AMMONIA-INDUCED TRIBOFILM INSTABILITY AND FRICTION-WEAR DECOUPLING IN PISTON RING CONTACTS

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KEYWORDS
Friction; Wear; Mixed Lubrication; Ammonia-dispersed engine oil

ABSTRACT
As the automotive sector advances toward decarbonisation, ammonia is gaining attention as a carbon-free fuel candidate. However, its influence on lubricant chemistry and tribological performance remains insufficiently understood. In particular, the interaction between ammonia, conventional engine oils, and metallic contact surfaces must be elucidated to assess its impact on friction and wear behavior. Unlike previous studies using laboratory-aged oils[1], the present work employs engine oil directly obtained from an ammonia-fueled engine after 20 hours of operation.

Tribological tests were conducted using SAE 10W-40 type fresh and ammonia-dispersed (NH_3) oils. The lubricant was supplied dropwise at 0.04 mL/min to a steel piston ring (Nippon Piston Ring) sliding against a cast iron liner (FC250) in a reciprocating tester (Heidon, Type 38) under a 30 mm stroke, 10 N load, 170°C liner surface temperature, sliding speeds of 100–3000 mm/min, and 170 m sliding distance at each speed.

Under these conditions, the NH_3-dispersed oil exhibited lower COF than the fresh oil, decreasing from 0.126 to 0.114 at 100 mm/min and from 0.134 to 0.127 at 3000 mm/min, while the fresh oil remained relatively stable across speeds. However, 3-D wear profile analysis (Fig. 1) revealed a significantly greater material removal under NH_3 lubrication, with an average wear volume increase of approximately 47% across the tested speeds, reaching 83% at the highest sliding speed.

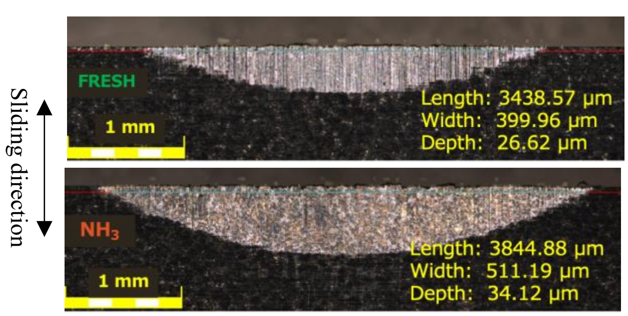

Fig.1 Piston ring wear under fresh and NH_3-dispersed oils

SEM observations (Fig. 2) reveal distinct differences between the two lubrication conditions. The fresh oil surface exhibits relatively uniform sliding grooves, whereas the NH_3-dispersed condition shows disrupted marks and localized patchy deposits, indicating formation of a chemically modified and spatially heterogeneous tribofilm.

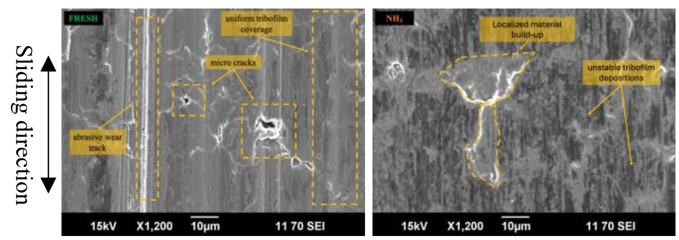

Fig.2 SEM images of piston ring wear scars under fresh (left) and NH_3-dispersed (right) oils

Table 1 Comparison of surface elemental composition (wt%) of piston ring wear tracks

Element	Fe	C	O	P	S	Ca	Zn	others
FRESH	76.4	6.2	9.3	1.3	0.15	0.24	1.36	5.1
NH_3	80.0	5.9	6.6	1.9	0.70	0.74	1.25	3.5
Change	4.7%	-4.8%	-29.0%	**46.2%**	**366.7%**	**208.3%**	-8.1%	

SEM-EDS analysis (Table 1) indicates substantial increase in S and Ca, indicating the formation of a heterogeneous tribofilm, likely made up of iron sulfides and calcium deposits. While the modified film lowers interfacial shear stress and reduces COF, SEM micrographs show that tribofilm under NH_3-lubrication is mechanically unstable[2]. Its discontinuous, patchy morphology suggests repeated rupture during sliding, consistent with a chemically assisted abrasive wear mechanism. These findings emphasize that tribofilm stability, rather than friction reduction alone, governs lubricant performance in NH_3-fueled engines.

REFERENCES
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