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Analiza właściwości dynamicznych układów pneumatycznych za pomocą rachunku różniczkowego niecałkowitych rzędów

ABSTRACT

Rapid development of technology which occurred at the turn of the 19th and 20th century has enforced development of new models describing reality, especially the technical objects working in extreme conditions or characterized by extreme parameters (a super-capacitor, a transmission line of infinite length, etc.). To describe such objects the classical calculus is insufficient. To make mathematical models which describe dynamics of the phenomena occurring in objects of extreme parameters, it is indispensable to use the differential and integral calculus of non-integer order (fractional calculus). This statement was an inspiration for carrying out research into the use of fractional calculus for describing technical objects working in extreme conditions or characterized by extreme parameters.

This doctoral dissertation presents a method of describing a pneumatic system working in extreme conditions by means of fractional calculus and with the use of the Reimann-Liouville definition of non-integer ordered derivatives. The dissertation shows the methods of determining mathematical models. What is more, the objects where the characteristic equation has real and complex roots are examined.

The aim of the dissertation is to develop a generalized description method of pneumatic system properties, the said method being based on fractional calculus.

The above mentioned objective leads to putting forward the following **research hypothesis of the doctoral dissertation**:

The fractional calculus-based method of describing dynamic properties of pneumatic systems enables analysis of properties of a wide spectrum of pneumatic systems of integer and non-integer order.

The doctoral thesis consists of 7 chapters.

Chapter One describes the history of fractional calculus and its application in different areas of science. It points to the fact that this mathematical tool has not been used for pneumatic system analysis.

Chapter Two introduces the aim and research hypothesis of the dissertation. The assumptions are formulated and organization of the doctoral dissertation is outlined.

Chapter Three describes fractional calculus. The Gamma function, Psi function and the Mittag-Leffler function are introduced. The Riemann – Liouville, Caputo and Grünwald – Letnikov fractional derivatives are defined. A transfer function and spectral transmittance of non-integer order are described.

Chapter Four focuses on the basic members of automatics: first- and second-order inertial member, integrating and differentiating, ideal and real, described by means of fractional calculus. Each member is described with the use of a differential equation of non-integer order, transfer function and spectral transmittance, step and impulse responses of non-integer order, the Nyquist plot and Bode plot.

Chapter Five describes dynamics of pneumatic systems with the use of classical differential calculus and fractional calculus. Mathematical models of a diaphragm pressure transducer, pneumatic actuator and two-chamber pneumatic cascade are presented.

Chapter Six deals with laboratory tests of a pneumatic transducer. Measurements have been taken and a real pneumatic system is analyzed and compared with a mathematical model. The analysis uses fractional calculus and is carried out with respect to time and frequency.

Final conclusions and directions of further work are included in Chapter 7. The Chapter states that the objectives of the research have been achieved and the research hypothesis of the doctoral dissertation has been confirmed.

The author is going to continue his research into the application of fractional calculus for objects of highly dynamic behaviour or extreme parameters. Further work can prove that there are or perhaps there will be in the future some applications which will have to be described by fractional calculus. In this aspect the method shown in the doctoral dissertation can find practical application for construction of prototypes of devices and systems (not necessarily pneumatic ones) characterized by high dynamics, the modelling of which with the use of differential equations of integer order may turn out insufficient.