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Research paper

Tooth contact analysis of crown gear coupling with misalignment

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ABSTRACT

In this paper, manufacturing methods are presented for crown gear coupling composed of a hub with longitude crowning and tip sphere teeth, and a sleeve with straight internal teeth. Complete geometrical mathematical models of tools are proposed, including the flank and tip fillet regions. The flank and root fillets of the hub and sleeve generated by the cutters are obtained based on the theories of differential geometry and gear mesh. An accurate method based on a tooth contact analysis technique is presented to determine the contact points (locations of the maximum interference or minimum clearance) and to analyze the crown gear coupling meshing with angular misalignment. In addition, the effects of misalignment angle and crowning depending on the displacement circle radius on the maximum interference, interference distribution and locations of the maximum interference in every angular position of the hub are discussed with an example. It is observed that the side edge contact of the hub tooth can be avoided by modifying the misalignment angle or displacement circle radius and that the location of the maximum value of the maximum interference during one rotation cycle of the hub tooth is around the pure tilted area.

1. Introduction

Crown gear couplings are mainly applied in mechanical drive systems to transfer rotary motion and torsion from one rotating component to another, for example, from a shaft to a gear or vice versa. The main advantage of crown gear couplings is their higher load carrying capacity that often represents better durability performance, than other forms of flexible couplings. Moreover, crown gear couplings allow for a certain amount of angular misalignment and relative sliding. Due to these advantages, crown gear couplings are widely used in aerospace [1], marine [2], wind energy [3], milling [4], railway [5] etc.

The most important components are the sleeve and the hub. The hub is an external gear that has longitude crowning and tip sphere teeth and the sleeve is an internal spur gear. The two components compose a special gear pair. The difference compared to other types of internal gear pairs is that the number of external gear teeth is the same as the number of internal gear teeth. When two axles are connected, the misalignment is unavoidable even when the axles are well installed. Particularly under the condition of a ship sailing at sea, deformation of the ship body, changes in the environment and the equipment's temperature, vibration and shock may worsen the initial alignment condition of the two axles. Fig. 1(a) shows an assembly of a crown gear coupling with angular misalignment.

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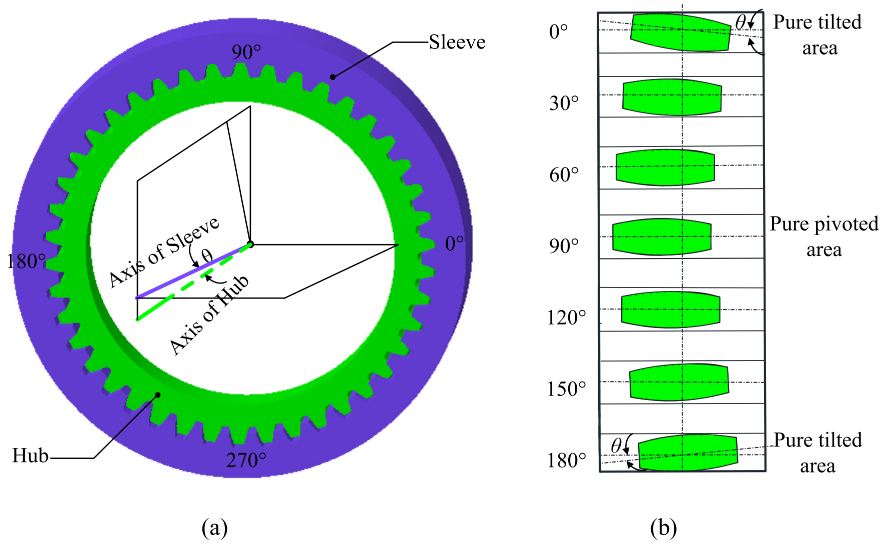

Fig. 1. Crown gear coupling: (a) assembly model with misalignment, and (b) motion diagram.

The motion of the crown gear coupling is complicated spatial motion. As shown in Fig. 1(b), the relative motion of the hub and the sleeve is divided into swing and turn motion in the state of misalignment. The crown gear coupling will experience pure turn movement, compound movement, pure swing movement, compound movement and pure turn movement in the half cycle of the meshing.

Great forces are transmitted through the crown gear coupling to the connected shafts and bearings, under extremely high misalignment. As the bearings wear incrementally over time and the misalignment increases, hub and sleeve root bending stress is increased and surface wear is exacerbated. Misalignment failures account for approximately 20% of the known crown gear coupling failures. Therefore, it is important to study tooth contact analysis under load distribution and estimate the wear when the crown gear coupling is working with misalignment. Several studies of crown gear couplings have been performed for loaded tooth contact analysis [6–11], wear [12]. Thus it can be seen that few studies can be found on the wear of crown gear couplings. However, the wear characteristic of spline couplings, one type of gear couplings, has been studied more [13–16]. From the literatures above, we can see that contact stress and relative slip have a significant effect on the wear of spline couplings. Tooth surface, contact positions and interference judgment, which are results from geometry design, are essential for analyzing the contact stress and relative slip of crown gear coupling. Therefore, it is important to perform tooth contact analysis (TCA) prior to any mechanical analysis of crown gear coupling.

As tooth surface, contact positions, and interference judgment are essential for analyzing the contact mechanics, friction and wear of crown gear coupling, several researchers have proposed different models for the calculation. Moked [17] and Renzo et al. [18] discussed the operation character of crown gear couplings under the condition of angular misalignment and described a simplified and approximate equation for the number of teeth in contact at certain angular misalignment. From the equation, they confirmed that the number of teeth in contact increased with the decrease in angular misalignment. Nakashima [19] derived the amount of minimum clearance at any rotated angle and obtained a path of contact on a tooth surface, which were used to calculate the number of teeth in contact and load distribution, assuming that the hub surface was formed by a positive continuous modification along the hub rotation axis. Then, using same geometric model as that proposed by Nakashima, Alfares [20] studied the influence of the gear modulus, pressure angle, crowning, and profile geometry on the minimum clearance distribution along the circumferential direction of each gear tooth under the condition of misalignment by dividing the hub surface into several nodes. The results showed that misalignment was the main factor determining the clearance distribution and that proper crowning could improve the clearance distribution. Based on the method for calculating the tooth clearance proposed by Alfares, Ohshima [21] calculated the tooth clearance of the gear coupling using the shape of the hub surface interpolated from many section profiles paralleling to the transverse section by means of parabolic approximation. Yi [22] derived the equation of the non-conjugate surface of crown gear with the crown curve of a circular arc, and calculated contact points by solving the equations of continuous tangency using an optimization method. Hakozaki [23] changed the curvature along the tooth width to modify the bearing area for angular misalignment. A larger bearing area and a smaller tooth gap, which were related to the gear tooth backlash-hit noise, were obtained by the method.

The above-mentioned researchers have made great contributions to the calculation of contact positions and clearances. However, there are still some issues left. First, no research has analyzed tooth contact analysis of crown gear couplings using the shape of the tooth surface actually generated by various types of tools. Second, the published studies mainly calculate the contact points and clearances or interferences by dividing the hub surface into several nodes, and the accuracy of this