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The effect on dynamics of using a new transmission design for eccentric speed reducers

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A R T I C L E I N F O

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A B S T R A C T

This paper proposes a new transmission design for eccentric speed reducers that differs from that used with a traditional cycloid speed reducer. The main difference, other than the input and output shafts, is that it uses the internal gear as its fixed part and transmission between the external gear and output shaft occurs via pins connected to a drive plate. In this paper, gearing theory is used to construct a mathematical model of the involute external and internal gears, based on which the trajectory equations, component geometry, and reducer kinematics can be derived. A dynamics analysis model is also constructed and used to test the feasibility of two types of drive plate designs — a cross piece and a round disc, each with a single-gear and double-gear design. The stress results show the infeasibility of the cross drive plate versus the feasibility of the round disc drive plate. An additional kinematic analysis provides evidence that the design of the gear tooth profile also affects the machine transmission and can lead to vibration and stress fluctuation.

1. Introduction

The cycloidal drive shown in Fig. 1, which mainly uses an eccentric shaft to drive the cycloidal gear in a planetary motion within the pinwheel, is a common component of the eccentric type of cycloidal speed reducers widely used in industry. During cycloidal gear operation, holes on the cycloidal gear drive the pin on the output shaft to reduce speed and eventually increase torque. In the research literature, numerous authors have advanced different aspects of cycloid drive design theory, including the influence of machining tolerances [1,2]; profile generation and analysis, avoidance of undercutting, and design region [3–11]; and calculation of the force distribution on cycloid drive elements, its power losses, and theoretical mechanical efficiency [12–14]. More recent work outlines the dynamic behavior of a cycloidal speed reducer [15] and performs a stress analysis on a proposed new design for a two-stage cycloidal speed reducer [16]. Models developed to aid such investigation include a model of meshing clearance in a trochoidal gear [17] and a method developed to predict efficiency based on a varied torque ratio, which is useful for identifying the benefits and disadvantages of different types of reducers [18,19].

When the load on the output end is heavy, however, the above type of transmission design may lead to huge stress fluctuation on the cycloidal gear and pinwheel, causing premature damage to its parts. Since the cost to produce a cycloidal gear and pinwheel are relatively high, this paper proposes a new type of transmission in which the stress variation is more evenly distributed. Not only will this new design lengthen the usage time for speed reducers, it will lower the usage cost. To identify the most feasible transmission design, this study also assesses how different speed reducer transmissions based on this design influence dynamics.

In general, this paper proposes a new transmission design that differs from that used in traditional cycloidal speed reducers. The main difference, other than the input and output shafts, lies in the different transmission modes for the interior mechanism.

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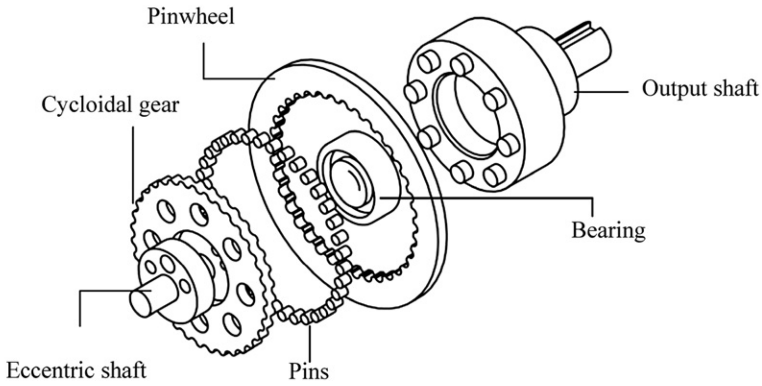

Fig. 1. A traditional cycloid speed reducer.

Whereas the cycloidal drive uses the pinwheel as its fixed part, the proposed transmission device uses the internal gear. Therefore, instead of the cycloid gear used in the cycloidal drive, in which the holes match output pins fixed on the output shaft, the new device transmits between the external gear and output shaft via pins connecting to drive plate. To identify the most feasible transmission design, the study tests two kinds of drive plates: a cross piece and a round disc, each with a single-gear and double gear design. For the cross piece drive plate, it first develops two types of external gear and cross piece sets, a single-gear cross piece design and a double-gear cross piece design whose involute gears have a two teeth number difference between the internal and external gears. The mathematical model of gears used to construct the reducer is derived from gear theory. The contact and collision conditions of the parts during transmission and the stress variation it causes are assessed using a system dynamic analysis model developed for this study. This stress analysis identifies any design problems with the cross drive plate. As a solution to the problems identified, two further designs are proposed for the round disc type of drive plate: a single-gear round disc and a double-gear round disc. Further analysis then identifies the transmission differences for the two designs.

2. Geometry design and analysis

2.1. Mathematical model of a gear

When an involute gear is generated by a rack, as Fig. 2(a) shows, the coordinate systems S_c, S_p, and S_f are rigidly attached to the rack, gear, and frame, respectively. The relation of the motion between the rack and gear can be represented as

$$s = rp_t\phi = \frac{r_b}{\cos\alpha_n}\phi \tag{1}$$

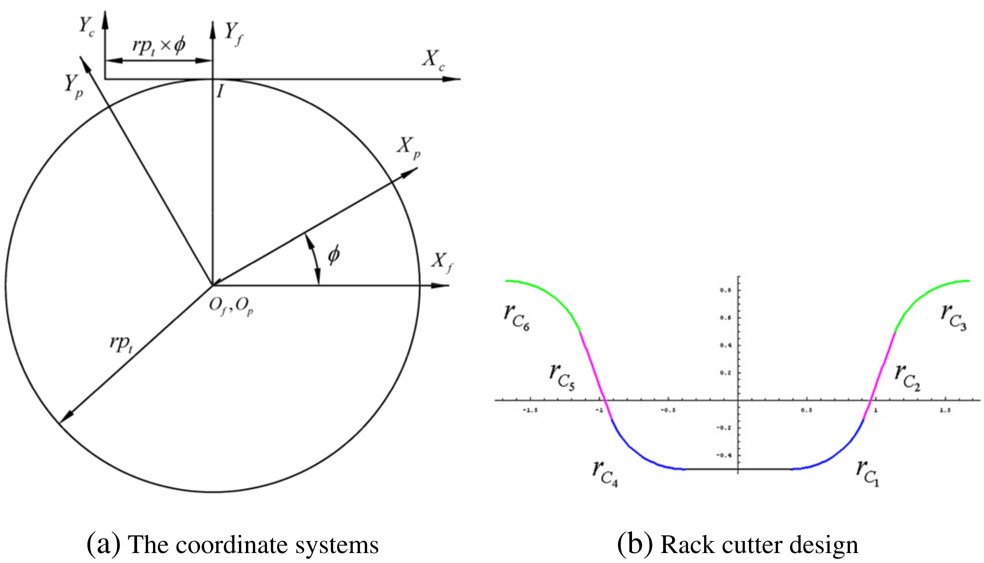

Fig. 2. The method of generating gear profile: (a) The coordinate systems; (b) Rack cutter design.