Annals of DAAAM for 2011 & Proceedings of the 22nd International DAAAM Symposium, Volume 22, No. 1, ISSN 1726-9679
ISBN 978-3-901509-83-4, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2011
Make Harmony between Technology and Nature, and Your Mind will Fly Free as a Bird
Annals & Proceedings of DAAAM International 2011

ROTATION SPEED CONTROL OF MILLING MACHINE

SAMEK, D[avid]

Abstract: *This paper describes design of control loop for spindle rotation speed on the milling machine. The milling machine to be controlled was developed in order to obtain a cheap and simple educational device for machining engineering lessons. Thus, the resulted device falls into the hobby class devices. Special attention was paid to the costs of the whole machine. The goal was to obtain cheap small CNC milling machine applicable in the student class lessons.*
Key words: *milling machine, rotation speed, control, PID controller, inductive sensor*

1. INTRODUCTION

Milling is one of the most popular machinery technologies, which is widely used for a variety of materials such as metal, plastics, wood, etc. (Cus & Zuperl, 2009). Milling technology brings powerful machining features. It provides multi-axes machining, complex-shape parts machining and machining of wide range of parts size (Dotcheva & Millward, 2008). Therefore, education institutions have to provide appropriate introduction to students including practical workshops and exercises on the real machines. However, the commercially sold machines are fairly expensive.

In this paper the proprietary design of the 3 axes CNC milling machine is introduced. The machine was designed and developed for milling plastics materials (Petruzela, 2010, Petruzela, 2011).

The machine uses gantry style because of simplicity of implementation (Williams, 2003). The working range of the milling machine is 205 x 115 x 28 mm. As can be seen from Fig. 1, three stepper drives are used for axes motion. Maximal programmable feed rates for axis X, Y, Z are 0.5, 0.3, 0.2 m/min, respectively. The programmable step sizes for axis X, Y, Z are 0.026, 0.014, 0.003 mm. Tool holder diameter is 6 mm. The spindle engine has 160W input power and rotation speed falls in range 15000 – 35000 rpm. Mach3 was used as the CNC programming software.

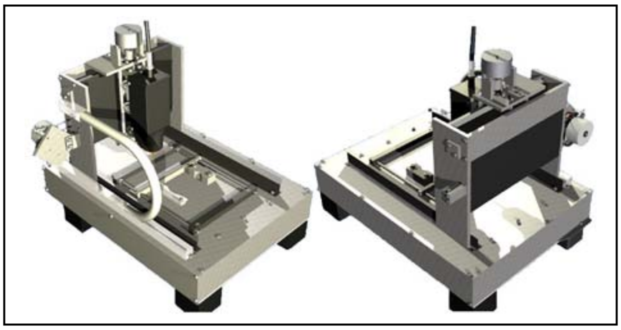

Fig. 1. 3D visualization of the milling machine

Nevertheless, the original design had not involved spindle rotation speed control. Thus, the operator could only set manually desired spindle rotation speed, but during milling the speed changed. In order to maintain optimal cutting conditions for various materials and tools it was necessary to upgrade given device with a rotation speed sensor and a controller.

2. ROTATION SPEED SENSOR AND TACHOMETER

The sensor had to meet the following conditions. It should have been able to sense the speed in the spindle full range (up to 35 000 rpm). At the same time it was required easy mounting to the current CNC milling machine. Furthermore, the implementation of the sensor should have not obstructed to future covering of the spindle. Because of the price and reliability, it was decided to use inductive sensor. The mounting scheme of the sensor is depicted in the Fig. 2.

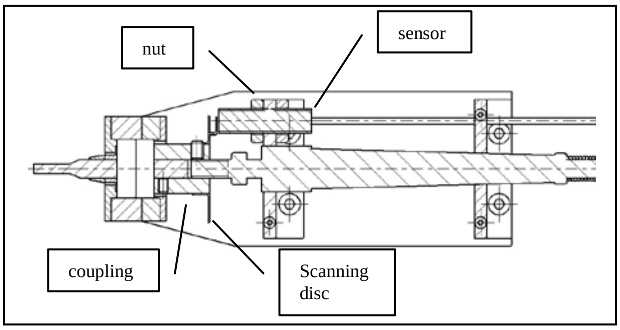

Fig. 2. Inductive sensor mounting to the spindle mechanism

Signal from the sensor is processed by monolithic integrated circuit IO NE556 (***, 1998). The output signal then goes to the 3−Digit BCD Counter (***, 2006) that controls the LED digital panel tachometer (Fig. 3).

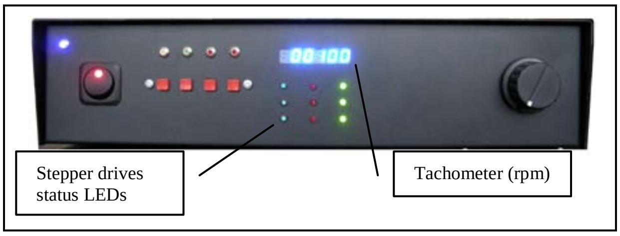

Fig. 3. Control panel

3. CONTROL LOOP

As the software package Mach3 supports spindle speed control, it was just necessary to connect the signal from rotation speed sensor to the PC and design proper actuator device.

3.1 Loopback to PC

It was obligatory to find solution how to bring pulses from the inductive sensor to the LPT port of the control PC, while the sensor output pulses have a voltage of 12 V. Direct connection of this voltage would cause damage of the personal computer. An optocoupler arose as the simplest solution which separates both devices. So the failure of one of them would not cause damage to the other. What is more, it also solves the problem with the voltage difference, since these two parts were voltage-dependent then. As can be seen from Fig. 4, another advantage resides in the fact that the output of the optocoupler is formed by transistor. Therefore, it was possible to connect its emitter within the LPT port ground and its collector within reading pin of the LPT port.

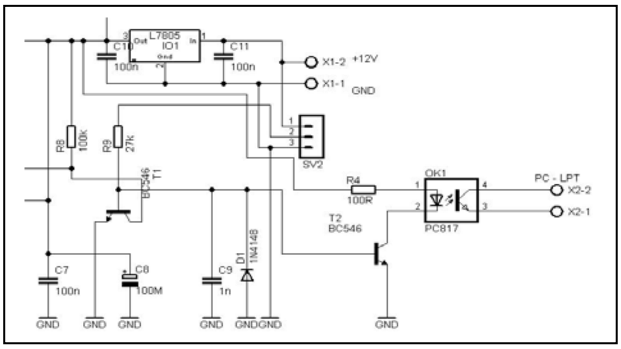

Fig. 4. Electronic scheme of the sensor – PC connection (Petruzela, 2011)

3.2 Actuator device

After few experiments with the Mach3 output signal settings it was selected the PWM signal modulation, because other methods (such as STEP/DIR signal) did not provide stable results. The VELLEMAN K2636 controller (***, 2004) was used as the actuator, thus it was needed to transform the PWM signal to 0-5V analog signal (Fig. 5). The K2636 controller was selected because it is specially designed to control the speed of any AC motors with carbon brushes and provides high torque at low speed.

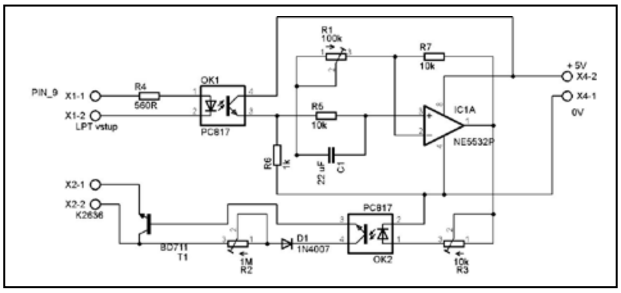

Fig. 5. Electronic scheme of PWM – voltage analog signal convertor (Petruzela, 2011)

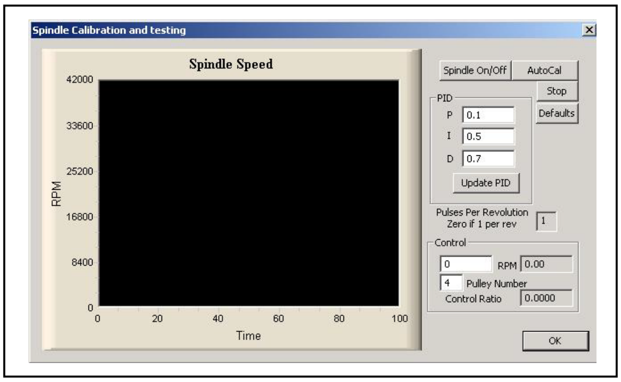

Fig. 6. PID controller tuning

3.3 Mach3 controller settings

The Mach3 software comprises simple PID controller for the spindle rotation speed. When *Closed Loop Spindle Control* option is checked, Mach3 implements a software servo loop that tries to match the actual spindle speed obtained by the sensor with that demanded by the S word (***, 2011). The settings of the controller were obtained using Mach3 build-in function *Calibrate spindle* (Fig. 6).

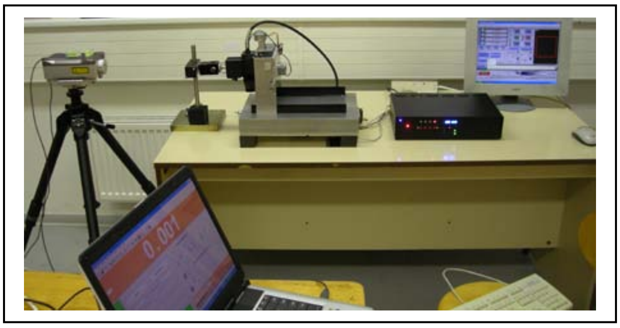

Fig. 7. Final testing of using laser interferometer

4. CONCLUSION

The paper presented cheap and simple design of the CNC milling machine that can be used for laboratory and educational purposes or in hobby workshops. In the limited space was not possible to describe all aspects of the presented device. Thus, the contribution focused to the design and implementation of the spindle rotation speed controller. The described control loop design was successfully experimentally tested on various plastic materials (Fig. 7) and could be considered as cheap and functional solution. The total costs of the CNC milling machine amounted to 500 EUR approximately. It is worth of noticing that the cheapest comparable standard commercially sold CNC machines cost more 2000 EUR and usually do not support spindle rotation speed control.

5. ACKNOWLEDGEMENTS

This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic under the grant MSM 7088352102 and by the European Regional Development Fund under the project CEBIA-Tech No. CZ.1.05/2.1.00/03.0089.

6. REFERENCES

Cus, F. & Zuperl, U. (2009). PSO Assisted Adaptive Force Control in Milling, Chapter 03, In: *DAAAM Int. Scientific Book 2009*, pp. 017-024, B. Katalinic (Ed.), Published by DAAAM Int., ISBN 978-3-901509-69-8, Vienna, Austria

Dotcheva, M. & Millward, H. (2008). A Generation of More Efficient CNC Tool Paths Using Simulation Modelling. *International Journal of Simulation Modelling*, Vol. 7, No. 3, (September 2008) 135-145, ISSN 1726-4529

Petruzela, T. (2010). *CNC milling machine with sensing of the spindle rotation speed*. Faculty of Technology, TBU in Zlin, SVOC research paper

Petruzela, T. (2011). *Laboratory device for plastics milling with rotation speed automatic control*. Faculty of Technology, TBU in Zlin, master thesis

Williams, G. (2003). *CNC Robotics*. McGraw-Hill. ISBN 0-07-141828-8, New York

*** (1998). NE556, SA556 - SE556, *Available from:* http://www.datasheetcatalog.org/datasheet/stmicroelectronics/2183.pdf *Accessed:* 2011-01-03

*** (2006). MC14553B, *Available from:* http://www.onsemi.com/pub_link/Collateral/MC14553B-D.PDF *Accessed:* 2011-01-03

*** (2004). K2636, *Available from:* http://www.velleman.eu/downloads/0/illustrated/illustrated_assembly_manual_k2636_rev2.pdf *Accessed:* 2011-01-03

*** (2011) http://www.machsupport.com – Artsoft: Division of Newfangled Solutions, Mach3, *Accessed on: 2011-06-10*