BOHR Journal of Material Sciences and Engineering
2025, Vol. 3, No. 1, pp. 1–10
DOI: 10.54646/bjmse.2025.11
www.bohrpub.com

RESEARCH

Failure analysis of SMS-1 EOT crane hoist C-hook

J. N. Mohapatra[1]*, Sujata Panda[1], G. Praveen Kumar[2] and D. Satish Kumar[1]

[1]Department of R&D, JSW Steel Ltd., Vijaynagar Works, Bellary, Karnataka, India
[2]Department of SMS-I, JSW Steel Ltd., Vijaynagar Works, Bellary, Karnataka, India

***Correspondence:**
J. N. Mohapatra,
jitendra.mohapatra@jsw.in

Received: 01 November 2025; **Accepted:** 27 December 2025; **Published:** 12 January 2026

A 40-ton capacity electric overhead traveling (EOT) crane hook failure was investigated for the root cause analysis. The analysis involves examination of drawing, visual inspection, chemical composition, microstructure, hardness, inclusion analysis, and fractography. From the drawing it was found that the hook failed at a thread groove where the stress concentration is maximum. The hook is a plain carbon steel grade. Visual inspection revealed fatigue striations on both sides on the diameter of the hook shaft, with the final fracture at the center. The chemical composition of the hook revealed lower carbon than the specification with lower hardness. The microstructure of the hook revealed a ferrite pearlite microstructure with no heat treatment, as there is no variation of microstructure from the surface to the core. A lot of large-sized manganese sulfide and silicate inclusions are found on the hook, revealing the steel is not a clean one. The fractography of the hook revealed fatigue striations with the final fracture in a rapid brittle mode with the cleavages seen through the scanning electron microscopy. Hence, it is suggested to use an alloy steel cleaned shaft with proper normalizing or Q&T heat treatment for a better life. Additionally, use of ultrasonic non-destructive testing (NDT) for the detection of cracks by periodic monitoring will help in preventing the accidental failures.

Keywords: crane hook, plain carbon steel, alloy steel, failure analysis, fatigue failure, NDT

Introduction

Overhead cranes are widely used in industrial applications for material handling. Due to the aggressive environment of heavy loading, high temperature etc., damage or degradation of wire rope, crane skew and alignment issues, excessive wear to end truck wheels, issues with the electrification system, and bent or damaged hooks crane can fail. Failure of the hook of the electric overhead traveling (EOT) crane is caused by a combination of material fatigue from repeated loading, overloading beyond its capacity, wear and tear, selection of improper materials and improper manufacturing, and environmental factors. These issues can be prevented through proper safety management, regular inspections and maintenance, and correct operation, including never exceeding the crane's load capacity. Due to failure of the cranes, not only disruption of normal operation of the cranes occur, it reduces productivity and may also pose significant risks to the safety of personnel and property. Hence, there is a need to conduct failure analysis of each component of the cranes at various industrial failures to address the root cause to take the corrective measures to prevent accidental failures. Use of suitable non-destructive testing (NDT) evaluation techniques to monitor the health of the cranes at periodic intervals is very much necessary to prevent accidental failures. Although visual examination can help a lot for the identification of tool marks/dents/notches or surface cracks during shutdown, fine/tight fatigue cracks are not visible and need techniques such as liquid penetrant testing (LPT) or eddy current testing (ECT), whereas there might be internal cracks or regions where visual examination cannot be made due to limited accessibility, and hence, ultasonic testing (UT) is required for the complete assessment of the hooks for the detection of cracks to take corrective action to prevent accidental failures.

In the present investigation failure analysis was carried out on a 40-ton hook of the EOT crane, which had served for

20 years, to find out the root cause of failure and corrective measures required to prevent such accidental failures in the future. A very similar type of failure was reported by Das et al. (1) in a 40-ton EOT crane hook at a hot strip mill, with the cause of failure reported to be poor quality/inferior material leading to lower fatigue life and failure in fatigue failure. Kishore et al. (2) reported on failure analysis of a 24-ton crane hook using a multidisciplinary approach. Fatigue failure of the hook is confirmed by fine striation marks indicating high-cycle fatigue failure of the hook, which was initiated by the presence of severe sulphide and titanium nitride inclusions and tool marks. Prasad et al. (3) reported failure of a 5-ton crane hook in a bar rod mill with the possible cause of failure an accumulation of stress from the machined chatter mark portion and improper heat treatment. Fatigue failure of crane hooks was also reported by Sirswey et al. (4). Dangi et al. (5) reported the use of alloy steel as the most versatile material for crane hooks. Different tools such as finite element analysis (FEM), ANalysis SYStems (ANSYS) software, and solid models are used for the study of deformation under stress and stress accumulation in the crane hook for the design of the hooks (5–10). Although a lot of analyses were reported earlier, each and every failure analysis will help to get evidence for the root cause of failure and help in alerting the operation team to take corrective measures to avoid such premature failures.

Use of various NDT is required to inspect the crane hook before use for the soundness check (detection of the presence of any hidden cracks, fatigue cracks, voids, and inclusions that threaten safety), whereas periodic monitoring of the engineering components will help to assess the health and thereby prevent accidental failures (11–13).

TABLE 1 | Various parts of the crane hook assembly.

25	1	SPACER. (ITEM NO. 3)	ST–42		0.4	SB 0 0600
24	2	NAME PLATE (ITEM NO.5)	STD	2.7	5.4	SB 0 0500
23	16	SPRING WASHER A12	IS:3063			
22	16	HEX SCREW M12x 40 LG N	IS:1363			
21	4	SPRING WASHER A20	IS:3063			
20	4	HEX SCREW M20x 40 LG	IS:1363			
19	6	SPRING WASHER A16	IS:3063		2.0	
18	6	HEX SCREW M16x 30 LG	IS:1363			
17	1	HOOKING LOCKING DEVICE	ASSLY		8.0	SB 4 0008
16	1	LOAD LOCKING FINGER	ASSLY		3.0	SB 1 0008
15	2	LOCKING PLATE(ITEM NO.4)	ST–42	0.4	0.8	M19 006
14	2	LOCKING PLATE(ITEM NO.5)	ST–42	0.9	1.8	M19 006
13	4	GREASE NIPPLE 1/4" BSP	STD			
12	1	GREASE NIPPLE 1/8" BSP	STD			
11	2	SIDE PLATE	IS:2062 GR–B	76.0	152.0	SB 6 0708
10	1	LOCKING PLATE (IT.NO. 07)	ST–42	[illegible]	0.9	SB 0 0100
9	1	BEARING COVER (IT.NO. 09)	IS:513	[illegible]	1.4	SB 0 0200
8	1	PIN	EN–24		42.0	SB 5 0808
7	1	THRUST BEARING – 51324	SKF/FAG		11.0	120x210x70
6	4	ø 710 PULLEY ASSLY.	ASSLY	69.0	276.0	N16 175
5	1	CENTRE CASING	IS:2062 GR–A		56.0	SB 4 0708
4	2	SIDE CASING	IS:2062 GR–A	70.0	140.0	SB 3 0706
3	1	TRUNNION	EN–8		85.0	SB 2 0808
2	1	NUT	EN–8		31.0	SB 1 0808
1	1	HOOK 40 T (IS:3815)	IS:1875 GR–?		138.0	

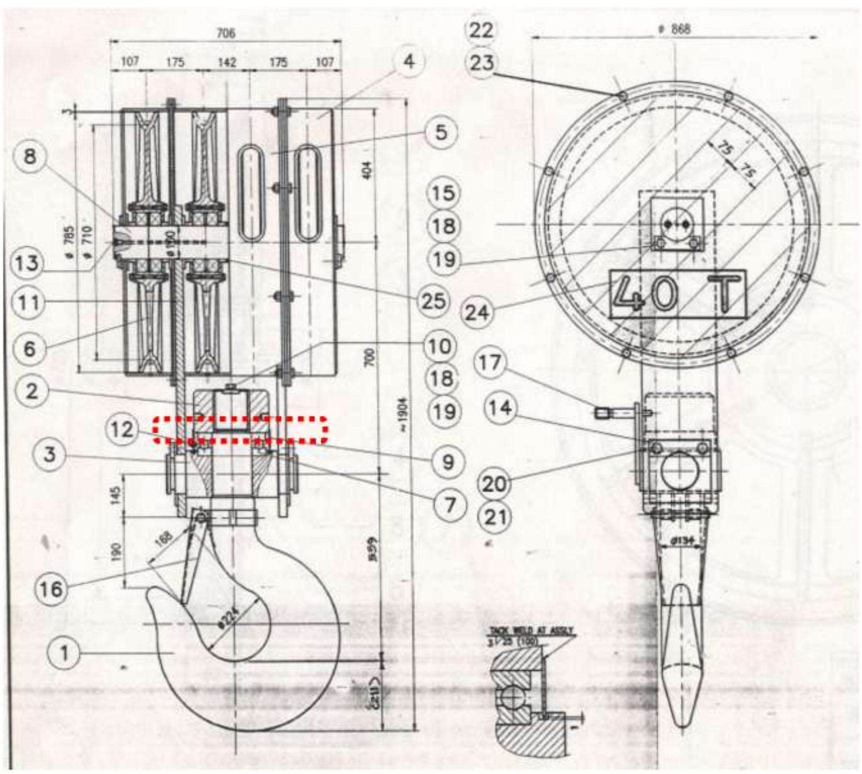


FIGURE 1 | Drawing of the 40-ton EOT crane hook with the location of failure.

Methodology

The EOT Crane Hoist C-Hook at SMS1-Slab Handling Crane-2 (tong capacity - 35 + 35 tons) failed while carrying a slab. The 40-ton capacity crane was installed in 2005 and failed on 19-10-2025 with approx. 20 years of service. The hook experience is approx. 600°C while hot slabs are lifting with tongs/ 55–60 tons. On a quarterly basis the crane hooks are inspected with visual inspection technique. However, inside the hook holder, due to non-accessibility,

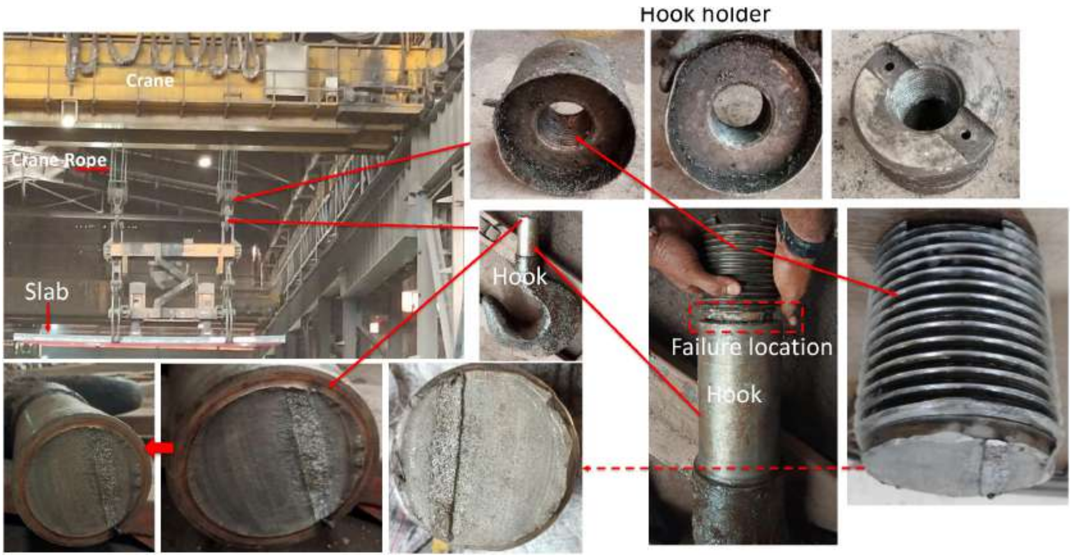


FIGURE 2 | Visual examination of the EOT crane hook showing failure at a thread groove region.

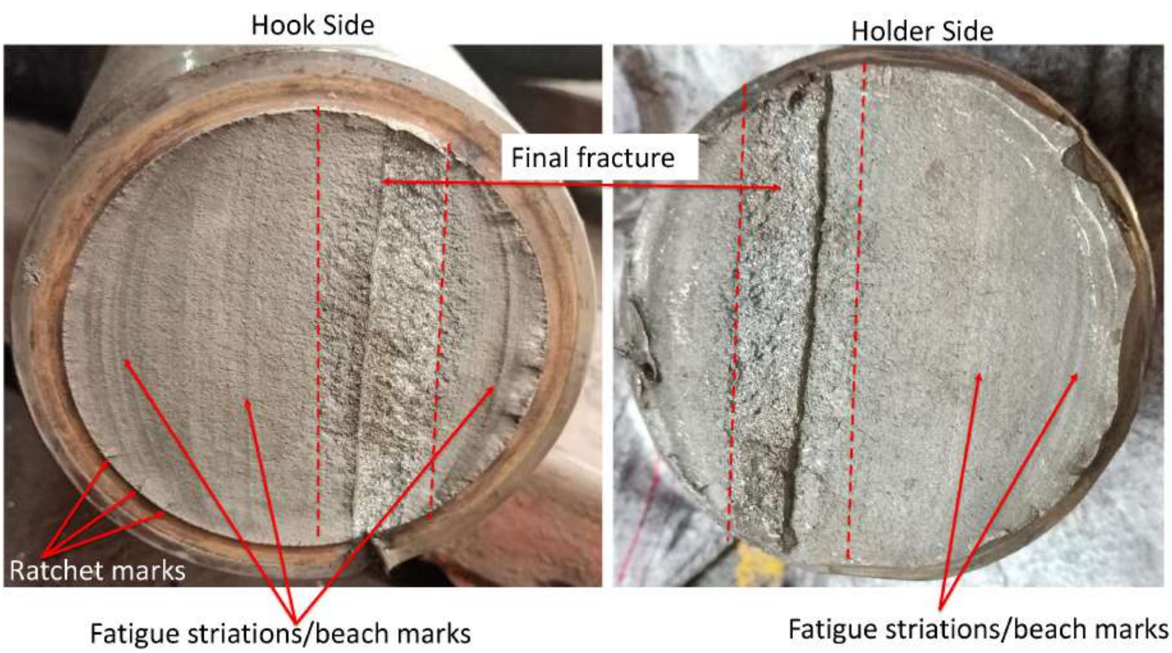


FIGURE 3 | Visual examination of fracture surface of hook side and holder side showing fatigue striations from both sides with final failure at the center.

TABLE 2 | Chemical composition of the hook compared with the specification IS 1875 Gr.2.

	C	Mn	S	P	Si	Al	Cr	Cu	Nb	V	Ti	Mo
IS 1875 Gr. 2	0.1–0.2	0.60–0.90	0.03	0.04	0.15–0.35							
Hook	0.069	0.40	0.026	0.023	0.063	0.001	0.016	0.006	0.001	0.001	0.001	0.001

FIGURE 4 | Brinell hardness of the hook shows no systematic variation from surface to core.

no inspections were made. The region of failure cannot be inspected visually, as the failure occurred at the nut and thread portion. The crane is a critical one and works in continuous operation. The crane, with 35 + 35 tons, is used to lift and shift hot and cold slabs. The failure occurred the first time at SMS-I. To sort out the root cause of failure, failure analysis was carried out at R&D JSW Steel Ltd., Vijayanagar Works.

The analysis involves a site visit, examination of the drawing and material of construction (MOC) of the crane hook, visual inspection to identify the location, and possible identification of the mode of failure. The small part of the hook that was apart from the hook was collected for the chemical composition through a SPECTRO make optical emission spectroscopy; microstructure was carried out using an Olympus make opto-digital microscope and a Hitachi make scanning electron microscope (SEM); hardness was carried out on a micro-Vickers' hardness tester; inclusion analysis was conducted on the un-etched samples in the rolling direction through the optical microscope; and fractography analysis was conducted on the SEM. Two slices were made approximately 10 mm thick—one along the fracture surface and the other on the back side of the first slice for the detailed study.

Results and discussions

Drawing

The drawing of the 40-ton EOT crane with the location of failure is shown in **Figure 1**. Various parts of the crane hook assembly are shown in **Table 1**. The crane hook is according to IS: 3815, with the material used according to IS 1875 Gr. 2, which is a plain carbon (low carbon) steel grade. The location of failure is found to be at the start of the thread groove shown in the red dot mark in **Figure 1** which is the stress concentration region in the design.

Visual examination

As shown in **Figure 2**, the EOT crane has the assembly of two hooks with ropes to carry the hot slabs. The hook has failed at the thread groove region marked

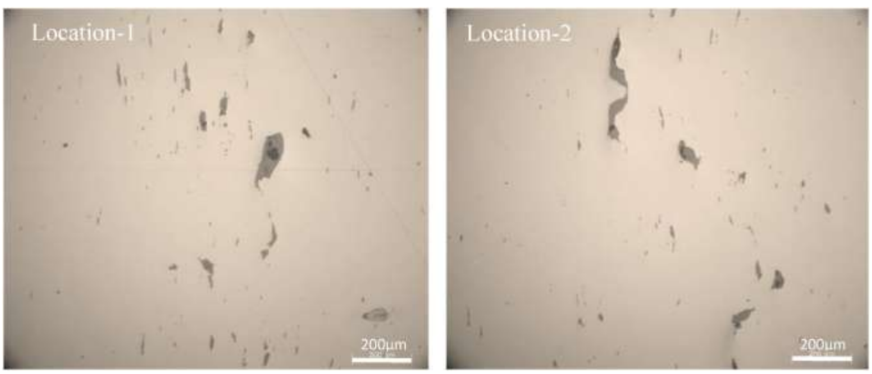


FIGURE 5 | Inclusion analysis—lot of MnS and silicate inclusions are found.

TABLE 3 | Inclusion rating.

A-sulfide		B-alumina		C-silicate		D-globular oxide	
Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick
1.0	2.0	-	-	1.5	2.5	2.5	1.5

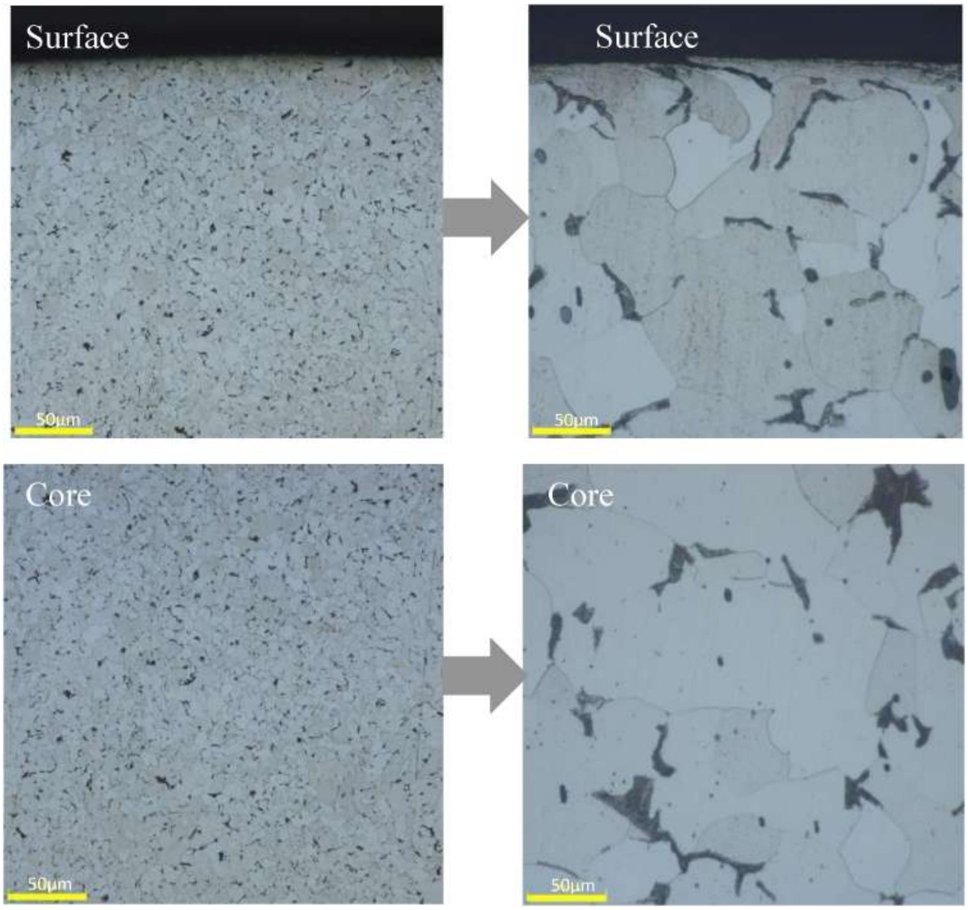


FIGURE 6 | Surface and core microstructure and their high-magnification images.

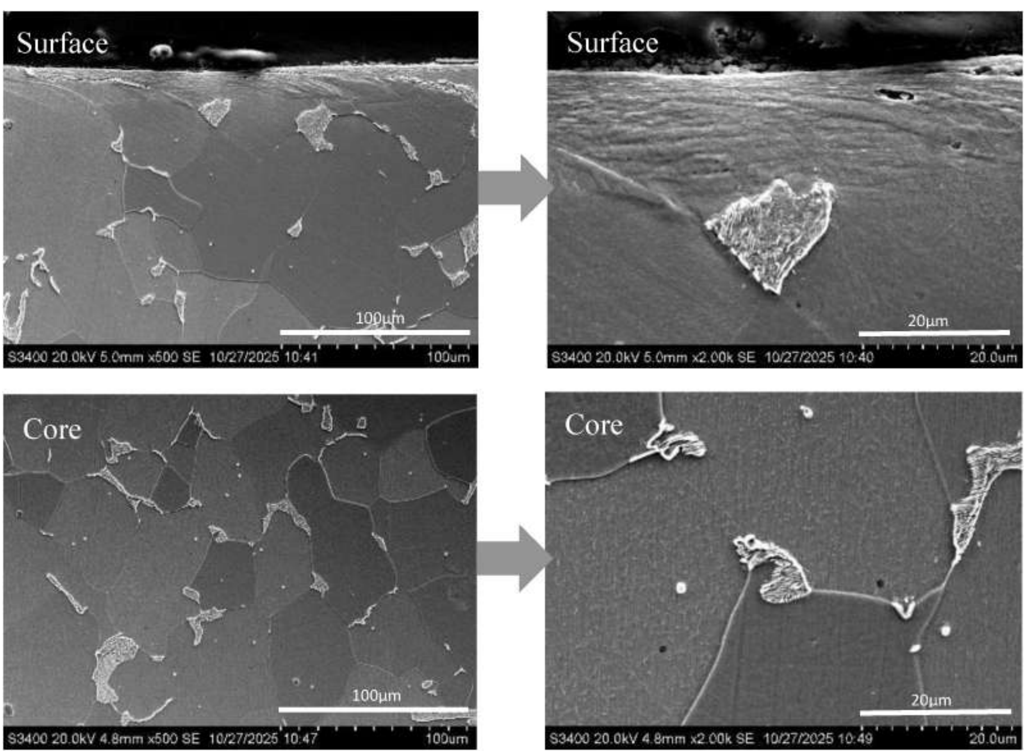


FIGURE 7 | Surface and core micrographs and their high-magnification micrographs.

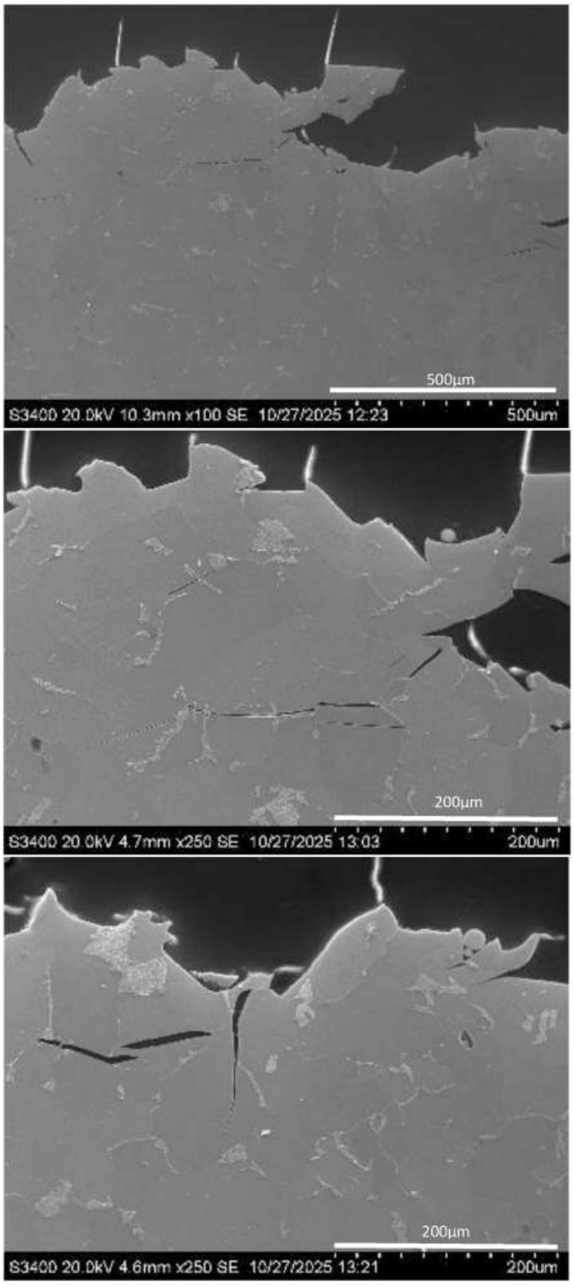


FIGURE 8 | A lot of transgranular cracks were observed near to the fracture in the hook.

by red dashed lines. The fracture surface of the hook from the hook side and from the holder side is shown in **Figure 3**. Fatigue striations/beach marks are found from both sides of the hook, with the final failure at the central part.

Chemical composition

The chemical composition of the hook was compared in **Table 2** with the specification IS 1875 Gr.2. The carbon and Mn in the hook are found to be lower than the specification. This lower carbon and Mn lead to lower mechanical properties of the hook. However, in some previous studies, it is reported to use an alloy steel hook (IS 4367) for a better life with proper normalization heat treatment to achieve desired hardness (1).

Bulk hardness

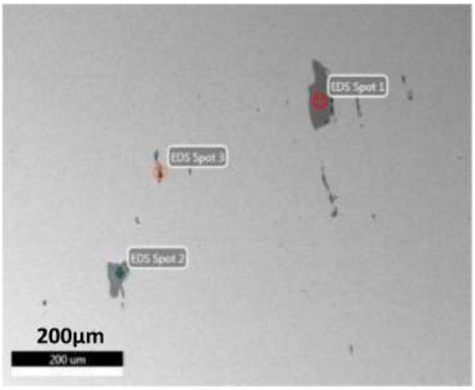
Hardness of the shaft in the Brinell scale is shown in **Figure 4**. No systematic variation in hardness is found from surface to core of the shaft, indicating no quench and temper heat treatment or surface hardening treatment was made on the hook. The hardness is found to be in the range of 90–108 BHN ($<$382 MPa UTS), which is lower than the specification of $>$110 BHN (402 MPa UTS) (1 A: IS1785:1992). Such hardness might have decreased in service due to exposure to high temperatures up to 600°C. A lower hardness leads to lower ultimate tensile strength and lower fatigue strength of the hook. Hence, hardness should be as per specification for the safe use of the hook to withstand the desired load in operation. The fatigue strength of steel is approximately half of its ultimate tensile strength, and hence, lower ultimate tensile strength leads to lower fatigue strength of the hook.

Inclusion analysis

Although a lot of locations were analyzed for inclusion analysis. Two representative regions (location-1 and location-2) are shown in **Figure 5**. A lot of manganese sulfide, silicate, and globular oxides are found on the shaft. The inclusion rating as per the worst field method (ASTME-45) is shown in **Table 3**. Such large-size inclusions are not acceptable for dynamic loading engineering components such as shaft, as inclusions act as the nucleation site for fatigue crack initiation. At the inclusion sites, stress concentration increases, which eventually lead to the initiation of fatigue crack, which, in long-term service, propagate and result in final fracture.

Microstructure

The microstructure of the hook close to surface, and core is shown in **Figure 6**, and its SEM micrograph is shown in **Figure 7**. It shows ferrite-pearlite microstructure with no variation in microstructure from surface to core, indicating no surface hardening heat treatment was made on the hook. Grains are found to be coarser in nature. **Figure 8** shows numerous transgranular cracks near to the fracture surface of the hook. No scale has been observed on the hook, although it is exposed to temperatures up to 600°C, which might be due to no direct contact of flame on the hook material.



Element	P1-Wt. %	P2-Wt. %	P3-Wt. %
O K	-	1.18	0.63
SiK	0.41	-	1.33
S K	12.73	-	2.67
MnK	70.47	-	36.07
FeK	16.39	98.82	61.97

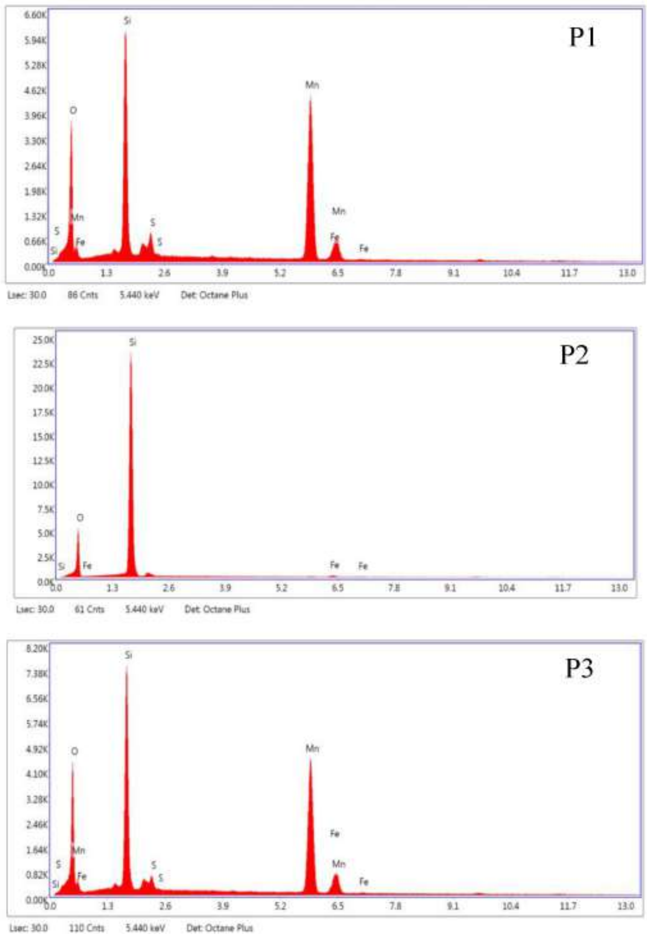


FIGURE 9 | SEM EDS of inclusions revealing MnS and silicates.

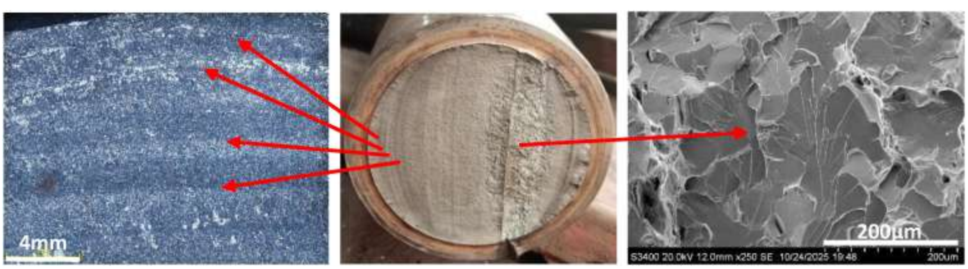
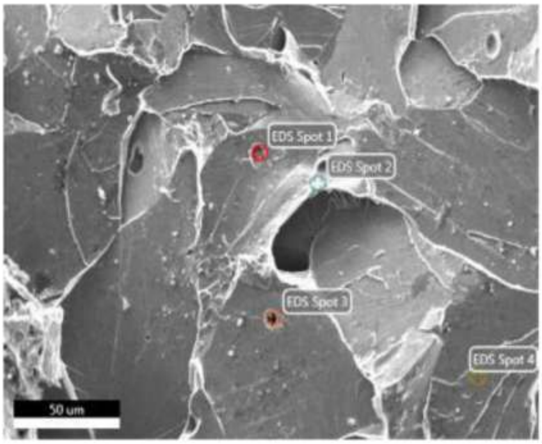


FIGURE 10 | Fatigue striations (left) and final brittle fracture (right) of the hook.



Element	P1-Wt. %	P2-Wt. %	P3-Wt. %
O K	11.69	24.28	12.36
SiK	17.74	72.78	19.81
S K	3.24	-	2.67
MnK	65.34	-	61.27
FeK	1.99	2.94	3.90

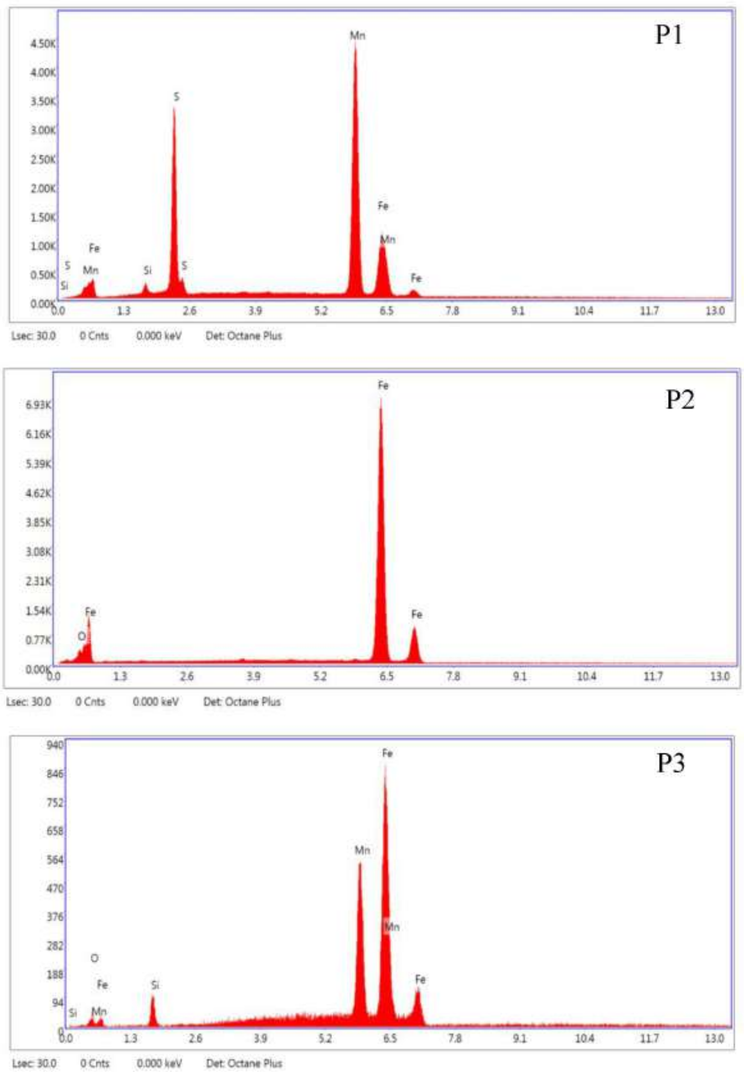


FIGURE 11 | SEM-EDS on the fracture surface showing MnS and silicate inclusions.

SEM-EDS of inclusions

A lot of MnS and silicate inclusions are found, as shown in **Figure 9**. Such inclusions are found in several regions, and hence one representative site is shown in the figure.

Fractography

Figure 10 shows the fractography analysis of the crane hook. It can be seen that (left) fatigue striations/beach marks indicate the fatigue failure of the shaft. The fatigue crack has started at the notch region of the thread groove starting position, which might have been supported by the large-sized MnS or silicate inclusions. The fatigue striations/beach marks are found from both side of the hook diameter, and the final fracture has occurred at the center of the hook diameter. A very similar failure is reported by Das et al. (1). The final fracture occurred in a rapid brittle mode when the cross-section of the hook decreased drastically. **Figure 11** shows the presence of MnS and silicate inclusions on the fracture surface of the crane hook.

It may be mentioned that a notch, dent, step, thread groove, or inclusion is the site for a stress concentration region in engineering components. Stress concentration increases, leading to the initiation of fatigue cracks at the sites, which eventually propagate for the final fracture when the cross section of an engineering component is reduced so that it could not withstand the load. Furthermore, there is a need to take care of the clean steel use in dynamic loading conditions and careful handling to avoid any dent formation or corrosion pit in service to avoid nucleation points for fatigue crack generation. In addition, as the fatigue strength of steel is half of the ultimate tensile strength of the steel, it is required to choose a steel with higher strength and proper heat treatment to achieve the desired strength as per specification to give a higher fatigue life to the engineering components under dynamic loading conditions.

For the detection of fatigue cracks, as they are very tight cracks, magnetic particle inspection with fluorescent particles or eddy current testing is required. However, with the increase in the crack size, ultrasonic testing would be more helpful to assess in the parts where assess is not good. Hence, the operator needs to have a thorough knowledge of the limitations and advantages of each NDT to evaluate the cracks in engineering components.

Conclusion

The root cause of failure of the crane hook is the use of a non-cleaned low-carbon steel with lower hardness (presence of a large number and size of MnS and silicate and oxide inclusions). Due to the presence of such inclusions, a fatigue crack initiated at a groove region of the thread and propagated for the final failure. The fatigue striations/beach marks are found on the fracture surface of the hook, indicating fatigue failure with the final failure mode as brittle failure. The microstructure of the hook shows a ferrite-pearlite structure, indicating no heat treatment was conducted. The microstructure from the surface to the core showed no variation, indicating no surface hardening treatment was adopted.

Suggestions: It is suggested to use clean steel for the crane hook. Alloy steel should be used for better performance (IS 4367). Heat treatment; normalizing, Q&T, or surface hardening treatment can further improve the life of the crane hook. Periodic monitoring through ultrasonic testing can help to identify the cracks for corrective actions to prevent such accidental failures.

Author contributions

JNM: Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. PKG: Conceptualization, Data curation. SP: Formal analysis, Data interpretation. DSK: Writing – review & editing. Others: NA.

Funding

No funding received for carrying out the research work.

Acknowledgments

The authors would like to thank the Management JSW STEE Ltd., for providing the infrastructure facility of R&D for doing the work and giving permission to publish the work.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

1. Das S, Mukhopadhyay G, Bhattacharyya S. Failure analysis of a 40 ton crane hook at a Hot Strip Mill. *MATEC Web of Conferences.* (2018) 165:10006. doi: 10.1051/matecconf/201816510006
2. Kishore K, Gujre VS, Choudhary S, Gujre AS, Vishwakarma M, Thirumurgan T, et al. Failure analysis of a 24 T crane hook using multi-disciplinary approach. *Eng Fail Anal.* (2020) 115:104666. doi: 10.1016/j.engfailanal.2020.104666
3. Prasad GV, Nair S. Failure investigation of 5T C-hook of EOT crane. *AIP Conf. Proc.* (2024) 3231(2024):020001. doi: 10.1063/5.0236758
4. Sirswey S, Gangrade K. Failure analysis of crane hook for different cross section. *Int J Res Pub Rev.* (2022) 3(6):1412–22.
5. Dangi R, Barelwala C, Shah HN. A review on design, selection of material, analysis and failure of hooks used in material handling equipment. *Gandhinagar Univ J Eng Technol.* (2023) 15:28–37.
6. Sonava M, Wankhade V. Study and review on the analysis of crane hook with different cross section area & materials. *Int Res J Eng Technol.* (2019) 6(12):1970–3.
7. Kardile VS, Khan ER, Dhakane PD, Gore AP, Mahajan BD. Design and analysis of crane hook with different materials. *Int Res J Eng Technol.* (2017) 4(3):1919–22.

8. Krishna ES, Kumar SS. Design and analysis of crane hook with different materials. *Int J Mech Eng Technol.* (2018) 9(4):786–91.
9. Zeleke Z, Tamiru T, Ashuro B, Bogale D. Design and failure stress analysis of crane hook by using mesh sensitivity analysis approach on finite element method. *Research Square Preprint.* (2023). doi: 10.21203/rs.3.rs-3720045/v1
10. Dipu NH, Apu MH, Chowdhury PP. Identification of the effective crane hook's cross-section by incorporating finite element method and programming language. *Hellyon* (2024) 10(29918):1–14.
11. ITAC. *Preventive Inspection Strategies for Crane Hook*. ITAC (2025). Available online at: https://www.itacsafety.com/blogs/preventive-inspection-strategies-for-crane-hook/ (Accessed 23 December 2025)
12. Irizar Forge. *How is a Crane Hook Tested?*. Irizar Forge (2025). Available online at: https://www.irizarforge.com/en/how-crane-hook-tested (Accessed 23 December 2025)
13. QDPowerful. *Crane Hook Inspection*. QDPowerful (2025). Available online at: https://qdpowerful.com/crane-hook-inspection/ (Accessed 23 December 2025).