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REDUCTION OF PISTON SKIRT FRICTION USING THE MICRO-SCALE PATTERNED SURFACE

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ABSTRACT–The purpose of this study is to determine whether piston friction can be reduced by applying a micro-pattern to the skirt portion of the piston, which accounts for the largest proportion of engine parts. The roughness of the ready-made pistons was reduced before etching the micro-scale pattern onto the piston skirt. The micro-patterns were screen-printed on the piston skirt, and kept uniform through etching. The friction reduction effect of the piston was confirmed through an engine experiment using a 1.6 L four-cylinder gasoline engine to remove parts. A hexagonal shape that is representative of bionic textures was selected for the micro-pattern, and circular and cross-hatch patterns were additionally produced for comparison. The friction experiments with the patterning pistons confirmed that friction was reduced by up to 6.74 % by adjusting the spacing of the hexagonal pattern. It was also confirmed that friction was reduced in the cross-hatch pattern by up to 5.28 %. The friction reduction effect may vary depending on the parameters used for a specific pattern.

KEY WORDS : Microscale patterning, Surface structure, Low friction, Engine friction, Piston skirt

1. INTRODUCTION

In the automotive industry, the development of high-efficiency engines is essential to meet stringent emissions regulations. The thermodynamic processes generated by combustion inside the engine are affected by thermal and mechanical energy losses. Of the energy consumed during the combustion process of the engine, exhaust heat loss accounts for about 26 %, cooling heat loss accounts for about 24 %, and mechanical loss due to friction accounts for about 17 % (Milojević *et al*., 2015). Considering that only about 30 % of the total energy is used for engine power, each form of energy loss is significant. For this reason, various studies have been conducted to improve these energy losses. Wakisaka *et al*. (2016) improved heat loss in diesel engines through the application of Thermo-Swing Wall Insulation Technology (TSWIN). Kundu *et al*. (2016) reviewed ways to improve heat loss by improving heat transfer modeling and applying it to the engine. Tormos *et al*. (2018) developed friction modeling to improve mechanical losses. Zhou *et al*. (2020b) reduced mechanical loss through a continuous variable valve lift with unthrottled load control. Since the fraction of energy loss caused by engine friction is large, this study focused on friction loss.

The friction losses in internal combustion engines are caused by many mechanical components, such as the piston assembly, crankshaft, valvetrain, and auxiliary devices (Hoshi, 1984). Among these various parts, the friction loss of the piston is about 20 to 30 %, accounting for the largest portion of the parts (Richardson, 2000). Piston friction is caused by the lubrication of the cylinder and the skirt on the side of the piston body during reciprocating motion. Zhang *et al*. (2017) analytically studied the change in piston friction loss with changing piston skirt profile. Increasing the area of the widest point on the surface of the piston skirt reduced the pressure acting on the piston, which slightly decreased friction loss in the combustion stroke. Joseph *et al*. (2018) conducted a friction experiment by designing asymmetric piston skirts and applying micro grooves to piston skirts. Zhou *et al*. (2020a) provided a theoretical basis for the analysis of the combustion chamber temperature field through the modeling of frictional heat in ring pack. As a result of the modifications, friction was reduced by about 6 % compared to the basic engine. Westerfield *et al*. (2016) measured piston friction after applying macro-scale patterns of various shapes to piston skirts. The row-patterned pistons had a slight friction reduction effect under low-load conditions, but high-load conditions and pistons with other patterns resulted in increased friction. The reason is that the features of the patterns reduced the flow resistance of the oil flow between the skirt and liner, thus reducing the hydrodynamic pressure, which in turn increased the direct solid-solid contact. Kim

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