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MICROSTRUCTURAL AND MECHANICAL PROPERTIES OF FAILED COUPLING WITH AN AIRLOCK IN A FLOUR MILL

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ABSTRACT

In the present work, we report the microstructural and mechanical properties of failed coupling with an airlock in a flour mill. The coupling which was made of aluminium alloy is used to transmit torque from the electric motor to an airlock used on a flour mill production line. The fracture that occurred at the root of the teeth of the coupling was investigated using various tests and analysis. The tests includes: macro examination, micro-structural examination, composition analysis, hardness and tensile test were employed for this investigation. From the tests carried out, it was observed from the macro examination that the coupling undergoes a brittle failure. However, composition analysis revealed a relatively high weight composition of aluminium (87.5 wt. %) suggesting that the coupling was made of aluminium based alloy. The significant presence of Cu and Zn at 2.77 wt. % and 1.03 wt. % respectively indicates that the alloying elements were mainly of copper and zinc. The tensile test result revealed that the material has an ultimate tensile strength of 178 N/mm^2 which is comparatively lower than most aluminium alloys. This might be as a result of the high Si composition of 7.24 wt. % observed from the chemical compositional analysis. The hardness result showed the Brinell hardness of the fractured samples as 76.53 BHN. The microstructure of the coupling at three different sections gave three *different micrographs, further proving uneven distribution of the aluminium alloy element. Thus, the presence of Si at relatively high percentage, often intended to increase the strength, wear resistance and weldability may be detrimental to the coupling ductility and tensile strength and may have contributed to the early fracture of the coupling.*

Keywords: Coupling, Failure Analysis, Mechanical Properties, Microstructure.

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1. INTRODUCTION

Failure is one of the most important aspects of material behaviour, because it directly influences the selection of a material for a particular application. The methods of manufacturing and the service life of the component can be altered when a material fails. Because of the many factors involved, the failure and fracture of materials are a complex area of study [1].Failure analysis deals with the determination of the causes of the failure of engineering parts or components [2]. It is an important discipline in many branches of manufacturing industry. The failure analysis process relies on collecting failed components for subsequent examination of the cause or causes of failure using a wide array of methods. Since material failures can be so costly in terms of human suffering and financial losses, parties harmed by a failure often seek recompense for their damages. Thus, failure analyses are also performed to assign blame [2]. Machines and structures have failed in service without warning and with disastrous consequences. Some of these disastrous consequences have been seen in the collapse of bridges and buildings, massive splitting of ships and tankers, explosions in chemical factories, in-flight disintegration of aircraft and space vehicles etc. The consequential damages of these mishaps are humanly unforgivable and can never be forgotten by mankind. Needless it is to emphasize the importance of the prompt investigation of these failures in order to ascertain their causes, inform the public, and to take remedial actions to prevent their recurrence [3].Childs [4] explained that material is a factor which might make components fail when they are not well selected for specific applications. Before selecting a material for certain applications the manufacturing process, functionality, cost and environmental effects are to be considered [5]. Most importantly, factors such as right selection, correct installation and regular maintenance [6] are essential condition for averting material/system failure.

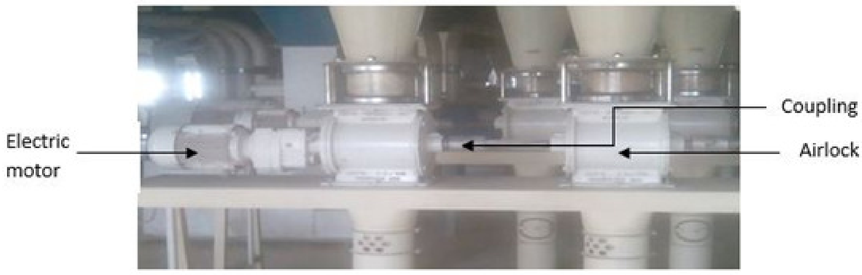

Figure 1. The coupling during operation

The aim of this study is to investigate the fracture that occurred at the root of the teeth of the coupling used with an airlock in a flour mill production line. The coupling was produced locally by sand casting, the choice of sand casting was informed by the relatively cheap process involved as compared to other manufacturing processes.

2. MATERIALS AND METHODS

2.1. Materials

The sample component of the complete coupling (shown in Figure 2b) and failed coupling used for this study as shown in Figure 2a were sourced at a Flour Mills in Ilorin, Kwara State, Nigeria.

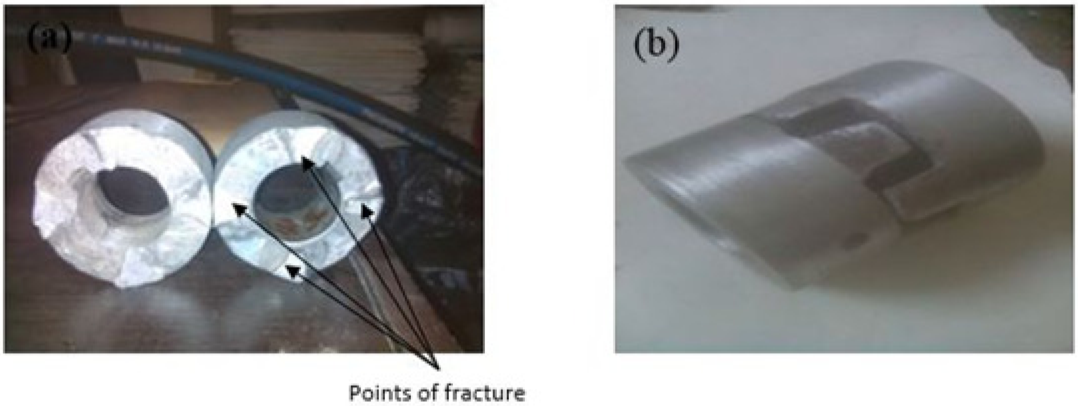

Figure 2(a-b). Failed coupling and complete coupling.

The failure analysis of the coupling was carried out by macro examination, micro-structural examination, composition analysis, hardness and tensile test.

The flow diagram in Figure 3 gives an insight of the overall study.

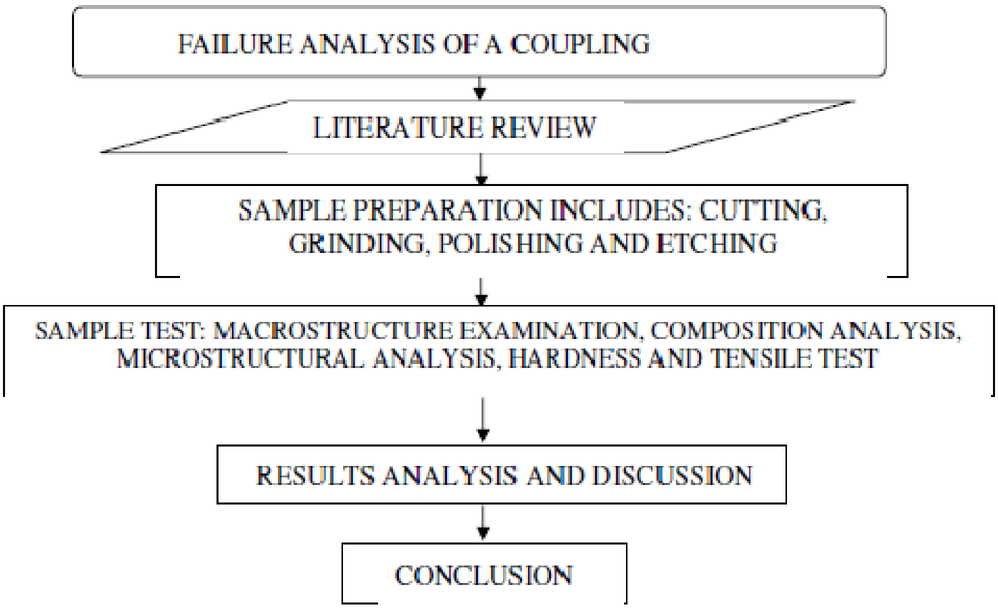

Figure 3. Flow diagram of the study

2.2. Methods

Different standard cutting technique can be used to section aluminium and its alloys.However, the damage produced at the surface varies substantially with different procedures. All cutting operation produces damage, but the degree of damage and depth of damage does vary with method chosen. The cutting process was performed on a work bench placing the sample on the vice and a hack saw was employed for cutting.

2.3. Chemical Composition Analysis

The chemical analysis of the sample was carried out using optical light emission spectrometer (SPECTRO-06000939). The surface of the sample was well grounded and taken to a spectrometer for spark emission. The result is as presented in Table1.

2.4. Tensile Test

A sectioned sample of 30 x 26 x 16.5 mm was tested. It was placed into a Monsanto Hounsfield tensometer and was subjected to tensile load until a plastic deformation was observed, following [7,8] standard. The hardness of the sample was determined on a Brinell hardness tester with an indenter of diameter 10 mm and load 500 Kg with a dwell time of 12s according to [9,10]. The microstructure of the sample was examined on a digital metallurgical microscope, Accuscope microscope with camera (Serial no 0524011). This was after grinding using silicon carbide papers of different grades placed on the grinding machine in the order of 320, 400, 600, 800 grits [7]. The sectioned surface was then placed on the polisher for initial polishing swamped with solution of one micron of silicon carbide solution at 150 rev/min. The process was followed by the final polishing stage with selvt cloth swamped with solution of 0.5 μm Silicon carbide solution to obtain scratch-free mirror surface. The mirror-like surface was etched in 2% nital (98% alcohol and 2% nitric acid). Etched surface was cleaned with clean water and dried under hot air prior to viewing under the metallurgical microscope.

3. RESULT AND DISCUSSIONS

3.1. Macro Examination

Physical examination using the naked eye revealed flat surfaces at points of fracture. This is a characteristic of brittle failure and indicating that the failed coupling may have experienced a brittle failure.The crack movement is perpendicular to the applied stress which is cyclic. This also supports the earlier prediction that the coupling may have experienced a brittle failure.

3.2. Chemical Properties

The compositional analysis showing the weight percentage of different element in the fractured coupling sample in Table 1 indicates a relatively high weight composition of aluminium of 87.5 wt. % suggesting that the coupling is made of aluminium based alloy. The significant presence of Cu and Zn at 2.77 wt. % and 1.03 wt. % respectively indicates that the alloying elements are mainly copper and zinc, which are the most common alloying elements used in aluminium alloys. The tolerable percentage of Si is about 2% above which the alloy is increased in strength; 7.24 wt. % in the material implies that Si has been introduced while casting to increase the material strength at the detriment of machinability and ductility. The presence of Si has been studied to be beneficial in Al alloys, and it had been found to improve castability of aluminium alloys by increasing the fluidity and reduction shrinkage [11]. Aluminium alloys usually contain Fe usually resulting from alloy processing, handling and impurities of scraps used as raw materials for casting the coupling[6,11]. However, the presence of Fe at 0.79% increases the hardness of the coupling at the detriment of the tensile strength, although presence of manganese will probably eliminate this effect. The compositional analysis revealed that proper measure might not have been followed during casting, which resulted in inaccurate percentages of aluminium, zinc and copper in the coupling.

Table 1 Chemical compositional analysis of the coupling sample

Elements	Al	Cu	Zn	Si	Fe	Mn	Mg	Cr	Ni	Ti	P	Pb
Wt.%	87.50	2.77	1.03	7.24	0.79	0.172	0.147	0.032	0.191	0.030	0.001	0.080

3.3. Tensile Properties

The stress-strain graph of the fractured coupling in Figure 4 indicate the curve starting from the origin as a straight line, this is because the force increases in direct proportionto the extension of the specimen up to point A. At this point, the extension remains proportional to the applied force, and the sample is said to obey the Hooke's law. This region of the stress-strain curve is called the elastic extension region. The fractured coupling has an ultimate tensile strength of 178 N/mm^2 which is comparatively lower than that of most aluminium alloys. This might be as a result of the high Si composition of 7.24 wt. % observed from the chemical compositional analysis. The low ultimate tensile strength reflects poor tensile properties and might have been a reason for the fracture of the coupling. The origin to the point labeled A is the proportional limit region, where the applied force seems to be proportional to the extension. Above this limit is the elastic limit region labeled B, which is the point in which the sample would return to its original length if the applied force is removed. The plastic deformation region labeled C is the region where the ultimate tensile strength is recorded and the breaking strength is also recorded as the point where the test sampled fractures.

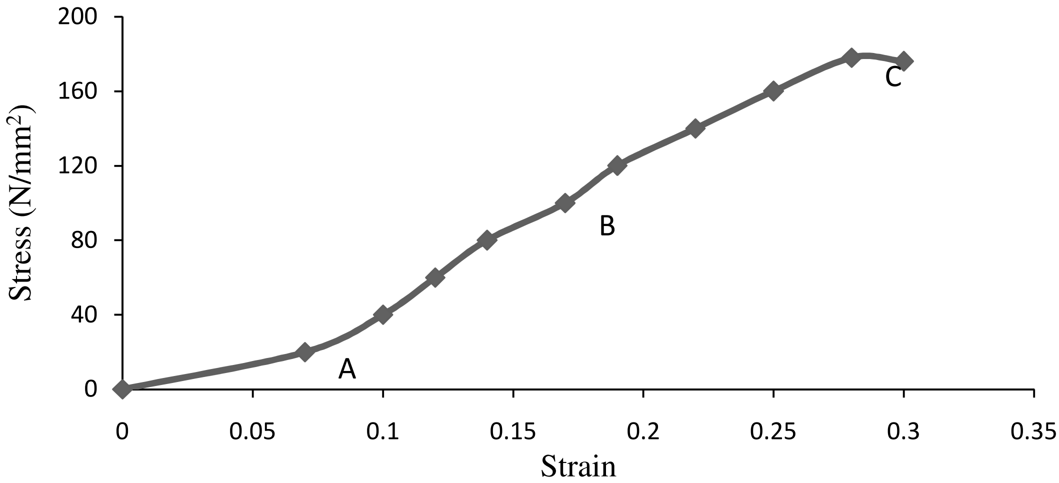

Figure 4. Stress-strain graph of the fractured coupling

3.4. Hardness Properties

The macro-hardness testing was carried out using Brinell hardness testing machine. Results of hardness testing are given in Table 2. From the table, the Brinell hardness of the fractured samples gave 76.53 BHN resulting from calculating the average of the three different values gotten from the three different sections of the coupling shown in the table. The hardness property varied throughout the cross section of the coupling, as a result of the uneven distribution of the alloying elements in the tested coupling. This implies that some sections of the coupling have high hardness property compared to some other parts of the coupling. This might be considered as another cause of the frequent fracture of the coupling.

Table 2 Brinell hardness of the fractured coupling.

Test	1st reading	2nd reading	3rd reading	Average Brinell Hardness
Hardness (BHN)	75.50	77.20	76.90	76.53

3.5. Micro-structural analysis

The microstructure examination of the fractured coupling was carried out at three different parts labeled section A, B and C in Figures 5a-c. A highly coarse precipitation of Zn and Cu compounds with little precipitation of Mg_2Si at the Al matrix boundaries was noticeable in Figure 5a. Mg_2Si is suggested to be the black clusters within the micrographs been observed by [8].

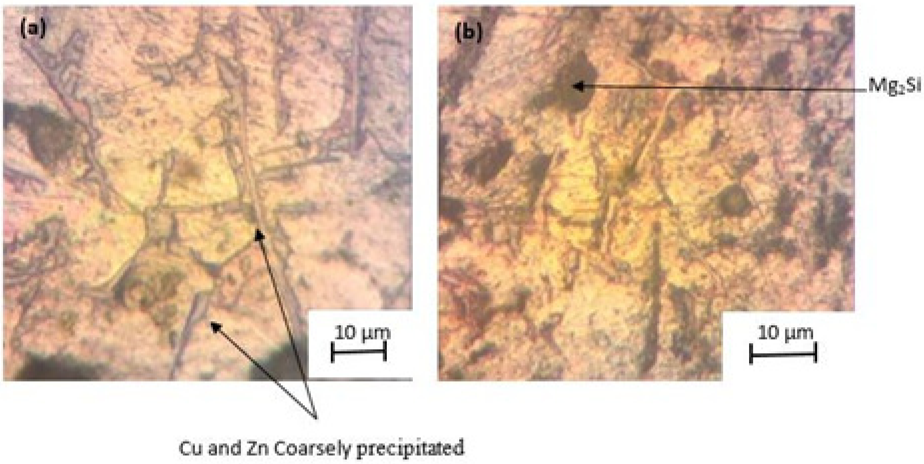

Figure 5a-b. Section A and B of the micrograph.

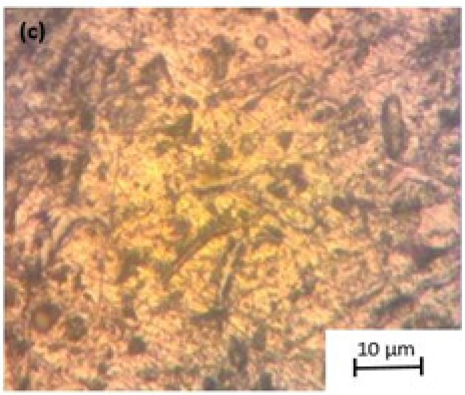

Figure 5c. Section C of the micrograph

Section A of the coupling shows high concentration of the alloying elements serving as reinforcement, making this section more ductile and would exhibit little strength because the elements are not properly distributed within the matrix of the aluminium alloy. Section B shows clusters of Mg_2Si with very little Zn and Cu precipitated within the aluminium alloy matrix. This section would be slightly brittle compared to section A, due to the lack of adequate presence of Zn and Cu reinforcement in this section. Section C shows slight proportional mixture of Mg_2Si, Zn, Cu and Al compounds precipitated within the matrix boundary of the captured region. This section according to the micrographs is the best of the three sections, having proper mixture of the base element and the other alloying elements. Section C exhibits little grain sizes and well-structured grain structures well distributed along the aluminum matrix boundary, causing good intermetallic and interfacial bond within the coupling. Therefore sections A and B can fracture easily compared to section C when force load is applied on the coupling which might have added to the course of coupling failure.

4. CONCLUSIONS

From the results of this investigation, the following conclusions are made;

1. The chemical compositional analysis confirms that the coupling is made up of aluminium based alloy, with the alloying elements copper and zinc.
2. The presence of Si at relatively high percentage, often intended to increase the strength, wear resistance and weldability. This is detrimental to the coupling ductility and tensile strength, which may have contributed to the early fracture of the coupling.
3. The brinell hardness value results from the variation in the hardness property from the three sections of the coupling, indicating that some parts of the coupling is harder than other parts which might be a result of poor mixture of the aluminium alloy while casting.
4. The microstructure of the coupling at three different sections gave three different micrographs further proving uneven distribution of the aluminium alloy element whilecasting.

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REFERENCES

[1] Kalpakjian, S. Schmid,S. *Manufacturing Engineering and Technology*, 5th ed. Upper Saddle River, NJ: Pearson Education, Inc., 2006.

[2] Brooks, C. R. Choudhury,A. *Failure Analysis of Engineering Materials*. New York: McGraw-Hill Education, 2002.

[3] Ramachandran,V., Raghuram,A. C.,Krishnan,R. V., Bhaumik,S. K.Failure Analysis of engineering structures methodology and case histories, 2005.

[4] Childs,P. R. *Mechanical Design*, 2nd ed. Oxford, Elsevier Butterworth-Heinemann, 2004.

[5] Black,R. Design and Manufacture: *An integrated approach*. Hamphire: Palgrave Macmillan, 1996.

[6] Ruland,I. Manufacturing Co. Avoiding Coupling Failure - Considerations in Design Selection, 2010.

[7] Adediran, A.A, Aribo, S, Amuda, M.O.H. Mechanical properties of dual phase steel quenched in bitumen medium, *Leonardo Electronic Journal of Practices and Technologies*, **14**, (26), 2015, pp. 1-16.

[8] ASTM E8/E8M-15a, Standard test methods for tension testing of metallic materials. ASTM International, West Conshohocken, PA, 2015.

[9] ASTM E8M-16, Standard test methods for hardness of metallic materials. ASTM International, West Conshohocken, PA, 2016.

[10] Ikubanni, P.P., Agboola, O.O., Adediran, A.A. Adeleke, A.A., Ogunsemi, B.T., Olabamiji, T.S., Uguru-Okorie, D.C., Osueke, C.O. Experimental data on mechanical properties evaluation of medium carbon steel quenched in different waste media, *Data in Brief*, **20,** 2018, pp. 1224–1228.

[11] Odusote,J. K. Ajayi,P. A. Mechanical properties and microstructure of aluminum cast with zinc and copper additions, *International Journal of Metal casting*, **10**,(4), 2016, pp. 483–490.

[12] Adeosun,S. O., Balogun,S. A., Osoba,L. O., Ayoola,W. A., Oladoye,A. M. Effect of Cu and Zn addition on the mechanical properties of structural aluminum alloy, *Journal of Modern Manufacturing Technology*, **3**(1) 2011, pp. 103-110.