Wear damage evolution of a hot rolling work roll under frictional shear conditions associated with slip transition

Sunrui Tao[a,b*], Caiyi Liu[a,b*], Jinhang Wang[a], Ruilai Yang[a], Silvia Barella[b], Shuo Guo[a,b], Ruowei Li[a,b], Xin Zhang[a], Yan Peng[a], Andrea Gruttadauria[b], Marco Belfi[b], De Li[a,b,c*], Carlo Mapelli[b]

[a] National Engineering Research Center for Equipment and Technology of Cold Strip Rolling, Yanshan University, Qinhuangdao, 066004, China

[b] Department of Mechanical Engineering, Politecnico di Milano, Milano, 20156, Italy

[c] Department of Electrical Engineering, Qinhuangdao Polytechnic Institute, Qinhuangdao, 066004, China

During hot rolling, the relative sliding state between the strip and work roll changes across the neutral point, reversing the frictional shear direction. However, the wear response of high-speed steel (HSS) work rolls under alternating shear remains insufficiently understood. In this study, twin-disc rolling-sliding and reciprocating sliding tests were employed to investigate wear evolution under continuous unidirectional and periodically reversed shear, respectively [1,2]. Reciprocating sliding exhibited higher and more variable friction coefficients, accompanied by pronounced spallation, debris accumulation, ploughing, and a more discontinuous oxide-rich layer. XRD identified Fe_3O_4, Fe_2O_3, and $FeCr_2O_4$, while EBSD revealed near-surface grain refinement and increased local misorientation. These results indicate that the tribological response is sensitive to the imposed frictional path and suggest that alternating shear may affect debris transport, oxide-layer stability, and local damage evolution. Since the two protocols also differ in contact kinematics and geometry, the observed differences are interpreted phenomenologically rather than attributed exclusively to shear reversal.

KEYWORDS: HOT ROLLING – WORK ROLL – HIGH-SPEED STEEL – SLIP TRANSITION – WEAR EVOLUTION – FRICTIONAL SHEAR – OXIDATION

Tab. 1 - Test conditions of the two tribological protocols

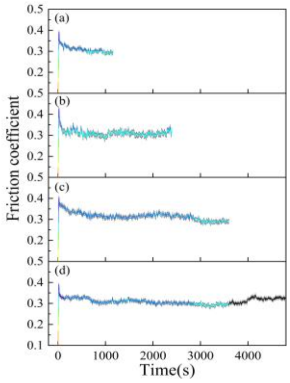
Test conditions			
Parameter	Twin-disc test	Reciprocating test	Unit
Temperature	500	500	°C
Contact stress	950 ± 50	950 ± 50	MPa
Cooling water	30	30	°C
Test duration	1200–4800	900–3600	s

The HSS material was obtained from the surface layer of a work roll used in the finishing stands of a hot strip mill. Two tribological protocols were employed to investigate wear evolution under different frictional shear paths. The twin-disc test generated rolling-sliding contact with continuous unidirectional shear, whereas the reciprocating sliding test introduced periodic reversal of the frictional shear direction. The coefficient of friction (COF) was continuously recorded. Surface and cross-sectional morphologies were characterized by SEM/EDS, while XRD and EBSD were employed to examine oxide phases and near-surface microstructural evolution, respectively.

RESULTS AND DISCUSSION

Frictional response

Distinct frictional responses were observed under the two test protocols. Under continuous unidirectional shear, the COF rapidly decreased after running-in and subsequently remained relatively stable at approximately 0.28–0.33. In contrast, reciprocating sliding produced a higher and more variable COF, mainly ranging from 0.35 to 0.60. The pronounced stage-dependent variations under reciprocating sliding indicate continuous evolution of the interfacial contact state during wear.



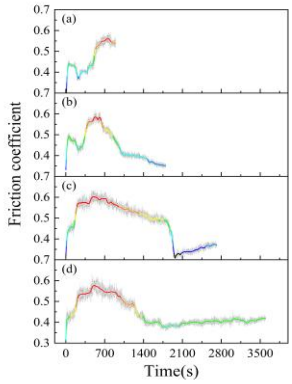


Fig. 1. Friction coefficient evolution without considering slip transition

Fig. 2. Friction coefficient evolution considering slip transition

Wear damage and oxidation evolution

Surface characterization revealed distinct damage evolution characteristics under the two frictional shear paths. Under continuous unidirectional shear, wear products progressively accumulated on the worn surface and developed into a relatively extensive coverage layer. The surface oxygen content increased from approximately 7 at.% to 33 at.% during the intermediate stage and subsequently decreased to about 18 at.%, indicating progressive oxidation followed by partial removal of surface products. Under reciprocating sliding, more pronounced grooves, debris accumulation, local spallation, and carbide-associated cracking were observed. The O-rich surface layer exhibited non-uniform thickness, cracking, and local discontinuities[3]. XRD analysis identified Fe_3O_4, Fe_2O_3, and $FeCr_2O_4$ throughout the wear process, confirming persistent oxidation at the contact interface [4].

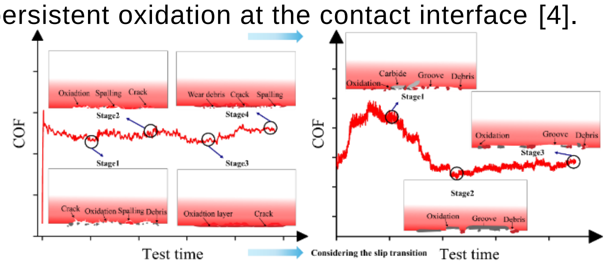


Fig. 3. Schematic illustration of damage evolution under different frictional shear conditions

CONCLUSIONS

The HSS work roll material exhibited distinctly different tribological responses under the two frictional shear paths. Continuous unidirectional shear produced a relatively stable friction coefficient and progressive surface-layer development, whereas reciprocating sliding resulted in higher and more variable friction, pronounced debris accumulation, local spallation, and a more discontinuous O-rich layer. These observations suggest that alternating shear associated with slip transition may affect debris transport and oxide-layer stability and thereby contribute to local wear damage. Since the two protocols also differ in contact kinematics and geometry, the results are interpreted as phenomenological evidence of the importance of frictional-path variations rather than as an exclusive effect of shear reversal.

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