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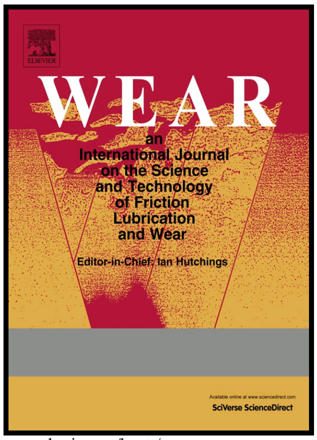

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Effect of Surface Texture on Wear Reduction of the Tilting Cylinder and the Valve Plate for a High-speed Electro-hydrostatic Actuator Pump

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Abstracts: High-speed axial piston pumps are the key components of electro-hydrostatic actuators (EHA). Pumps of this kind have been used in large civil aircraft like the Airbus A380. Preventing the tilting micro-motion of the rotating cylinder in an EHA pump is an important issue for reducing wear and prolonging their lifetime. Aiming to reduce the cylinder tilt behaviour, a laser surface texturing (LST) technique was applied to the steel valve plate, which is in contact with a brass cylinder. An experimental investigation was conducted on an EHA pump prototype running at 10,000 r/min and 28 MPa. The mechanical and volumetric efficiencies of the prototype equipped with the textured valve plate are improved by about 2.6% and 1.4%, respectively. Wear mechanisms of the tested components are analysed comprehensively to elucidate the cause for cylinder tilt behaviour and the functional mechanism of surface texture. The surface texture is found to increase efficiencies by reducing wear and the cylinder tilt angle. The cylinders are prone to tilt towards the high-pressure side, and the most severe wear of the valve plates does not occur on the contact regions near the cylinder outer edge on that side. Finally, implications for designing surface textures for the cylinder/valve plate interface are described.

Keywords: Electro-hydrostatic actuator pump; Laser surface texturing; Steel; Sliding wear; Efficiency.

1. Introduction

Electro-hydrostatic actuator (EHA) networks have replaced partial hydraulic circuits in more electric aircrafts (MEA) like the Airbus A380, due to their prominent advantages such as efficiency improvement, weight and space savings [1,2]. The hydraulic power supply of an EHA is a high-speed and small-sized pump, for example, an axial piston pump utilized in aircrafts in Fig. 1. The EHA pump is mainly composed of a splined shaft, a cylinder, a valve plate and nine piston-slipper assemblies. A compression spring in the cylinder centre bore pushes the cylinder towards the valve plate, and at the same time, the spring force is transferred to press the slippers towards the swash plate pad which has an inclining angle β_s. As the cylinder rotates with the shaft at the speed n_s, each piston moves back and forth inside the cylinder chamber, periodically suctioning oil on the low-pressure side and discharging oil on the high-pressure side through the valve plate ports. Meanwhile, tribological contacts form between the motional components, including the cylinder/valve plate, the slipper/swash plate pad and the piston/cylinder friction pairs. These friction pairs accomplish both the bearing and sealing functions, so the mechanical and volumetric losses of a pump are mainly attributed to the friction and gap flow of the lubricating gaps [3].

The cylinder/valve plate friction pair is not a simple ring-on-disk pair. Besides the macro-motion of rotating, the cylinder also has micro-motions in multiple degrees of freedom, due to the clearance within the spline drive and the shaft deflection [4]. The nonuniform pressure distribution caused by the high- and low-pressure ports, the inertial forces of piston-slipper assemblies caused by their high rotating speeds, and the side forces caused by the inclined swash plate, jointly generate a time-varying bias load, leading to the cylinder tilting micro-motion, as illustrated in Fig. 2. Consequently, the wear marks are usually not evenly distributed on the contact regions between the cylinder and the valve plate, namely the inner, middle and outer sealing lands, and the sector pad sliding area. The position where the piston locates farthest from the valve plate is the outer dead centre (ODC), and the position where the piston locates closest to the valve plate is the inner dead centre (IDC) [5], as shown in