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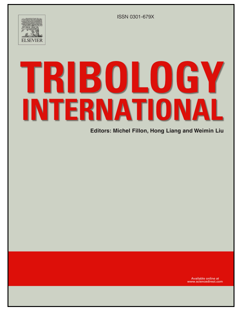

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Churning power losses of a gearbox with spiral bevel geared transmission

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Abstract: To predict the churning power losses in a gearbox with spiral bevel geared transmission, based on the Computational Fluid Dynamics (CFD) method, a numerical simulation model for the splash lubrication of the intermediate gearbox of a helicopter including gear box housing, a spiral bevel gear pair and an oil guide device is established and validated with the churning power losses prediction by previous researchers showing a good agreement. With the model, churning power losses of a gearbox with spiral bevel geared transmission are obtained; influences of gear rotational speed, oil fill level, oil temperature, oil dynamic viscosity, oil density, and tilt angle of the helicopter, on the churning power losses are analyzed.

Keywords: churning power losses; spiral bevel gear; splash lubrication; intermediate gearbox

1. Introduction

Efficiency of geared transmission is becoming a significant concern. Therefore, in the design phase, it is important to predict the power losses, which can be separated into two groups: load dependent power losses and load independent power losses. The load dependent losses are caused mainly due to friction by contacts of gears and bearings. The load independent power losses are mainly composed of the churning power losses and the windage losses. Churning power losses is one of main components of load independent power losses, especially at higher rotational speeds and higher oil fill level.

In recent decades, numerous studies have been conducted on power losses in gearboxes, mainly including influence of energy loss parameters and energy loss mechanisms. For instance, Boness [1] used smooth disks instead of gears to study the influence of disk diameter and oil fill level on the gear resistance moment through experiments, and the resistance moment empirical calculation formula of gear was drawn. Through experimental work, Höhn et al. [2] concluded that reducing the oil fill level of the gear can reduce the resistance moment and the churning power losses, but the temperature of the gear body will rise. Seetharaman et al. [3–4] assumed that the churning power losses were mainly composed of two parts. The first part was the loss caused by the rotation of gears to drive the oil; the second part was the loss caused by the constant suction and extrusion of oil at the contact zone between the engaging gears, and they established a physical model to predict the churning power losses of gears. Changenet et al. [5] analyzed several established formulas for churning power losses, and found that the effectiveness of formulas depended on the Reynolds number, and they concluded that the effect of tooth profile on churning power losses was relatively weak. BS ISO/TR 14179-1 and 14179-2 [6-7] present equations for the calculation of churning losses which are modified with considering influences of lubricant viscosity, geometrical parameters and the type of lubrication etc. Schaffner et al. [8] presented a rotational multi-body model to investigate power losses of automotive manual gearboxes and found that churning losses of gears increased with increasing input speed while decreased with increasing oil temperature. Laruelle et al. [9] used a specific test rig to conduct experiments on churning losses of spiral bevel gears with splash lubrication. They presented an equation which was extended from previous formulas to predict churning losses of spiral bevel gears as the experimental results were not in good agreement with the predictions from the published literature. Neurouth et al. [10] measured churning losses of a single spur or helical gear using a test rig in different operating conditions. They discussed

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