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Failure Analysis of Drive Spindle Sleeve of Finishing Mill of Hot Strip Mill

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Abstract: ***This paper analyses the failure of a bottom spindle head sleeve in a finishing mill stand. The sleeve, manufactured by Mill OEM and installed in 2022 (after overhauling), exhibited fatigue cracking after approximately 2.9 years of service. Metallurgical analysis revealed lower hardness and microstructural changes in the interphase weld zone, stemming from multiple previous refurbishments involving hard facing. Repetitive welding during these overhauls induced thermal cycles, leading to softening of the parent material and ultimately, fatigue failure. Finite Element Analysis (FEA) showed that stress levels at the failure location remained within the acceptable range at rated load but exceeded the safe limit at peak loads (150% of rated current). Recommendations include improved supplier oversight, enhanced quality assurance procedures for overhauling, and a more robust maintenance protocol to prevent recurrence.***
Keywords: Spindle, Wobblers, Sleeves

I. INTRODUCTION

Spindle head sleeves are critical components in hot strip mills, responsible for transmitting torque from the drive spindle to the work roll. Failure of these components can lead to production losses and safety risks. This paper investigates the failure of a bottom spindle head sleeve in the finishing mill of an HSM to determine the root cause and recommend preventative actions. The general arrangement of the spindle head assembly is shown in Figure-1[1].

II. THE INCIDENT

Work roll side sleeve of bottom spindle of F1 stand was found cracked during running of hot strip mill. Spindle was changed with spare in breakdown which caused costly downtime of mill.

III. KEY OBSERVATIONS

During dismantling of sleeve unit from spindle, sleeve was found cracked at 3 nos of location as shown below in figure 2 and 3. Visual observation of fracture surface indicates, crack has been initiated from wear pad of sleeve. These wear pads are coming in direct contact of work roll neck for transmission circular motion. These wear pads have case hardened as shown in drawing in fig.7. Fracture surface indicating, fatigue crack generated nearby wear pad portion a shown below in fig 8. These were refurbished sleeves of spindle. Exact purchase date of these spindles was not available. this spindle sleeve had undergone 5 no's overhauling. In each overhauling sleeve wear pad window distance were measured and if found out of tolerance limit it was sent to supplier for refurbished. In refurbishing hard facing of wear pad were done as per procedure. There is no TBM based discarding criteria of these sleeves presently in department. Spindle head changed based on CBM (wear measured in spindle sleeve if found out of tolerance limit, sleeve send for refurbishment).

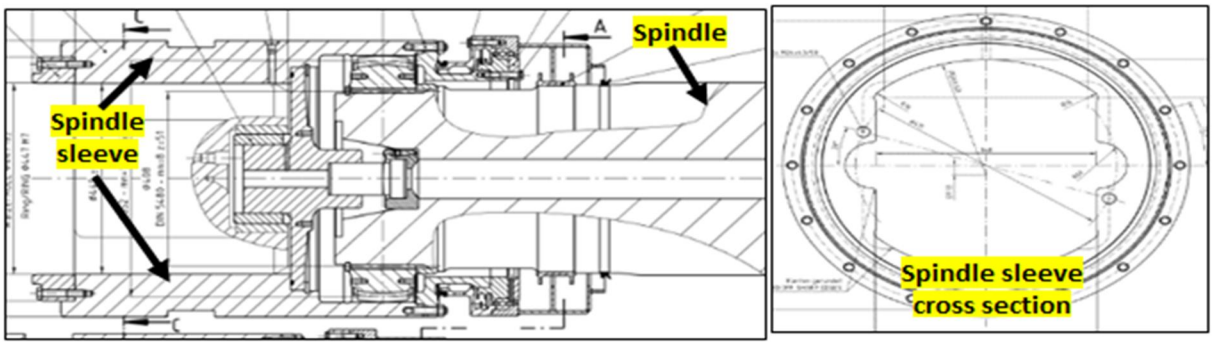


Fig. 1: General arrangement of spindle head assembly.

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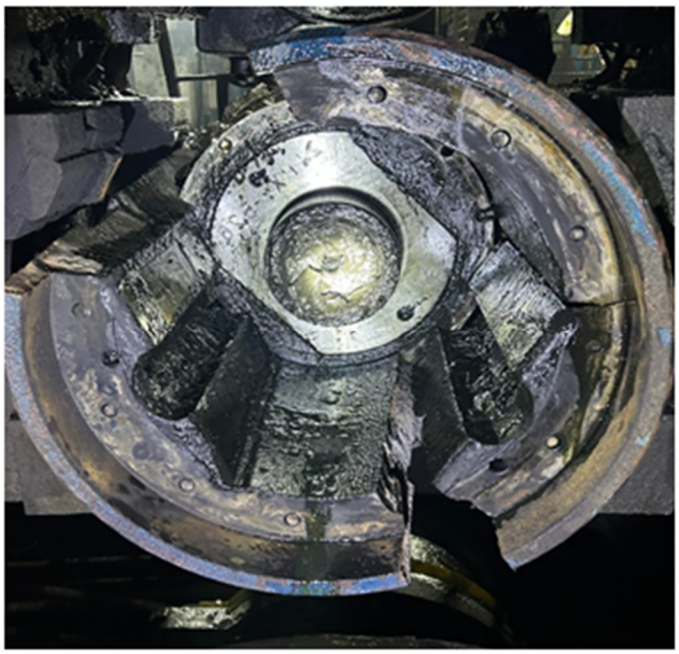


Fig.2 Sleeve found cracked at 3 nos of location



Fig.3 Cracks found nearby wear pad zone



Fig.4 Fatigue crack initiation nearby wear pad of sleeve

IV. FAILURE ANALYSIS

A. Material Analysis

Failed sleeve sample was analysed. Material chemistry, microstructure of Sleeve was found to be satisfactory as per drawing matching with Sleeve material: 18CrNiMo7-6. Wear pad zone hardness was found 50 to 54 Hrc which was ok as per reconditioning procedure for HSM spindle sleeve.

Chemical Analysis Results:

SAMPLE_ID	C	Mn	S	P	Si	Al	Ti	Cr	Ni	Mo	V	Cu	Nb	B
Sample (4369-24)	0.189	0.521	0.016	0.013	0.30	0.031	0.0029	1.56	1.51	0.28	0.0056	0.0733	0.0076	0.0003
16Ni6Cr7Mo3 (IS:1570 part-4)	**0.14-0.19**	**0.40-0.60**	**0.030 max**	**0.030 max**	**0.15-0.35**			**1.50-1.80**	**1.40-1.70**	**0.25-0.35**				

*Chemical analysis was carried out in RAC#1 chemical Lab

Fig.5 Fatigue crack initiation nearby wear pad of sleeve

B. Manufacturing Defect (Overhauling defect analysis)

Failed sleeve is refurbished one. This spindle sleeve had undergone 5 no's overhauling. In each overhauling sleeve wear pad window distance were measured and if found out of tolerance limit it was sent to supplier for refurbishment. In refurbishing hard facing of wear pad were done as per procedure. After machining of wear pad zone final UT inspection done for cracks. Presently there is no limit for number of overhauling for these sleeves. However, metallurgical analysis indicated there was lower hardness & microstructure change found around inter phase weld zone as shown below in figure 6 & 7. Overall metaluurgical report confirmed, etched microstructure of cladded zone revealed untampered martensite structure. Interphase revealed fine tempered martensite structure. Base material revealed mixture of tempered and bainite structure. Hardness profile also measured from cladded zone to base material. Cladded zone hardness is found around 50-54 HRC, inter phase zone hardness found around 175 BHN, Parent material hardness found 270 to 260 BHN. Multiple cracks observed originated from cladded zone and propagated towards base material.

From above analysis, it can be concluded that repetitive welding in repetitive overhauling can indeed cause softening of the parent material, because of Thermal Cycles, Heat-Affected (inter phase) Zone (HAZ), Microstructural Changes, Grain Growth. The softening of the parent material due to repetitive welding can have significant consequences, including like Reduced Strength, Increased Risk of Failure. To mitigate these effects, it's essential to Optimize Welding Parameter, Use Proper Welding Techniques, monitor parent Material Properties like hardness & microstructure and Consider Post-Weld Heat Treatment.

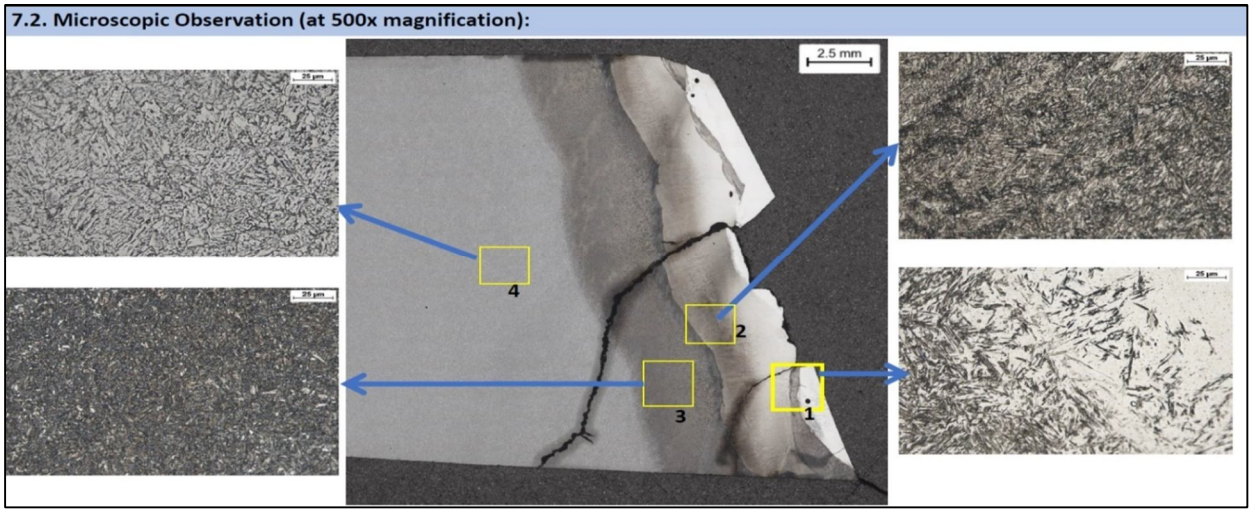


Fig.6 Fatigue crack initiation nearby wear pad of sleeve.

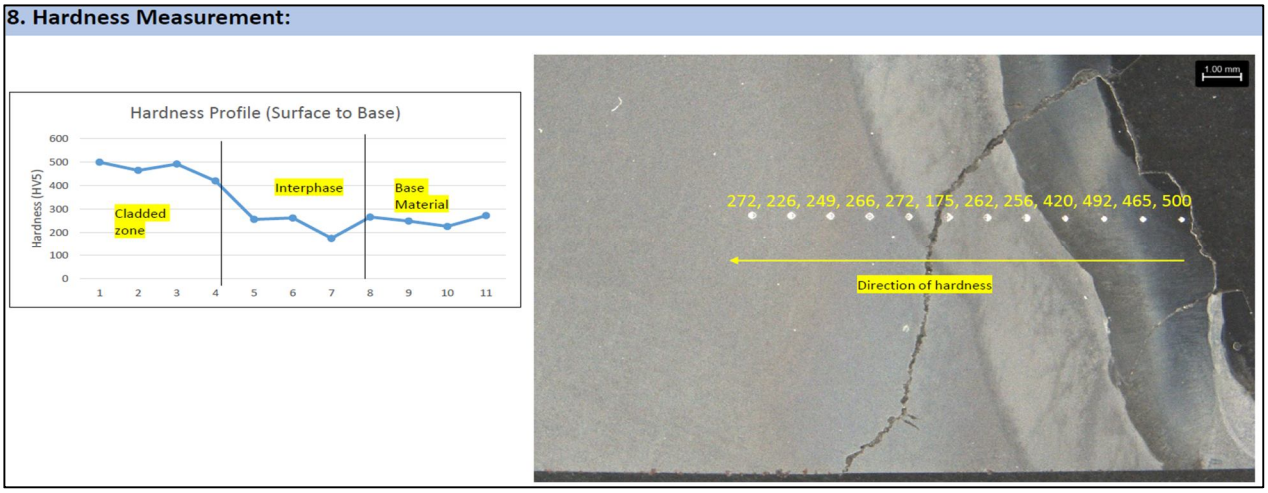


Fig.7 Hardness measurement of cladded portion.

Supplier test certificate was checked, only few parameters were checked like wear pad zone hardness, dimensions & UT inspection of wear pad zone. Rest test reports like parent hardness checking after machining wear pad zone, thorough UT of complete sleeve shell before welding, Post-Weld Heat Treatment graphs were missing as per Reconditioning procedure for HSM spindle sleeves. Thus, it can be concluded that lower inter phase zone hardness (around 175 BHN) than parent material hardness (270 to 290 BHN) and microstructure change from base material mixture of tempered and bainite structure to Interphase area having fine tempered martensite structure caused fatigue cracks to generate and failure. Further low hardness & microstructure change at inter phase zone caused because of inadequate post welding heat treatment.

V. REASONS OF FAILURE

From all above analysis, it is concluded that lower inter phase zone hardness (around 175 BHN) than parent material base hardness of spindle sleeve (270 to 290 BHN) and microstructure change from base material mixture of tempered and bainite structure to interphase weld zone (HAZ) having fine tempered martensite structure caused fatigue cracks to initiate and caused complete failure. Low hardness and microstructure change at inter-phase (HAZ) zone caused by inadequate post welding heat treatment (overhauling defect).

VI. CONCLUSION

1) Communicate overhauling defects and low hardness issues to the supplier.
2) Develop a comprehensive Overhauling Quality Assurance Plan (QAP) for spindle sleeves, including:

- DPT and UT inspections after removing the hard face layer.
- In-situ microstructure and hardness checks of the parent sleeve body.
- Rejection criteria based on abnormalities.
- Hardness criteria for interphase/parent material.
- Complete test certificates, including post-weld heat treatment data.
- Specifications for welding electrode type, size, and number of layers.

VII. ACKNOWLEDGEMENT

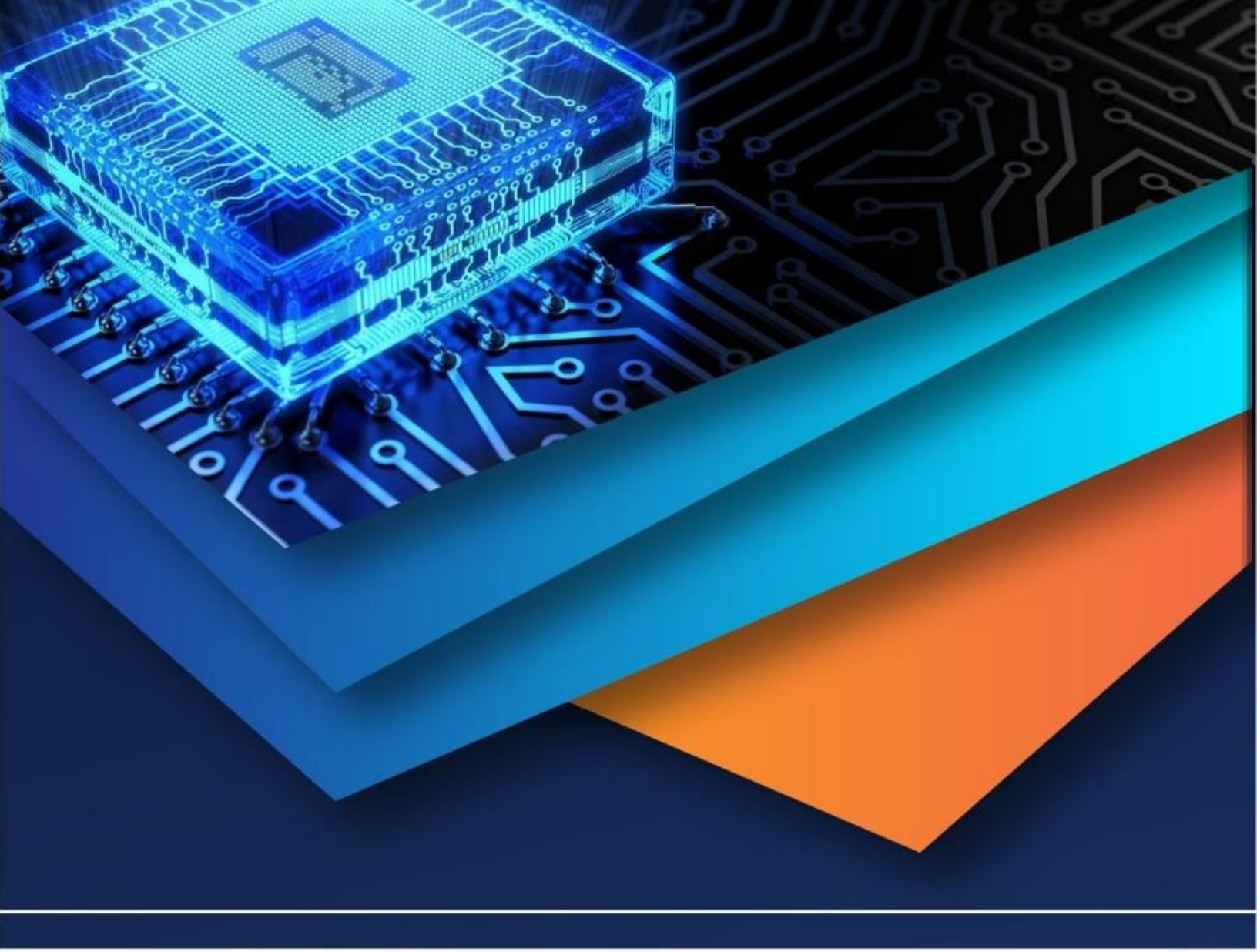
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VIII. COI DECLARATION

Authors declare that there is no conflict of interest in this paper.

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