# Abstracts

## Group 6: Pneumatic Applications

### 6-0 Pneumatics- Future through mechatronic Integration and Efficiency

F. Schnur, M. Fiedler

This paper shows a survey of market requirements, research and development activities of pneumatic components and systems, independently from suppliers.
The market stream, driven by legal and society requirements for saving resources, moves to overall energetic consideration of fluidic and electric drives or handling systems.
Besides savings in electric power supplies of components as well as savings of compressed air by lowering the pressure level, reduction of compressed air leakages, recuperation of exhaust air and compression losses, this paper summarises the benefits of higher integration designs by minimising the amount of parts, size, weight, and costs.
Densification of functionalities in subsystems allows online condition monitoring and remote control.
Using well improved software tools for system calculations, pneumatic drives and components can be used with tremendous saving potential of compressed air. Over engineered layouts will be replaced by miniaturisation and design according to required function. Miniaturisation, light weight design and smart combination of modern production technologies enable further reduction of moving masses and electric power supply e.g. of industrial robots.
A rich variety of benefits and improved functionality will justify the future of pneumatics.

### 6-1 Development of a New 5 mm Solenoid Valve with a Rocker Type Armature

P. Tappe, J. Weiß

For solenoid valves with an overall width less than 10 mm also rotationally acting functional principles become more significant as a supplement to translatory armature movements. Already at the beginning of the 90s Magnet-Schultz has developed a 5 mm solenoid valve on the basis of a rocker armature (rotationally acting). The present patented design represents a consequently continued development with the following targets: Performance-oriented magnetic circuit with double coil, reduction of the swelling behavior of the sealing nipples, sealed overmoulding of the magnetic coil, integration of manual override and media separation.

### 6-2 Highly Integrated Rotational Drives for Servopneumatic Applications

O. Reinertz, H. Murrenhoff

This paper summarises the development of pneumatic rotational drives under aspects of miniaturisation and sensor integration. At this, an ample miniaturisation can only be achieved by significantly minimising leakage and friction while these often are contradictory optimisation goals, requiring a methodical development of novel actuator principles. Furthermore the integration of customised sensor and gear modules is necessary to meet the miniaturisation requirements. After a simulative optimisation of several novel drive concepts, the best suited concept and a test rig for its characterisation are built up. The paper closes with a discussion of the obtained measurement results and an outlook on ongoing research activities on the described subject.

### 6-3 Adaptive Gripper Jaws for High-Value Crops Harvesting

W. Gauchel, S. Saller

Grippers for agricultural application must be able to adapt to different sizes and different geometries of the fruit. The following paper describes two possibilities to realize adaptive gripper jaws. One of the grippers is used for apple harvesting, the other for sweet pepper handling. Further on the paper explains options to detect if such an adaptive gripper has gripped a fruit or not. Especially the integration of a force sensor into a FinRay finger produced with rapid prototyping technologies is presented.

## 6-4 Alternative Operating Concepts for Decentralised Automation of Pneumatically-Controlled Hygienic Process Valves

R. Bachmann, U. Brinkmann, K. Große

This paper presents two concepts for local operation and display that can be used for pneumatically-controlled hygienic process valves. The first concept is based on coded magnetic fields applicable for a simple manual override or for a wireless magnetic keyboard. Using this purely mechanical keyboard, a control device can be operated in the field in a convenient, cost-effective and safe way without needing to be opened. The other concept for application-specific integration of indicators and displays into housings makes use of an innovative internal selective metallic coating technology for plastics in combination with laser technology. The most stringent hygiene and environmental requirements are fulfilled at reasonable costs.
Both concepts have been successfully implemented in a new control head and have proven to be very effective for this kind of application.

## 6-5 Exergy Flow Diagrams as Novel Approach to Discuss the Efficiency of Compressed Air Systems

S. V. Krichel, O. Sawodny, S. Hülsmann, S. Hirzel, R. Elsland

Compressed air systems are among the major consumers of electrical energy in industry. As the importance of energy-efficiency grows in general, so does the need for valid and reliable metrics for discussing efficiency. Today, energy flow diagrams are a common tool to illustrate energy efficiency in compressed air systems. They are however subject to various shortcomings which are mainly related to their lack of transparency and reproducibility. Therefore, a novel approach for the assessment of efficiency is presented which is based on the exergy concept. This approach allows for a transparent calculation of flow diagrams for compressed air systems, including the possibility to illustrate the effects of a heat recovery system. The concept is illustrated at the example of an industrial set-up starting at the compressor inlet and ending at the application. The resulting diagram allows a more transparent and objective view on efficiency evaluations and thus contributes to a better understanding of energy-efficiency in compressed air systems and related applications.

## 6-6 Improving Energy Efficiency of Pneumatic Handling Systems

J. Hepke, J. Weber

This paper proposes an approach for the investigation and further development of the energy efficiency of pneumatic handling systems. A new aspect in this paper is that the analysis is not only based on the compressed air consumption of pneumatic systems but rather on the balancing of energies. This strategy enables the continuous balancing of all fractions of energy and energy losses. Thereby the foundations to detect and address energy saving potentials can be laid.
In this article the energy distribution within a typical standard pneumatic handling system is analysed based on an experimental and simulation-based method. The results are used for the identification of energy saving potentials. With regards to these potentials adequate energy saving measures can be selected. In the first instance these measures are tested via simulation. Then they are validated by implementing them at selected pneumatic drives of the handling system. The experimental results of the energy consumption comparison of the handling system before and after the modification, show energy savings of more than 20 %.

## 6-7 Energy Efficient Adaptive Control of Pneumatic Drives with Switching Valves

M. Doll, O. Sawodny, R. Neumann

With an increasing interest in energy efficiency in automation processes, pneumatic drive applications are often compared to their complementary technology of electrical drives. Motion tasks performed by pneumatic cylinders are said to be energy inefficient due to the operational mode of throttling the exhaust air at the outlet of the cylinder. A novel, model-based operational strategy is presented in order to improve the energy efficiency of the overall pneumatic drive application. The advantage of huge air savings for the optimized system is accompanied by a reduction of the system's stiffness and robustness. A thorough system analysis shows high sensitivities towards parameter uncertainties and the operational strategy itself. To overcome these drawbacks, an adaptive open-loop control strategy is proposed, which adjusts the dynamic model to the real system dynamics. Thus, maximum robustness of the system is satisfied. The result is a stable pneumatic drive system with air savings from 50% to 80% in comparison to the standard pneumatic systems.

## 6-8 Air Bearings for Heavy-Duty Industrial Applications - Effect of Bearing Type and Operating Conditions on Energy Efficienc

O. Calonius, P. Kiviluoma, P. Kuosmanen

In the process industry, air bearing technology could provide a competitive alternative to the oil lubricated sliding bearing technology which has high power consumption due to the high viscosity of oil. Typically, air bearings are used in applications where frictionless and precise motion is needed. There are also air-cushion bearings for moving heavy loads in along the fairly rough factory floor in the production of, e.g., trains and large diesel engines. The purpose of this study is to explore the possibility for using air-cushion bearings in industrial machinery in cases with moderate counter-surface quality, fairly large tolerances and dynamic loading. The operating characteristics of an air-cushion type of bearing are put in contrast with those of an air bearing of the porous material type. It was found that the latter type is a good choice for machinery where adequate sliding surface quality can be achieved. High stiffness and fairly low air consumption was found. The air-cushion bearing lacks stiffness but it could function in machinery as additional load carrying unit. Good energy efficiency appears to be possible in the low-leakage mode of operation that was found. However, further testing is needed to determine if the low leakage is associated with contact between the air-cushion membrane and the counter surface.

## 6-9 Improvement in Dynamic Properties of a Pilot-Operated Gas Pressure Control Valve

V. Sverbilov, G. Makaryants, M. Makaryants, et al.

In this paper, dynamics of a pilot-operated gas pressure control valve are studied through measurement and mathematical modeling for the purpose of obtaining high accuracy and stability over a wide range of flow rate. The pilot stage helps to increase accuracy. However, fluid-born noise and vibration often occur in such type of valves and pressure controllers running at supersonic pressure drop and high flow rate value. These phenomena are caused by instability of balance of the valve in a flow, instability of damping and friction forces. In the paper, the analytical and experimental research is carried out to reveal the most essential factors influencing stability and dynamic properties of the valve. The nonlinear and simplified linear models based on the perturbation technique are developed to predict the stability domain in the space of structural and operational parameters. The stability criterion for the system is deduced using D-decomposing method. CFD software is employed to study the effect of the poppet geometry on aerodynamic lifting force. Simulation is carried out with MatLab/Simulink, considering factors that influence on the dynamic properties of the valve such as lifting force, nonlinear friction and pilot dynamics. The analysis and simulations show general agreement with experimental data. Effective means for obtaining stable operation of the system are proposed.

## 6-10 Reducing the Limit Cycle Oscillation of a Full-Digital Pneumatic Motor Speed Control System

J.-C. Renn

In this paper, an improved full-digital closed-loop pneumatic motor speed control system with reduced limit cycle oscillation is developed and realized. A significant feature of the proposed structure is the combination of the proportional technology as well as the full-digital control scheme. The utilized proportional full-digital control valve (FDCV) consists of four parallel-connected 2/2 pneumatic on-off valves with multiple flow-rate outputs. Compared to the PWM flow control scheme using four fast-switching 2/2 on-off valves, the proposed FDCV possesses several advantages like medium operating noise, long life, ease of control and low cost. The simple but effective binary coding system is chosen for this study. The major fault of the conventional FDCV, however, is its nonlinear saw-toothed flow-rate characteristic which generally results in the undesirable limit-cycle oscillation in the steady-state response. Therefore, a novel technique to reduce the amplitude of limit-cycle oscillation is developed in this paper. The basic idea is to reduce the opening areas of four on-off valves in the FDCV simultaneously by applying lower current inputs to the valve coils in the steady-state. Consequently, the limit cycle oscillation of the pneumatic motor speed control can be successfully reduced without any hardware modification. Finally, experiment results prove that the amplitude of the steady-state limit cycle oscillation is significantly reduced by using the proposed two-step current switching controller. Therefore, the FDCV together with the proposed novel current switching control strategy is a potential alternative of precise closed-loop pneumatic motor speed control.