Received: 8 Dec. 2017
Accepted: 20 Dec. 2017

VERIFICATION OF OPERATING CHARACTERISTICS OF PNEUMATIC ARTIFICIAL MUSCLES WITH THE REAL TIME CONTROL SYSTEM

Miroslav Rimár
The Technical University of Košice, Faculty of Manufacturing Technologies with a seat in Prešov, Department of Process Technique, Štúrova 31,080 01 Prešov, miroslav.rimar@tuke.sk
Peter Šmeringai
The Technical University of Košice, Faculty of Manufacturing Technologies with a seat in Prešov, Department of Process Technique, Štúrova 31,080 01 Prešov, peter.smeringai@tuke.sk
Marcel Fedák
The Technical University of Košice, Faculty of Manufacturing Technologies with a seat in Prešov, Department of Process Technique, Štúrova 31,080 01 Prešov, marcel.fedak@tuke.sk

Keywords: PAM, vibrations, PWM
Abstract: The article describes an experimental device based on the antagonistic involvement of pneumatic artificial muscles, a draught for changes of the experimental device, made to provide possibilities for a more fluid operation of the device and at the same time measurement of the operational characteristics. The article also describes a test measurement performed to verify its performance characteristics using a wide-pulse modulation.

1 Introduction

Research and development in the field of manufacturing technology is continually driven by new challenges from manufacturing companies and companies focusing on manufacturing machines and handling equipment. Efforts to maintain a strong competitive environment lead manufacturers of production technologies to look for new solutions to manufacturing nodes and to introduce modern technologies into production. Currently, for example, there are requirements for modern production operations, capable of fulfilling its function even in aggressive environments. Or vice versa, there is a need for a technical device, with an adapted drive for an environment where standard types of drive can not be used for their negative impact on the working environment [1],[2],[3],[4],[5].

In today's manufacturing plants, companies often go through automation. In view of development trends such as the Industry 4.0 concept, it is important for automation to take into account structural management as well as to implement modular management elements and network interconnection of individual elements of the production system into its structure. Within the manufacturing system elements, pneumatically-operated production facilities are not an exception. For pneumatic actuators, drive based on the Pneumatic Artificial Muscle (PAM) is now commonplace [1],[6],[7].

The article describes an online control system for an experimental actuator based on the antagonistic involvement of pneumatic artificial muscles (PAMs). The aim of this work is to propose a methodology for online monitoring, measurement of dynamic characteristics and control of systems operating on a similar principle, in order to achieve optimal operation of the equipment, in the stage of basic management utilization, previous implementation of advanced control functions. The control system was created using LabVIEW graphical programming software. The designed control program uses hardware from National Instruments company for its operation. In order to transport the compressed medium into the transport system between the pressurized medium source and the pneumatic artificial muscles, are used electropneumatic valves which allows pulse-width modulation (PWM) [4], [7].

2 Description of the Experimental Involvement and Its Amendments

2.1 Original experimental device

In Figure 1 is a depicted experimental facility comprising antagonistic involvement of pneumatic artificial muscles.

Copyright © Acta Tecnología, www.actatecnologia.eu

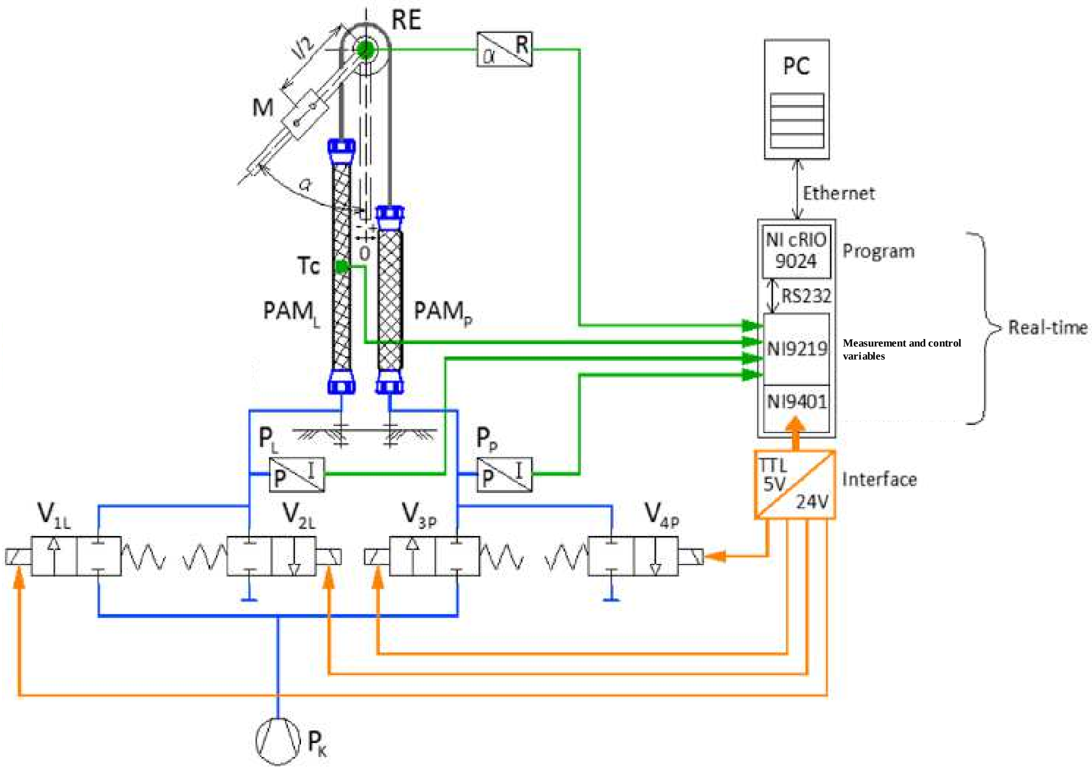

Figure 1 Experimental assembly of PAMs in antagonistic assembly [4]

Description of the image: PAM_L/PAM_P – pneumatic artificial muscle left/right, M – weight, RE – position sensor, α - the angle of rotation of the arm from the zero (vertical) position, Tc – thermocouple, R – electric resistance, PC – Control stand, P_L/P_P – pressure sensor left/right, P – pressure, I – electric current, V_{1L}/V_{3P} – inflation electro-pneumatic valve left/right, V_{2L}/V_{4P} – deflation electro-pneumatic valve left/right, PK – pressure at the compressor output.

The above diagram of the device shows that there are constantly monitored pressure in PAMs, the size of the carrier arm rotation and the left muscle temperature, during the operation of the device.

Assembly management is provided by a real-time control system, consisting of NI CompactRIO components, designed for real-time monitoring, diagnostics and control. The control system algorithm itself was designed in the LabVIEW Real Time graphical development environment. The PC provides the user with the ability to monitor the progress of the measured variables while controlling the device in the user environment of the program [7].

After the initial experiments were completed [4], the experimental device had to be modified for future integration into more complex systems, to eliminate its limitations and to do redeeming. The original system included temperature measurement on the left PAM via a thermocouple. This method of measuring the temperature did not suit the used analog-to-digital converter. Measurement of the temperature on the surface of the pneumatic artificial muscle in the vertical position and with the inlet and outlet of the air at its lower part was not equally suitable for several reasons. During operation, the thermocouple was able to measure the temperature of only one point on the PAM surface. Due to the PAMs structure and its function, the temperature of each point at the shape of the PAM was different. For this reason, an alternative was chosen where the surface temperature of the PAM will be measured thermographically in the future. The previous scheme also does not allow control of the movement of the carrier arm, except for the use of feedback control using the mathematical model of the PAM system.

2.2 Modified Experimental facility

For a more detailed monitoring of the operating conditions of the equipment, the original system was supplemented by measuring the acceleration of the support arm in the directions of its movement and also in the forward direction of the carrier arm, in the event of imperfect connection of the drive shaft with the support arm and also to detect any mechanical failure of the device.

The new design of the experimental device is shown in Fig. 2. Thermal sensor temperature sensing was left to test the accuracy of the proposed system. Later it was removed [8].

Copyright © Acta Tecnología, www.actatecnologia.eu

Acta Tecnología - International Scientific Journal about Technologies
Volume: 3 2017 Issue: 4 Pages: 25-28 ISSN 2453-675X

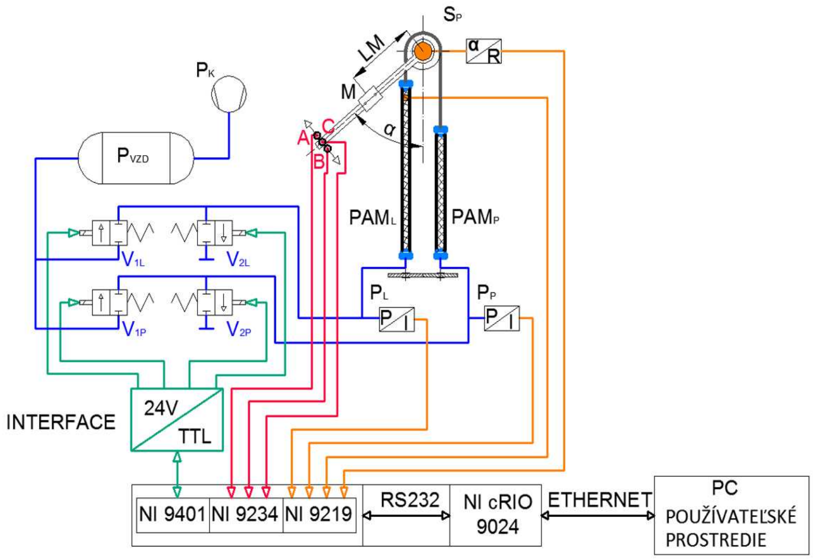

Figure 2 Modified experimental device assembly with PAMs [7]

Image description: PAM_L – left PAM, PAM_P – right PAM, LM -the center of gravity of the load-bearing member M from the pivot arm shaft, S_P – potentiometric position sensor, α – angle of arm rotation from zero position, P_L – left pressure sensor, P_P – right pressure sensor, P – pressure, I – electric current, R – electric resistance, P_K – pressure at the compressor output, V_{1L} / V_{1P} – left/right inflation electro-pneumatic valve, V_{1L} / V_{1P} – left/right deflation electro-pneumatic valve, P_{VZD} – pressure in the pressure vessel, A/B/C – acceleration sensors. The orange wires represent the signals from the original sensors, the red wires represent vibration sensor signals, the green wires are used for control signals for electropneumatic valves and the blue color represent the cross connection between the PAMs and pressure vessel [7]. After the experimental device modifications were processed, experimental measurements were performed to describe the operating conditions of antagonistic involvement of PAMs.

3 Experimental Measurements Results

PWM utilization allows smaller rotation of the support arm as well as it has partial impact to a change in the speed of its movement. The disadvantage of pneumatic systems is the interconnection of their parts with the need for lower pressure of the working medium with the source of the pressurized working medium with higher pressure. At low pressure in both PAMs, when the electropneumatic valves are opened, pneumatic impacts occur which, can lead to undesirable overhang of the support arm, at the time of acceleration and deceleration of the support arm.

The partial results from the experimental measurement are shown in Fig. 3. The carry arm was positioned in to position of 15 ° from its zero vertical position where the working pressure in both PAMs is at the lowest level. In this case was the positioning arm starting from the minimum working pressure setting level in both PAM. The results are shown in the iterations of the repeating control program.

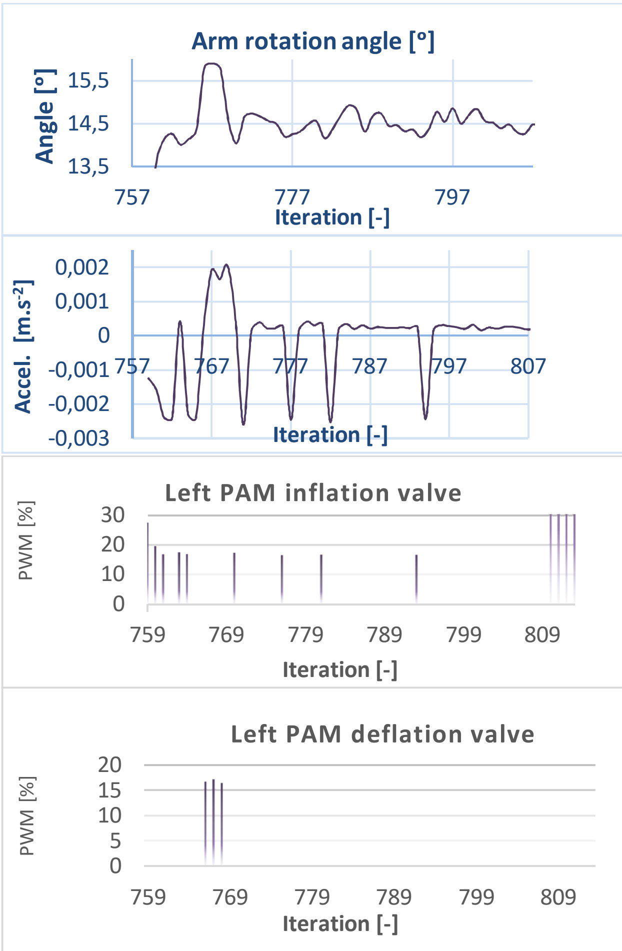

Figure 3 Results of experimental measurements

Copyright © Acta Tecnología, www.actatecnologia.eu

The results of the experimental measurement showed that the justification of the application of the acceleration sensors for monitoring the events taking place inside the pneumatic system.

The experimental measurement results show the dependence between the opening of the electropneumatic valve and the acceleration of the support arm. Also, the dependence between the acceleration of the carry arm and the deviation (overlap) of the actual position of the carry arm from the required position, can be seen. This deviation is a result of carry arm movement with the corresponding acceleration and the number of iterations of its duration.
With the system's low stiffness, the positioning accuracy of the end element of the device is significantly influenced by the number of iterations (duration) during which the electropneumatic valve is open.

Conclusions

An experimental device with a drive based on the antagonistic assembly of pneumatic artificial muscles was designed and modified, at the Department of Process Engineering. This article describes the schema of individual parts of the assembly, in its original and in its modified form, and one of a series of measurements performed to verify the functionality of the proposed real-time control system. Results of the measurements performed on the device have shown the justification for the implementation of the acceleration sensors to the actuator system. Vibration sensing has provided the control program with greater flexibility and improved capabilities of the drive based on the antagonistic involvement of pneumatic artificial muscles, to control the performance of the device during deceleration and acceleration. However, all this advantages are performed at the expense of the time required to handle the workpiece. In the future, it is necessary to minimize the measured values to the minimum necessary level, to optimize the calculation time required to execute one iteration of the control program, to analyze the time requirements for transmitting signals within the mechatronic system using current hardware, and possibly replacing the components with their faster alternatives. At the same time, after modifying the system, the module for control of the carrier arm position can be replaced, for instance with algorithms for Fuzzy logic control.

Acknowledgement
„This paper is supported by the VUKONZE - Research Centrum for Combined and Renewable Resources of Energy ITMS code: 26220220064“.

References

[1] TONDU, B.: Modelling of the Mckibben Artificial Muscle: A review, *Journal of Intelligent Material Systems and Structures*, SAGE, Vol. 23, No. 3, p. 225-253, 2012.
[2] DEARDEN, F., LEFEBER, D.: Pneumatic artificial muscles: Actuators for robotics and automation, *European Journal of Mechanical and Environmental Engineering*, p. 11-21, 2002.
[3] KLUTE, G. K., HANNAFORD, B.: Accounting for Elastic Energy Storage in McKibben Artificial Muscle Actuators, *Journal of Dynamic Systems, Measurement and Control*, Vol. 122, No. 2, p. 386-388, 2000.
[4] KUNA, Š.: *Research methods for real time monitoring and diagnostics of production machines*, Dissertation Thesis, TUKE, Prešov, 2015.
[5] LAPLANTE, A.P., OVASKA, J.S.: *Real-Time Systems Design and Analysis*, 4 ed., John Wiley & Sons Ltd, USA, p. 560, 2012.
[6] KUO, S. M., et al.: *Real-Time Digital Signal Processing: Implementations and Applications*, 2 ed. England: John Wiley & Sons Ltd, p. 646, 2006.
[7] ŠMERINGAI, P.: *Výskum metód online monitorovania výrobných zariadení s umelými svalmi*, Dissertation Thesis, TUKE, Prešov, 2016. (Original in Slovak)

Review process
Single-blind peer reviewed process by two reviewers.

Copyright © Acta Tecnología, www.actatecnologia.eu