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3K Mechanical Paradox transmissions: The shaping of the meshing zone for better efficiency

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In the paper, a new method (Hori and Hayashi) for the design of tooth addendum in a Mechanical Paradox 3K transmission gear was presented. A meshing scheme obtained in agreement with this method and actual meshing schemes after inclusion of generation and engagement limitations were presented. The results of calculations using a different approach proposed by the author to the problem of access/recess contact ratio equalisation were also included.

Keywords: *3K gear transmissions, efficiency, equalization, contact ratio*

1. Introduction

"Make four wheels, one wheel as thick as the other three. Cut teeth in all wheels. Set the thick wheels in line. Set the thick wheel so its teeth take into the three ones. Turn the thick wheel: One of the three wheels rotates in one way, the second in the other way and the third does not rotate at all" [1].

This procedure was first proposed at the end of the 17th century by James Ferguson, an English clockmaker, who used it for the construction of an orrery (Figure 1). His name was given to all transmission based upon this concept and become part of the engineering heritage.

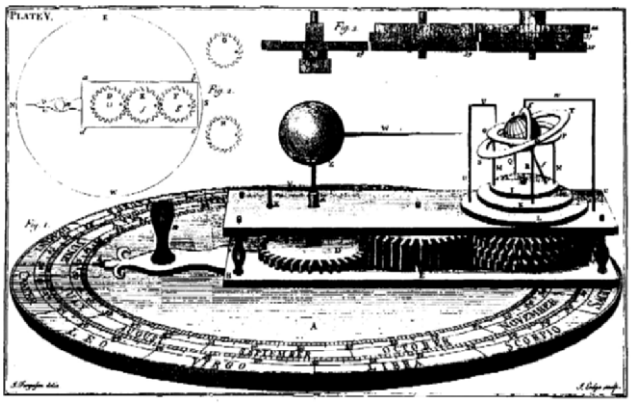

Fig. 1. Ferguson's orrery, 1773 [1]

The meshing scheme proposed by Ferguson (Figure 2a) had been employed for the modification of a traditional 3K transmission (a Wolfrom's transmission, Figure 2b). It consisted in the replacement of the two (different in size) planet gears by one uniform planet gear with the same number of teeth along its width (Figure 2c). This made it possible to avoid problems with the proper angular alignment of the planet gears, which are present in traditional gear sets of this type.

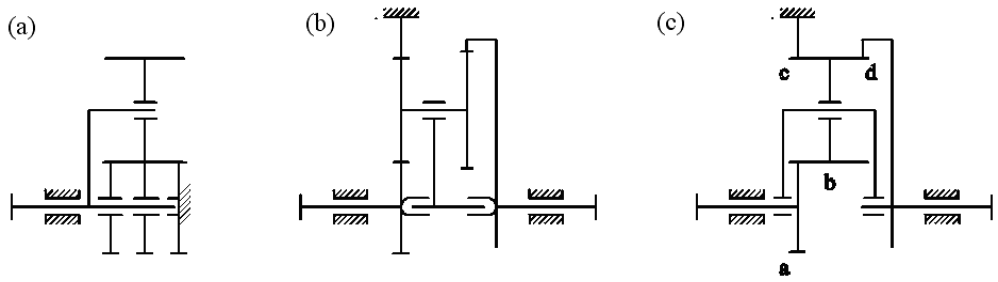

Fig. 2. Schemes of the Ferguson's (a), conventional 3K (b), and 3K Paradox (c) gear trains

First research projects dealing with this transmission had been carried out by Jastrebov [2], [3]. He gave a brief description of advantages and disadvantages of these transmissions together with the results of testing. The tested units featured nearly constant efficiency, equal to approx. 78%, in a wide range of transmission ratios. Based upon the results obtained by Jastrebov, Hori and Kurita [4] proposed a modification in the design of the whole gear train that aimed at its higher efficiency. The ultimate objective was to employ the transmission in the main arm of a space robot. The modification consisted in the equalization of the approach and recess contact ratios in the meshing of the common planet gear with the two internally toothed gears. The modified transmission was manufactured and tested. The results confirmed a roughly 10% increase in efficiency when compared to the efficiency of traditional gear sets. Hori and Hayashi [5] analysed in detail the proposed approach and offered a new method that supposedly guarantees the maximum equalisation of the approach and recess contact ratios over a wide range of overlap ratios.

As the proposed modifications result in non-standard tooth proportions and the authors, when questioned in a direct e-mail contact, gave only vague remarks concerning the generation process, the author analysed in detail these problems in conference papers [6]. A new area of application or 3K transmissions is micro-robotics. Suzumori et all [7] used this type of transmission to drive the feed of a robot operating in a pipe, one inch in diameter.

The objective of this paper is a short presentation of the method proposed by Hori, Kurita, and Hayashi, its verification in view of all constraints present during the generation and meshing processes and a proposal for further steps aiming at the best equalization of the approach and recess contact ratios.