Study of Technological Process Realised by Pneumatic High–Speed Machine Drive with Built–in Chamber

Pneumatic drive systems are used both in building new machines and in modernisation of already existing ones. Currently manufactured typical pneumatic actuators with disk piston can provide piston velocities of a range 0.5÷1.5 m/s whereas actuators without a piston rod 2.5 m/s. Increase of this velocity causes not only an increase of the devices' efficiency but also makes possible high kinetic energy processes realisation (for example products marking) as well as high–speeds of executing elements (for instance plastics cutting). One of broadly used methods of increasing the actuator's piston movement speed is to build–in a chamber between a feeding installation and a working–chamber of this actuator. Two agents: a compressed air in the container and an appropriate construction of the actuator enable obtaining velocities of 12 m/s or more. These actuators are called Pneumatic High–Speed Machine Drives with a built–in chamber (PHSMD), and in the Division of Control Systems we conduct research for many years.
Their advantages count among:

- simple construction of drive that utilises the same elements as typical actuators,
- low weight in relation to developed powers, for example small presses manufactured with the use of PHSMD (100 mm in diameter, 300 mm long, fed with air under pressure of 0.5 MPa) can substitute hydraulic presses of 3.5 T tonnage, weighing at the same time at least 20 times less,
- low production costs in relation to hydraulic presses of comparable parameters; existing compressed air installations can be utilised for PHSMD feeding, high–speeds can be achieved with normal 0.6 MPa feed pressure,
- simple setting methods of working organ velocity and energies attained,
- the use of standard actuator control elements.

Their disadvantages are:

- relatively long time of a preparatory period, occasionally it happens to be several times longer than a working period,
- difficulties with a piston braking during reverse movement.

For over 20 years different approaches to PHSMD industrial application are being checked. Serial production drives found its application in the construction of small high–speed presses, goods marking devices, etc. Despite considerable development of pneumatics applications in machine building these actuators are not broadly put into use. It is caused by insufficient research state in the field of:

- technological processes and stocks where utilisation of machining high–speeds will bring economic benefits or will rise product quality,
- technological requirements of high–speed machining for instance minimal and maximal (not mentioning optimal) cutting speeds, despite of acknowledged benefits of this kind of processing,
- profitableness of hydraulic presses exchange for PHSMD ones (for example tools making costs, production magnitude, etc.) both in large and small plants.

The use of complex and expensive drives in the research on high–speed machining seems to be the fundamental cause to this state. Present state of technology knowledge precludes rational selection and design of PHSMDs.

PHSMD properties predestinate them for being utilised in many fields like in high–speed plastic working, goods marking, riveting, drawing, cutting, striking (coins, medals, buttons), in–dimension cutting and piercing (holes in electronic boards, glass panels and bones), blanking, moulding sand dynamic tamping, etc. From the plasticity theory it is known, that increase of plastic deformation velocity causes increase of material yield stress. This property can be used for forming the surface layer with increased compressive stress what increases exploitation properties. One of the main reasons constraining PHSMD applications was the lack of simple calculation methods such as of typical actuators and the lack of selection algorithms for specific technological applications. Research carried out in our Division brought us to:

1. a simple PHSMD mathematical model with accuracy sufficient for design requirements; based on this model a simple methodology of PHSMD selection depending from the actuator's tasks has been introduced,
2. a computer programme for PHSMD calculation according to proposed methodology,

3. a computer programme for PHSMD calculation, simulation and optimisation,
4. PHSMD experimental research stand.

Significant limitations in PHSMD use are:

- the lack of principles of process parameters specification taking in account product quality and energy required,
- the lack of principles of tools design that could cooperate with PHSMDs,
- the lack of methods of technical and economic profitableness estimation of high–speed drives.

Utilising our research achievements it is possible to perform:

- PHSMD calculations and selection ensuring desired performance,
- analysis and research (simulational and experimental) of PHSMD applications in chosen technological operations that desire high kinetic energy and high–speed of working organs,
- research on influence of plastic deformation velocity of material on stress in the product's surface layer,
- research on influence of velocity, geometric shape, tool accuracy and blanking process conditions (clearance magnitude between die block and punch, process realisation with and without the die) on technological quality of the product that is shape–dimension accuracy, surface state and surface layer zones state,
- definition of influence of chosen construction parameters and work conditions on PHSMD work effect,
- structural strength analysis,
- construction optimisation in respect to technological performance and energy consumption.

It will allow to:

- construct and make a pneumatic stroke press,
- work out PHSMD series of types assumptions,
- work out the methodology of PHSMD calculation and selection for specific technological processes,
- work out PHSMD construction optimisation method.

Research aims:

1. definition of technological operations which desire high kinetic energy and high–speed of working organs,
2. definition of influence of plastic deformation velocity of material on strain and stress in the product's surface layer,
3. definition of influence of velocity, geometric shape, tool accuracy and blanking process conditions (clearance magnitude between die block and punch, process realisation with and without the die) on technological quality of the product (shape–dimension accuracy, surface state and surface layer zones state) and tools durability,
4. construction strength analysis and strength calculation method both for PHSMD and tools utilised in technological processes,
5. PHSMD construction optimisation in respect to technological performance and energy consumption.

Useful effects:

1. construction design and making a pneumatic stroke press,
2. working out PHSMD series of types assumptions,
3. working out the methodology of PHSMD calculation and selection for specific technological processes,
4. working out PHSMD construction optimisation method,
5. working out the methods of economic profitability of PHSMD utilisation.

Selected publications:

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2. Tarnowski W., Kiczkowiak T.: *Computer Simulation as an Optimisation Tool of Objects with Nonlinear Processes.* International Conference on Engineering Design ICED 97 Tampere 1997r. tom 3 pp. 295–298.
3. Kiczkowiak T., Tarnowski W.: *Optimisation of a High Speed Pneumatic Drive on Simplified Mathematical Models.* II Polsko–Niemieckie Seminarium "Inowacje i postep w hydraulice i pneumatyce". Warszawa 1997r. pp. 116–135.
4. Kiczkowiak T., Tarnowski W.: *Multi–stages Optimisation of a High Speed Pneumatic Cylinder Drive with an In–built Chamber.* 1. Internationales Fluidtechnisches Kolloquium in Aachen. Aachen 1998r. Band 2 pp. 379–391.
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6. Mikulczynski T., Kiczkowiak T.: a *High–Speed Pneumatic Drive Utilisation in Moulding Sand Dynamic Tamping.* Przeglad Odlewnictwa (Founding Overview), tom 49, No. 4, 1999, pp. 141–143, (in polish).

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