Booklet of Abstracts

"1st International Conference on Mathematical Modelling in Mechanics and Engineering"

Mathematical Institute of the Serbian Academy of Sciences and Arts
Belgrade, 08.-10. September 2022.

Editors: Ivana Atanasovska, Milan Cajić, Danilo Karličić

Organized by:

Mathematical Institute of the Serbian Academy of Sciences and Arts

Faculty of Mechanical Engineering, University of Belgrade

Faculty of Mechanical and Civil Engineering in Kraljevo, University of Kragujevac

Institute for Information Technologies, University of Kragujevac

Supported by:

Ministry of Education, Science and Technological Development of the Republic of Serbia

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SHIMADZU, Serbia

Belgrade, 2022

CAM PROFILE OPTIMIZATION FOR MINIMAL JERK

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Keywords: Cam Profile Optimization, Marine Predators Algorithm, Snake Optimizer

ABSTRACT

Cam-follower systems are widespread in today's society as one of the most robust systems used in various mechanisms, and sometimes can even replace other elements such as springs or reduce the total number of parts in some system. A cam-follower system consists of a camshaft and a follower where the profile shape of the camshaft, rotating at a constant angular velocity, defines the law of movement of the follower. One of the most common applications of the cam-follower system is found in the internal combustion engine design where the shape of the camshaft determines a sequence in which appropriate valves on the cylinders open. The angular velocity of the camshafts in those applications are high, in order of magnitude of couple of thousands revolutions per second. A properly designed profile of the cam can have significant impact on the systems' performance.

The cam-follower system has a program that distinguishes two main stages: rise and dwell, and the program can consist of multiple rise and dwell sections. During the dwell section, the follower is not changing its position, and it is usually represented as a flat line in the unwrapped cam-follower program. Rise represents the change of altitude of the follower, meaning that during that phase, the follower is being displaced, and it can be modelled with smooth curves. The curve that is used for the rise should be continuous, and at least three times differentiable. The first three derivatives represent velocity, acceleration, and jerk, which are all important factors for the systems performance. The curve is usually modelled with polynomials of at least fifth degree (3-4-5), harmonic curves such as cycloid, Fourier functions etc. The use of computer techniques, numerical, metaheuristic optimization methods, such as MPA algorithm and Snake Optimizer, allows calculating the constants that make up the equations that describe the curves in higher degree than it was possible with analytic tools due to lack of boundary conditions, for different purposes.

Marine Predator Algorithm (MPA) and Snake Optimizer were used in order to determine the optimal curve of the cam profile during the rise stage of the cam-follower program for which the jerk has minimal absolute value, as well as the degree of polynomial after which these methods become unstable, or the gain of considering higher polynomials of higher degree becomes insignificant. Compared to the 3-4-5, using the polynomial of 8^{th} degree instead of 5^{th}, with the use of Snake Optimizer or Marine Predator Algorithm, considering that both give similar results, the jerk is decreased by 12,8%, and compared to the cycloidal motion the jerk is decreased by 0,27%. Increasing the degree of the polynomial up to 16^{th} degree, the jerk can be decreased by an additional 3% using the MPA compared to the 3-4-5 method and 1,7% compared to the cycloidal motion, with the same optimizer settings. When polynomial has a degree higher than 16^{th}, if the maximum number of iterations is 1000 and the size of initial population is 30, the optimizer doesn't give any useful improvement and becomes unstable. By increasing the maximum number of iterations and the population size with the rise of degrees of the polynomials, the MPA gives more stable results even after 16^{th} degree of the polynomial.

Considering that there is a 12,8% improvement through increasing the degree of the polynomial from 5th to 8th, and only a 3% improvement from 8th to 16th degree of the polynomial, increasing the polynomial degree beyond 16 results only in an increase of computational time and adds to the instability of optimization process.

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