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Studying the Reasons behind the Occurrence of Cracks in the Bucket Elevator in the Lebda Cement Factory

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Abstract

Bucket elevators always face problems during the accumulation of loads. When buckets are damaged, the bucket elevator breaks down. Replacing or repairing damaged buckets increases overall maintenance costs; it takes technicians at least several days, depending on how severe the damage is, which will result in decreased productivity and increased downtime. The main goal of this paper is to find out the reason for the cracks that occur at the edges of the bucket conveying cement in the Al- Lebda Cement Factory. According to the manufacturer's catalogue, the material of the bucket is made of EU EN S235JR steel.

To study this problem, we conducted a series of tests on samples of the bucket's metal, including chemical composition analysis, tensile strength testing, hardness testing, and microscopic examination. We then compared the results of these tests to the standard specifications for the S235JR steel grade. The results of bucket samples showed the carbon content was C 0.1107 Wt. %, yield strength was 350 N/mm2, ultimate tensile strength was 445 N/mm2 and hardness test was 77HRB, and the

metallurgical analysis indicated an irregular distribution of the grain boundaries with, the accumulation of cementite in several areas. It should be noted that the temperature of the cement was not taken into consideration in this study.

Keywords: Material Handling, Bucket Elevator, EN S235JR steel Cracks.

1. Introduction

Material handling is a very important part of different sectors such as logistics, manufacturing, and others. It deals with the movement, storage control, and protection of materials across the supply chain, from raw materials to finished products. Efficiency in material handling operations is necessary for improved productivity through streamlining operations, which helps in lowering costs incurred, thus ensuring customer satisfaction is achieved by a company or organization. [1].

Additionally, timely delivery of goods to their required places reduces disruption time during production, hence enabling smooth flow between departments within an industry, leading to minimum idle time while waiting for items to be transported among them. Besides this, it prevents damage or loss of goods, hence making sure that resources are used efficiently, and it also aids in promoting safety at work since risks associated with accidents can be minimised due to ergonomic practices adopted during this process.

A bucket elevator, also known as a material handling elevator, is a highly efficient and versatile material handling equipment widely used in various industries for vertical transportation of bulk materials. It consists of a series of buckets attached to a belt or chain that moves in a continuous loop, allowing for the vertical movement of materials [2].

Bucket elevators are utilized in diverse industries including agriculture, mining, construction, food processing, and many more. They play a crucial role in streamlining material handling processes, enhancing productivity, and ensuring the smooth flow of materials within a production or storage facility. It's a mechanism designed for the vertical transportation of bulk materials, ranging from powdery to granular and small block materials.

Bucket elevators play a vital role in cement factories, facilitating the efficient transportation of various materials involved in the production process, these materials often include limestone, coal, gypsum, clinker, dry clay, and other solid block materials, as well as cement, pulverized coal, and other powder materials [3]. Their robust design and functionality make them an indispensable tool in the industry.

The material is poured into the boot of the elevator and lifted up by the buckets as they pass around the bottom pulley or sprocket. The buckets move unidirectionally within a casing, collecting bulk materials at the bottom end of the equipment and delivering them at the top end using a flexible belt or chain [4]. Figure (1) shows the main components of a bucket elevator [1]. The objective of this study is to address the problem by conducting comparative analyses between S235JR steel and the steel used in bucket manufacturing.

2. Literature Review

N. Yashaswini, et al. [1] conducted a study on the" Design and Optimization of bucket elevator using FEA", In this paper the bucket was designed in NX software and analyzed for vibration using ANSYS. The study also investigated the dynamic behaviour of the bucket.

Snehal Patel et al. [5] conducted a study on the "Design and Analysis of Different Parts of Bucket Elevators." They identified that the failure of the shaft is a primary cause of bucket failure. The paper focuses on shaft analysis and proposes material updates to prevent failures.

F.J. C. Rademacher [6] analyzed the "Non-Spill Discharge Characteristics of Bucket Elevators." The study highlights that backflow leads to bucket failure. The paper examines the spill-free characteristics of the bucket.

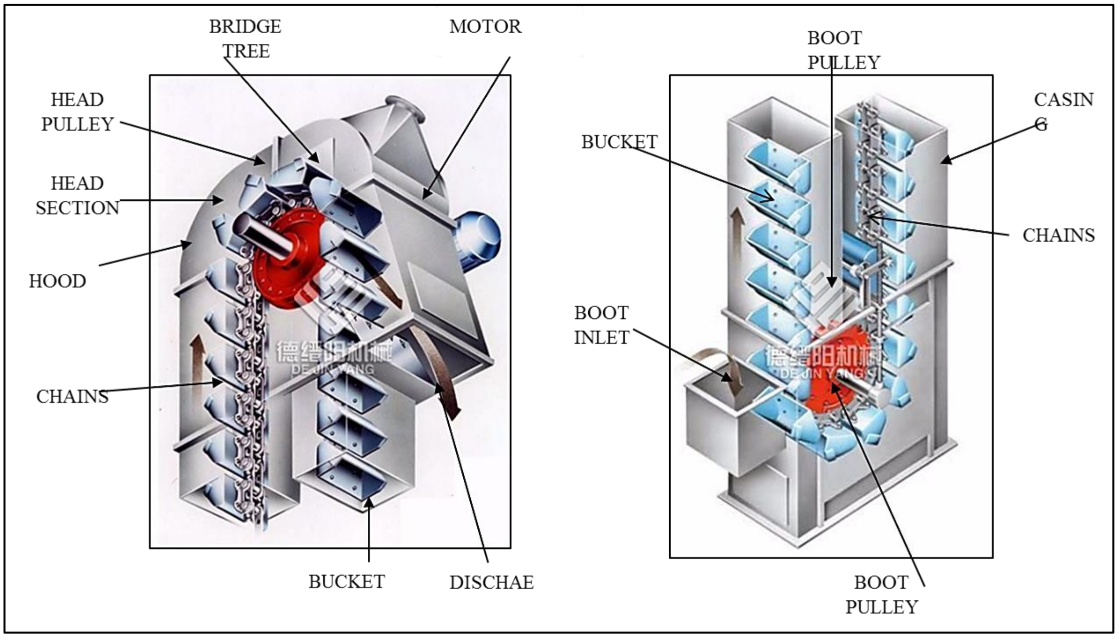

Figure (1): Parts of the chain bucket elevator's boot head and upper head [1].

Edward Yin, et al. [7] studied, “Bucket Elevator central chain links is analysed’’. The study emphasized the importance of promptly replacing chain links to minimize production downtime and productivity loss. The research includes chemical and metallurgical analyses.

Gazi Abu Taher, et al. [8] studied, “Automation in Material Handling with different techniques”. The paper compares belt conveyors and bucket elevators as methods for material transportation. The study aimed to highlight the differences between these two techniques through experimentation.

Kulkarni Digambar, et al. [9] studied, “Chain breakdown of Bucket elevator using analysis”. The paper designs and analyzes a chain drive system for bucket elevators. It proposes replacing roller chains and sprocket chains with duplex chains.

Lunawat, A. S. H., & More, K. [10] studied, “DESIGN AND ANALYSIS OF BUCKET”. The paper involves designing and analyzing an elevator for conveying granular materials. They use CAD software (CATIA) to model the bucket elevator and employ finite element analysis (ANSYS) to assess its performance.

3. Problem Statement

Bucket elevators are widely used equipment in the mechanical industry. Buckets always face problems during loads. Fracture is always a problem in any structure, so it’s necessary to find out the reasons for this problem.

This study aims to identify the reasons behind cracks that occur in buckets at the Lebda Cement Factory [11], and Figure (2) shows a bucket with cracks.

Figure (2): a bucket with cracks.

4. Results and Discussion

4.1Bucket material

The bucket was made with a 5mm thin plain steel sheet by folding the sheet at a particular dimension.

According to the manufacturer's catalogue, the material of the bucket is made of EU EN S235JR steel which is equivalent to DIN ST37-2, JIS: SS400, ASTM: A283C, UNI: FE360B and USA C 1015 steel.

We will take several samples from the bucket to conduct some experiments, such as chemical analysis, hardness testing, tensile testing, and metallurgical analysis, and then compare them with the standard specifications of steel EN S235JR.

4.2 Material properties

4.2.1 Chemical composition

4.2.1.1 Chemical composition of S235JR steel

S235JR steel is a low-carbon steel and is widely used in various industries due to its favourable properties and versatility and its chemical composition plays a crucial role in determining its mechanical properties [12].

Table (1) shows the chemical composition of EN S235JR steel according to European steel standards:

Table (1) Chemical composition of EN S235JR steel [13].

Elements	C	Si	Mn	P	S	Cu
Wt.%	0.17-0.22	0.4	≤ 1.4	0.05 ≤ 0.03	0.05 ≤ 0.03	≤ 0. 55

4.2.1.2 Chemical Composition of Bucket

The chemical analysis of the bucket metal was carried out in the Misurata Iron and Steel Factory laboratories using an optical emission spectrometer (ARL 3460-OES-METALS ANALYZER), and Figure (3) shows the optical emission spectrometer.

Figure (3): The optical emission spectrometer

The following table shows the chemical analysis of the bucket metal.

Table (2): Chemical composition of bucket metal

Elements	Fe	C	Si	Mn	P	S	Cu
Wt.%	99.06	0.1107	0.0085	0.72	0.0066	0.015	0.13

4.2.1.3 Discussion of the chemical analyses results

Table (3) shows the chemical composition of S235JR steel and bucket metal

Table (3): combines the chemical compositions of S235JR steel and bucket metal.

Material	Elements %					
	C	Si	Mn	P	S	Cu
EN S235JR steel	0.17-0.22	0.4	≤ 1.4	0.05 ≤ 0.03	0.05 ≤ 0.03	≤ 0. 55
Bucket metal	0.1107	0.0085	0.72	0.0066	0.015	0.13

Chemical analyses showed that the percentage of carbon and Si are below the required standards, which would affect the mechanical properties such as toughness, corrosion resistance and resistance to cracking.

4.2.2 Physical properties

The goal of studying physical properties is to gain a comprehensive understanding of materials, their behaviour, and their suitability for specific applications.

4.2.2.1 Physical properties of EN S235JR steel

The following table displays the physical properties of S235JR steel under European standard EN 10025-2 [14].

Table (4): Physical properties of EN S235JR steel (thickness ≤ 16mm)

Yield Strength N/mm^2	Tensile Strength N/mm^2	Elongation %
235	360-510	≥ 26

4.2.2.2 Physical properties of bucket steel

The tensile test aims to find the yield point and maximum stress, for samples under static and axial tensile loads. Tensile properties often are used to predict the behaviour of a material under forms of loading.

The samples were prepared according to (ASTM E8-81) and tested at the Misurata Iron and Steel Factory [15]. The average tensile test results are presented in Table (5).

Figures (4) and (5) display, respectively, the samples prepared for tensile testing and the tensile testing machine used to examine the tensile specimens for this study.

Figure (4): Samples for the Tensile Test

Figure (5): Tensile test machine

Table (5): shows the Physical properties of the bucket steel

Yield Strength N/mm^2	Ultimate Tensile Strength, N/mm^2	Elongation %
350	445	29

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4.2.2.3 Hardness Test

Hardness is one of the important mechanical properties for studying the surface of a material. It is defined as the resistance of the material surface to dents or scratches, or the resistance of the material to local plastic deformations [16].

According to the European standard EN 10025-2, the hardness of S235JR steel of a Vickers hardness test is 360 to 510 (HV), and the Brinell hardness scale is 140 to 170 (HB) [17]. The Rockwell B Hardness is 60.0 to 80.5 HRB [18].

The hardness test of the bucket sample was performed on three samples in the laboratory of Misurata Iron and Steel Factory, and the reading average was 77 HRB.

4.2.2.4 Discussion of the Physical Properties Results

Table (6) combines the Physical properties of S235JR steel and bucket steel

Table (6): shows the Physical properties of S235JR steel and bucket metal.

Material	Yield Strength N/mm^2	Tensile Strength, **N/mm^2**	Elongation %	Hardness HRB
EN S235JR steel	235	360-510	≥ 26	60-80
Bucket metal	350	445	29	77

The tensile and hardness test results in Table 4 show that the values of tensile strength, elongation, and hardness are within the recommended range, but the yield strength value is higher than the recommended range.

The measured value is substantially higher than the specified value and exceeds it by more than 100 N/mm2.

4.3 Microscopic examination

Figures (6) and (7) display, respectively, the microscopic examination of the bucket metal samples (20x) and (100x).

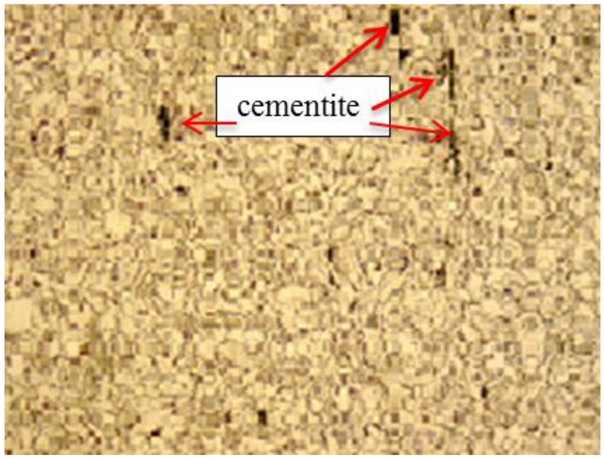

Figure (6): Microstructure of bucket metal sample (20x)

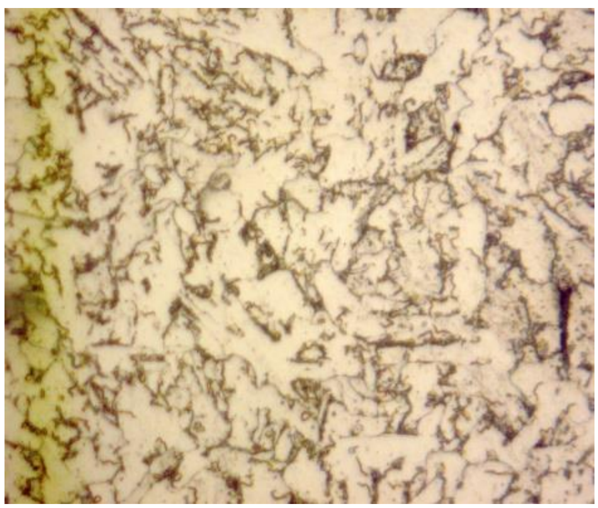

Figure (7): Microstructure of bucket metal sample (100x)

The metallurgical analysis revealed that the microstructure is ferrite and perlite; it is evident that there is a significant amount of ferrite, exceeding 85%, and a small amount of perlite. There is an irregular distribution of the grain boundaries with, the accumulation of cementite in several areas, indicating that the metal has not been heat treated.

5. Conclusion

In this study, a series of tests were conducted on samples of the bucket's metal in order to investigate the underlying cause of cracks occurring at the edges of the cement transport bucket. Various tests were carried out, including chemical analysis, tensile strength testing, hardness testing, and metallurgical analysis. The results of these tests were then compared to the standard specifications for the S235JR steel, which the bucket was made of. Chemical analyses showed that the percentage of carbon and Si are below the required standards. However, the tensile strength, elongation, and hardness were found to be within the recommended range, but the yield strength value is higher than the specified value and exceeds it by more than 100 N/mm2. The metallurgical analysis indicated an irregular distribution of the grain boundaries with, the accumulation of cementite in several areas, indicating that the metal has not been properly heat treated, which may contributed to the cracks occurring at the edges of the cement transport bucket.

References

[1] N. Yashaswini, Raju. B and A. Purushottham, ―Design and optimization of bucket elevator through finite element analysis‖, International Journal of Mechanical Engineering Volume 2, Issue 9, 2014.
[2] Shinde, S. T., Dixit, V. S., Nukulwar, M. R., & Pimpale, S. S. (2016). Material optimization and Modal Analysis of Elevator bucket
[3] Barshi, A., Singh, K., Patil, O., & Yadav, S. (2019). Design, analysis and optimization of bucket elevator. International Journal of Advanced Engineering and Innovative Technology, 1(1), 85-89.
[4] Design and Fabrication of Bucket Elevator. Sheetal Tanaji Jadhav1, Vrushabh Prakash Shete2, Samruddhi Sambhaji More3, Akshay Bajarang Desai4, Satyajit Diliprao Ghorpade5 ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429Volume 9 Issue VI Jun 2021
[5] Snehal Patel, Sumant Patel, Jigar Patel, A Review on Design and Analysis of Bucket Elevator, International Journal of Engineering Research and Applications Vol. 2, Issue 5, 2012.

[6] F. J. C. Rademacher, ―Non-Spill Discharge Characteristics of Bucket Elevators‖, Powder Technology, Volume 22, Issue 10, 2014.

[7] Edward Yin, Onumus Muvengei, John Kihiu, Kenneth Njoroge,‖Failure Analysis on Conveyor Chain Links of a Central Bucket Elevator‖, IOSR Journal of Mechanical and Civil Engineering Volume 13, Issue 4 Ver. VII (2016), PP 56-63.

[8] Ghazi Abu Taher, Yousuf Howlader, Md. Asheke Rabbi, Fahim Ahmed Touqir, ―Automation of Material Handling with Bucket Elevator and Belt Conveyor‖, International Journal of Scientific and Research Publications, Volume 4, Issue 3, 2014

[9] Kulkarni Digambar Rangnathrao, Prof Swami M.C, Mr. Shinde, Experimental Analysis of Bucket Elevator Chain Breakdown‖, International Research Journal of Engineering and Technology Volume: 05 Issue: 05 | 2018.

[10] Lunawat, A. S. H., & More, K. C. (2018). DESIGN AND ANALYSIS OF BUCKET ELAVATOR. Asian Journal For Convergence In Technology (AJCT) ISSN-2350-1146, 4(3).

[11] https://ahcc.ly/en.

[12] Lipiński, T. (2022). Corrosion of the S235JR Carbon Steel after Normalizing and Overheating Annealing in 2.5% Sulphuric Acid at Room Temperature. Materials Research Proceedings, 24.

[13] Boniardi, M. V., & Casaroli, A. Steel Metallurgy-Volume II, Lucefin SpA.

[14] European Committee for Standardization (CEN). (2004). EN 10025-2:2004 - Hot rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels

[15] ASTM E8 [Annual book of ASTM standards (2004) American society for Testing of Materials. Philadelphia, PA.

[16] D.William callister. Jr. "Materials science and Engineering An Introduction" , 7th ed., 2007.

[17] European Committee for Standardization (CEN). (2004). EN 10025-2:2004 - Hot rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels.

[18] https://www.portlandbolt.com/technical/steel-hardness-conversion.