemingly trivial solution can help students to learn various techniques that can improve their creativity and effectiveness in real life situation in industry. The article deals with the application of such resources to support the teaching which deals with CNC manufacturing technology [1, 2].

The article deals with training machine tool Emco Concept Mill (CM) 105 using other production resources available at Department of Automation and Production Systems, Faculty of Mechanical Engineering, University of Zilina. The proposed solution include design of camera mount for GoPro Hero camera in interior of machine tool, design of technological palate, and design of device for measurement of tool offsets. Necessity of designing and implementing of these devices resulted from specificity of used machine tool. The machine tool described in next chapter slightly deviates from machine tools commonly used in industry as it is designed specifically for industrial training with focus on versatility, easiness of operation and maintenance.

2 Emco Concept Mill

Training with real machine tools is important part of educational process in field of mechanical engineering. However common machine tools have limited options in terms of control system and it usually requires significant space. In terms of training and education it is good to have one machine that can be controlled with multiple control systems.

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EMCO CM 105 (Figure 1) is compact machine tool designed for industrial training and educational purposes. Such machine tools are commonly used at technical high schools and universities. Tools are stored in ten station turret. Slides and load-bearing elements are made of gray cast iron. This machine is equipped with infinitely variable main drive and 10-station turret tool changer [3, 4].

Fig. 1. EMCO Concept MILL 105 [3].

Compact table format is suitable for teaching of common manufacturing technologies. Safety glass window provides high level of protection against chips and prevents coolant leakage, but in same time it render recording of high quality video, from outside of the machine, virtually impossible because of reflections. The control for the CM 105 is connected via PC with interchangeable WinNC control from EMCO. The uncommon arrangement of control system where machine tool is controlled by simulated control system what is actually an computer program brings some problems with compatibility of control system with real production machines but it also allow to use another software to interact with simulated control system [3, 4].

The worktable have T-slots, but workpiece is usually mounted to with mechanical vice permanently mounted to worktable. That reduces necessity to repeatedly measure and set workpiece offset as it can be aligned with corner of vice. Machine tool workspace provides capability of clamping workpiece with dimensions 200×150mm and its maximal size in Z axis depends on length of used tool. Effective length of Z axis is 150mm. Inner space of machine tool is significantly larger than effective workspace what allows placement of small action camera and other equipment inside of machine tool [3, 4].

Sadly, the control system of CM 105 lacks ability to connect automatic device for measuring of tool length and diameter and therefor the investment to such device commonly used in industry would be waste of money. The machine is relatively limited in terms of peripherals accessories, for example it is not possible to use it with 3D measuring probe commonly used in industry. But again, these shortcomings are more than enough compensated by ability to be used with various control systems, what saves space, finances. Another benefit of this machine tool is that it uses rather small tools which are more affordable and thus more suitable for training and education.

3 Camera mount

Capturing of video of machining in machine tool is seemingly trivial task but it brings several problem such as camera size, its strength and resistance to specific environmental factors (swarf, coolant, vibrations, etc.). That led us to simple choice of so called action camera - GoPro HD HERO 3 which was highest available model in time when this problem was solved. The camera features video resolutions up to 1080p30, 5MP photos up to 3 frames per second, an ultra-wide angle lens and built-in Wi-Fi.

The camera can be equipped with wide scale of stands and mounts usually connected together with forks that forms an angle joints. One of these forks is fitted with M5 closed cap nut and joints are fastened with knob screw. Combination of specific selected camera and machine tool provides several possible places for mounting, shown on Figure 2, each of which provides different type of view:

1. Mounting on turret - Tool POV.
2. Mounting on worktable - Workpiece POV.
3. Mounting on machine tool frame - Static video.

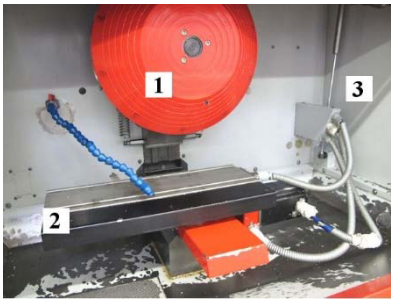

Fig. 2. Places for camera placement at workspace of EMCO CM 105 [7].

Standard set of mounts for this camera can be used to be mount it to worktable or to machine tool frame but it does not offer the angle of view that we desire – the view with tool in center of picture. It would require sticking ten mountpads around the turret one for each tool position what would require manual realignment of camera after each tool change during machining. Therefor we designed special pendulum-like mount mounted to center of rotation of turret. As turret spins during tool exchange, camera keeps facing downwards because it is self-oriented by gravity. This way camera is constantly facing to the tool which is currently active. Such placement also eliminate possible problems with changing focusing distance that could rise when camera is mounted on machine tool frame or on worktable [1, 5].

The design was based on fact that the turret have ten positions, it rotates during tool exchange,and mount had to allow recording individual tools in their specific positions. Camera and mount components should not affect production capability of machine tool in any negative way and operation of machine should not affect camera and its stability.

The design of prototype was also focused to use as much standardized components as possible in order to verify its functionality and reduce costs of production and still keep relative freedom in terms of adjustability of camera position relative to active tool. Fluent rotation of pendulum during tool exchange is ensured by using of ball bearing mounted to the center of turret by center pivot.

The final construction (Figure 3) consists of rotary joint, angle joint connecting rotary section with carrier rod with attached clamp with standard fork that allows connection of camera or its equipment. Carrier rod is made of long Allen screw screwed into nut glued in hexagonal hole in one part of angle joint. Using standard size thread allows us to easily

replace carrier rod by another screw with different length if necessary. Screw head also serve as stopper that prevents slip off and fall of the camera [1].

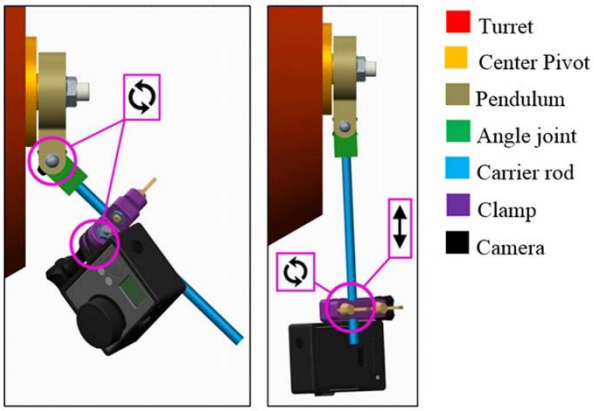

Fig. 3. Model of camera mount construction and possibilities of adjusting of camera position [5].

The design and concepts were verified by producing prototype (Figure 4 – left) using standardized and 3D printed parts. Testing of prototype showed problems with focusing to tool placed too close to camera lens. This was solved with 58mm close up filter ×2 and step up ring 37 to 58 mm. Rectangle of same size as front part of camera case was milled into the step up ring which was glued on 3D printed adaptor designed to fit on front element of camera lens. Inner surface of 3D printed part was covered by rubber tape in order to increase friction and secure proper mounting of filter to camera case [5].

Fig. 4. Camera on prototype of mount fitted in machine tool (left) and detail of mounting close up filter to camera case (right).

The diameter of close up filter significantly larger than diameter of lens was selected in order to eliminate picture vignetting. Test confirmed that with close up filter attached to camera it is possible to focus on tool properly and thus dramatically increase quality of recorded video [1].

Camera placed in machine tool workspace can be used thru wireless network what allow implementing remote observation of machining process.

4 Device for measurement of tools

Measurement of tool length and diameter is common task in standard operation machine tool that is necessary to ensure accuracy of dimensions of produced parts. Commonly it is automatized and even added to programs for production used together with conditional tool exchange based on tool state.

However, the CM 105 does not allow input from device and thus we can implement only device that can be used by operator and not by automatic cycle in program. Therefor we designed simple battery operated tool setter optical gateway with acoustic output that can be used to measure tool offsets in manual mode of machine tool.

Proposed design consist of two separated parts – the emitter and the receiver (Figure 5). The functional part of emitter is simple battery laser aligned with base with pushbutton to switch on or off. The receiver unit is also battery operated, it contains receiver for laser beam, buzzer that indicates laser beam interruption, and pushbutton for switching device on or off. Both parts have its own batteries and switches as they are not connected by wires, each unit is controlled by simple microcontrollers Digispark ATtiny85. In the emitter the microcontroller serve just as timed switch in order to save battery. The receiver uses microcontroller in order to analyze frequency of signal from laser emitter resulting from rotating flutes of tool crossing the beam [6].

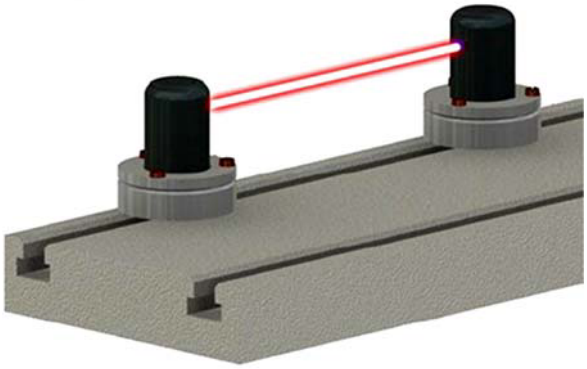

Fig. 5. Placement of units of custom tool setter on worktable.

In order to ensure proper functionality of device it is firstly necessary to properly align laser beam of emitter with X axis of machine tool. It can be easily done by moving worktable along the axis and adjusting horizontal angle of emitter until the red dot (laser spot) stops moving to the sides with moving of worktable. Second step is placing of receiver in path of the beam in way that allows reception. The strength of signal from laser can be measured by long press of pushbutton (at least ten seconds), in such setup mode tone of acoustic signal represent strength of signal [6].

Main mechanical construction of units is made of machined aluminum grinded and fitted together with Allen screws. All electronics are covered with 3D printed plastic covers that protect construction from swarf and still allow to pushbutton to be pressed by applying force in Z axis to the cover. Base construction is divided to two parts bottom of which is fixed to worktable using T-slot and top part allows precise adjustment with three Allen screws that allows leveling of unit in order to make laser beam perpendicular with table movement. Programing of microcontroller in receiver allows to filter signals from interruption of laser beam and thus remove unnecessary acoustic signals during machine tool operation. It is possible because of measurement of tool dimensions is done with tool rotating on low speed. The tool setter design described in this chapter is not very precise but

it help us to explain and clarify principles, commonly used in industry, on machine that in normal circumstances would not allow that. The main benefit of described construction is that it allows to measure tool dimensions near the vice what is necessary property for CM 105 as its effective workspace is too small to place such device as it is usual on industrial machines.

5 Technological pallets

The technological pallets are commonly used in mass production but it is not so common in smaller scale productions. The training and educational machines such as CM 105 are typically equipped with very limited workspace what renders common technological pallets virtually unusable. Therefor we decided to design small quick releasable technological pallet compatible with our machine tool that would provide practical example of usage of such aids in industry.

Basic design was based on requirement of hand manipulation of pallet, it should be easily and automatically positioned and aligned in machine tool workspace and it should also allow easy fixation and release of parts. It should provide secure clamping and it should reduce workspace as little as possible.

The final design of exchangeable technological pallet system (Figure 6) consists of base plate mounted on worktable, pallet itself clamped by eccentric levers. Position of pallet on base plate is ensured by taper pins fitted with housing drilled into pallet [7].

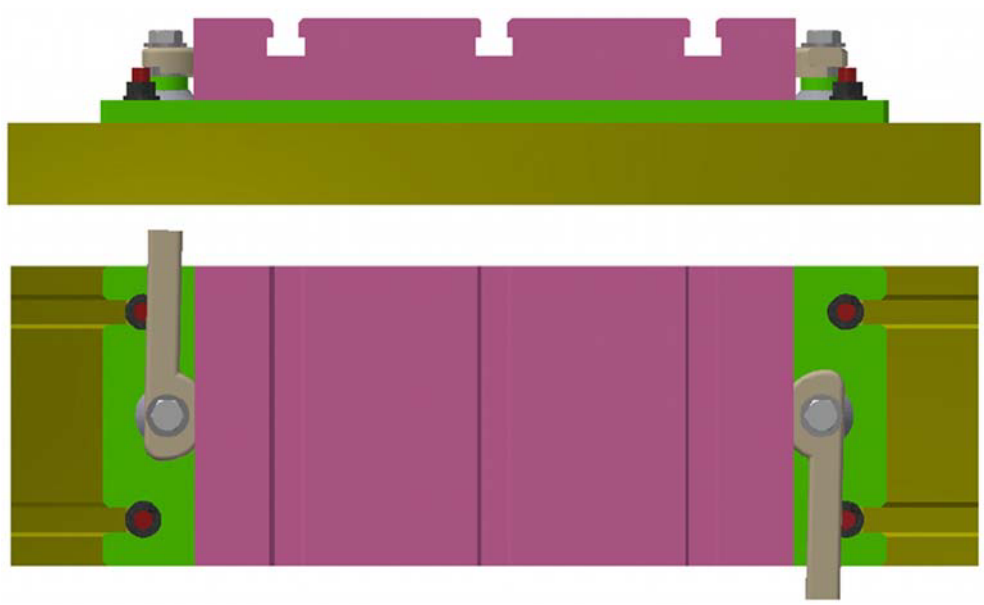

Fig. 6. Model of exchangeable technological pallet system.

Mounting of the pallet is done by friction between pallet and base plate, the clamping force is produced by turning of lever – there are helical surfaces on bottom of the levers and on the cavities at the sides of palette. The sizing and optimization of construction was done thru simulations. Complete system should contain at least two pallets in order to present benefits of implementation of such system especially reduction of the time necessary to clamping workpieces in workspace [7, 8].

Pallets can be modified to another system for clamping such as system with matrix of threated holes or it can be equipped with various clamping devices such as magnetic table, mechanical vice, etc.

6 Monitoring of machine tool usage

Monitoring of machine tool Emco CM 105 is possible with relatively simple computer program as it is not controlled by official control system of common producer. It have system of interchangeable control systems which is implemented as computer program with user interface and behavior simulating official control systems used on common industrial machines. Computer that runs WinNC software that mediates user interface, communicate with PLC in machine tool via Ethernet [3, 4, 9].

If we want to monitor some technological parameters in real time it can relatively easily be done by one of two ways. Either by monitoring network communication between machine tool and controlling computer, or by reading memory allocated by control software. We decided to use second method.

The reverse engineering methods were used to find addresses of variables storing values we desired to monitor. The Cheat Engine,an open-source software designed to read memory allocated by programs in order to cheat in computer games, was used as tool for scanning memory allocated by process Sie840Du.exe for addresses of variables [9, 10].

Using addresses found with the Cheat Engine software we created custom software for monitoring technological parameters. This software is not meant to be used by machine tool operator so it is designed to start with system as hidden. User interface is accessible thru icon in notification area. Graphical user interface is therefore relatively simple and it serves primarily for initial setup and debugging. Also in order to reduce allocation of system resources, the instance of the form with user interface is not loaded until it is manually requested by double clicking icon in notification area (system tray) [9].

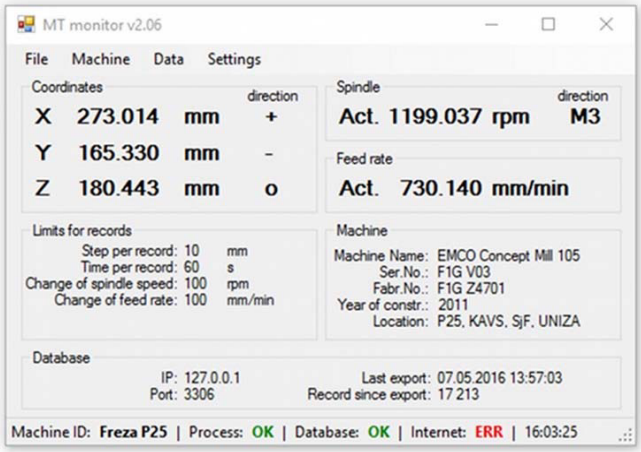

Fig. 7. Custom software "MT monitor" for monitoring of Emco Concept Machine tools.

Current version of MT monitor is capable of real time reading of tool position in machine coordinate system, spindle speed, and feed rate. It also displays current direction per axis and direction of spindle rotation. User interface also shows state of process that simulates control system, state of connection to database and to internet (if it is possible). There are also basic information about machine and count of records since last data export.

The data captured thru monitoring software will be analyzed together with data gained by technical diagnostic such as results of measurements of tool positioning precision in order to get relevant data for establishing trend and correlation between machine tool usage and its condition. For example monitored data can be used to compare with measured wear of feeds, to check most used parts of workspace, and more. Functionalities of the MT monitor will have to be widened to support other control systems supported in WinNC software used for controlling Emco Concept machines and to collect data independently on control system used for machine tool operation. This is necessary because same machine tool can be used with multiple control system, but effects to hardware remains regardless of system used [9].

7 Conclusion

Constant development and improvement should be essential part of educational processes. Implementation of machine tools to educational process offers lots of opportunities to enhance education by developing new and improving old accessories. This article contains small sample of work in this field. The process of improvement is never finished and it requires constant effort and care. All described solutions was designed with focus on increasing educational potential of training machine tools located in the laboratory of CNC programing, department of automation and production systems, Faculty of mechanical engineering, University of Zilina.

This article was made under support projects KEGA 037ŽU-4/2014 and KEGA 024ŽU-4/2016

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