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Geometric interference in cylindrical worm gear drives using oversized hob to cut worm gears

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ABSTRACT

This study examined the geometric interference of cylindrical worm gear drives using an oversized hob to cut the worm gear. The instantaneous line contact of a fully conjugated gear set becomes an instantaneous point contact when an oversized hob is used. In this type of worm gear drive, however, an edge contact can occur between the worm and worm gear. The edge contact is caused by geometric interference, and it occurs regardless of the presence of elastic deformation, misalignment, and transmission error. Aspects of the interference are presented through graphical illustrations. For examining the interference based on the differential geometry, two methods are proposed. The first method is for determining the surface separation topology between the tooth surfaces of a worm and a worm gear for an entire meshing cycle, and the second method for determining the boundary of the initially occurring area of interference when the hob oversize changes from zero to a nonzero value. By using the presented methods, the influence of various design parameters, such as the lead angle of the worm, the oversize of the hob, and the normal pressure angle, on the interference are examined and discussed through numerical examples.

1. Introduction

Cylindrical worm gear drives with cylindrical worms and enveloping worm gears are widely used in industrial applications for speed reduction. Many studies have investigated the characteristics of the cylindrical worm gear drives and also the methods for improving their performance. In particular, owing to the complex geometry of the worm and worm gear surfaces, accurate simulation of their contact has been an important topic. Janninck [1] presented a method of estimating the initial contact pattern of the entire worm gear surface based on the contact surface topology. Octrue [2] proposed a calculation method for the load distribution of a worm gear set in an instantaneous line contact. A generalized tooth contact analysis (TCA) that can be used for various types of worm gear drives, was developed by Litvin and Kin [3]. Narayan et al. [4] studied the effect of machining parameters on the driving performance of worm gears. Fang and Tsay [5,6] examined changes in the bearing contact and contact path according to the oversize of hob and the shaft misalignment for ZK and ZN type worm gears. Seol and Litvin [7,8] proposed a method for modifying the geometry of the existing design of worm gear drives that provide a localized and stabilized bearing contact, reduced sensitivity to misalignments, and low transmission error with a favorable shape. An improved geometry for a longitudinally localized bearing contact with a negative transmission error function is proposed by Litvin et al. [9]. They also performed unloaded and loaded TCA with stress analysis. Simon [10,11] presented the load distribution and loaded TCA of cylindrical worm gears. To calculate the load distribution, the separations of the mating tooth surfaces are calculated along the potential

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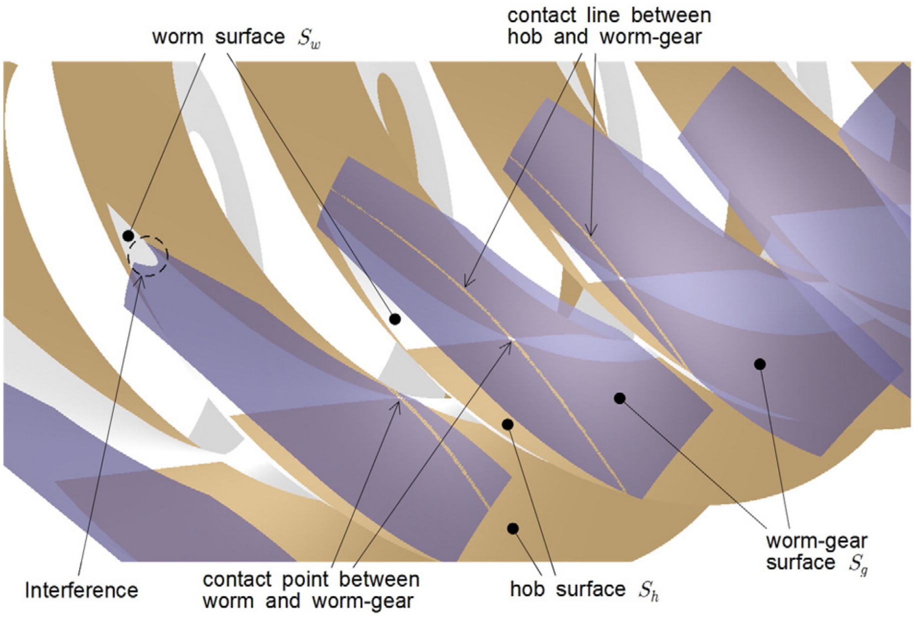

Fig. 1. 3D illustration of the geometric interference occurring between worm and worm gear tooth surfaces.

contact line instead of the instantaneous elliptical contact pattern. The effects of the tooth spacing error, misalignment, hob oversize, and machine tool settings on the loaded tooth contact were also studied by Simon [12,13].

As addressed in previous works [1–13], reasons for unacceptable contacts can be attributed to elastic deformation of the tooth, the misalignment of a gear set, error in the machine tool setting, and an unacceptable shape of the transmission error function. However, unacceptable contact may occur even without the abovementioned causes on cylindrical worm gears that are cut by an oversized hob. This type of unacceptable contact is caused by the geometric interference of the worm and worm gear tooth surfaces. Fig. 1 shows a 3D illustration of the geometric interference occurring between the tooth surfaces of a worm and a worm gear of involute worm gear drives. The surfaces are drawn using sets of points. The coordinates of the points are calculated using the mathematical expressions given in this paper. There is neither misalignment nor surface error included in this illustration. The surfaces that are in contact slightly overlap each other by rotating the surface about its axis of rotation to visualize the contact. The worm gear surfaces are set to be transparent. The generating surface of the oversized hob and the worm gear surfaces are a fully conjugated pair, which in turn makes a line contact. The worm and worm gear surfaces are in point contact

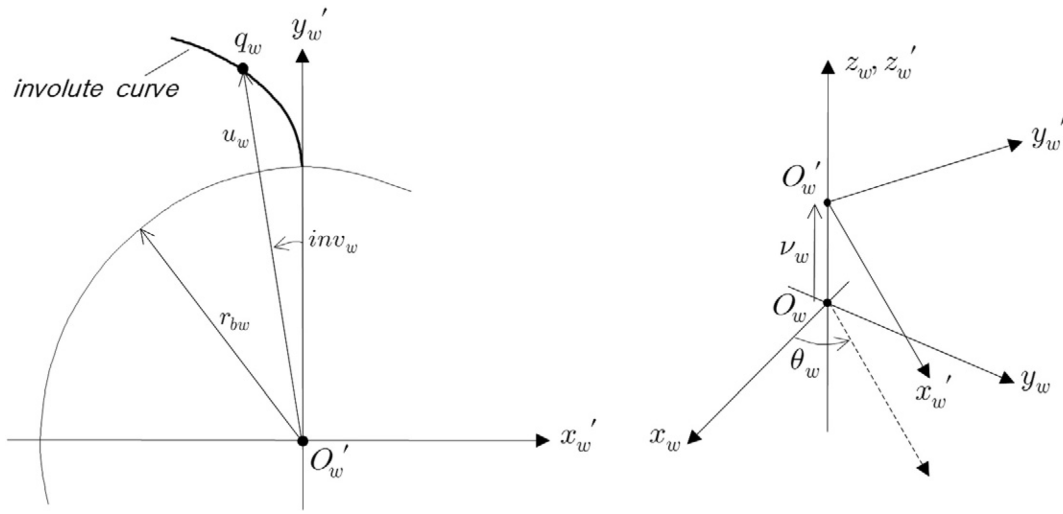

Fig. 2. Illustration of the involute worm surface S_{wI}.