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MATERIAL PERFORMANCE INVESTIGATION ON THE FAILURE OF AN AIRCRAFT (ABT-18) NOSE WHEEL STRUT

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ABSTRACT

The study investigated the cause and mechanism of failure of the nose wheel strut of a trainer aircraft with respect to material selection.Various methods and tests ranging from visual examination via unaided eye and fractography, hardness tests, chemical analysis and microstructural examination were employed for the study. The results show chevrons on the fracture surface which indicates fatigue failure characteristic of brittle fracture. Also, thefractographshowsincidence of a ductile pull and high energy fracture.This is evident by the cone shape of the fractograph and the observed tear.Hardness tests results showed high discrepancy between the values of the failed and undamaged samples indicating loss of strength and ductility in the failed sample as a result of fatigue.

The outcomeof chemical analysis revealed that the component is made from medium carbon steel of the tough grade instead of the required spring steel.Therefore, a major cause of the failurecan be linked to improper material specification for the nose wheel strut.The failure mechanism was further confirmed by microstructural examination which revealed fatigue cracks propagated from inclusions in the microstructure of the failed sample.

KEYWORDS: Nose Wheel Strut, Fatigue, Failure, Fractograph, Strength, Ductility

INTRODUCTION

Aircraft represents the quickest and most efficient means of transport, but people are still afraid of flying[1]. The reason probably lies in the near impossibility of surviving an aircraft crash. Aircraft crashes may be due to several factors such as materials failure (impact damage, fatigue, hidden defects, corrosion and quick crack propagation), adverse atmospheric conditions, and human errors.Public acceptability of aviation injuries is extremely low, and since aviation is inherently sensitive to failures, there is great reliance on design and manufacturing approaches that minimize the risk of losing an aircraft. Several approaches to aircraft design and construction have evolved since the beginning of aviation. Some of such approaches include fail safe, safe life and crash resistance. However, things still go wrong and forensic engineering is a key part of maintaining aviation safety. It is therefore hardly surprising that forensic engineering is a critically important part of operating and maintaining military fleets[2].

Military helicopters provide ideal conditions for the nucleation and propagation of failure damage. Examples include dust-laden environments, heavy and repeated exposure to salt water and operation from rough airstrips. It is often assumed that failures are a direct consequence of these extreme operating conditions. The failure of a component on a military helicopter can have wide reaching implications involving flight safety, fleet status and operational requirements

[3].The necessity of ensuring the required durability of particular construction elements, engine, separate installations and even minor equipment details is a key factor. One of such elements is the landing gear, which has direct influence on safety of the aircraft during the most neuralgic phases of the flight (i.e. take-off and landing).

The aircraft under study is a locally assembled ABT-18 aircraft which is being used for pilot training. A major component failure of the aircraft has to do with itslanding gear which is the main point of contact between the aircraft and the ground as well as supports the weight of the aircraft and its crew members.

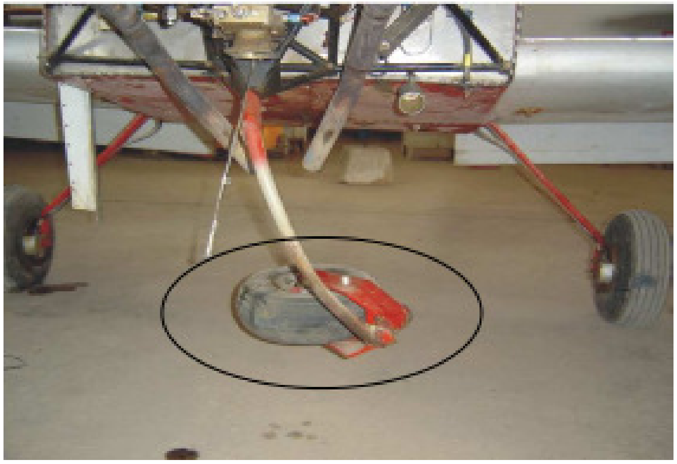

Plate 1: The Failed Strut

The landing gear comprises of the nose wheel as depicted by the circle and two main landinggear assemblies. The nose wheel of the ABT-18 aircraft is designed to be equipped with spring steel shock absorbers underlain with wood and wrapped with fiber glass fairing while the former trainer aircraft such as Piaggo and Bulldog makes use of oleo-pneumatic shock absorbers.

It has been observed that during the years of conducting flying training, several incidents have been recorded whereby the nose wheel strut failed particularly during hard landings. These incidents had resulted in severe damage to the propeller, engine, airframe and sometimes injury to Pilots.This in turn contributes to delays and disruption of Pilot trainings. Since the ABT-18 aircraft is for training purposes, hard landings cannot be ruled out.

More so, various reasons can be adduced to be the cause of its strut failure.Landing gears are usually subjected to severe environmental conditions, such as temperatures, climates and operational situations such as runway conditions among others. A study reported the rupture of the nose landing gear of a military transport aircraft, EMB 121 – Xingu, which collapsed during take-off procedure.

A comparison of its composition within the range of commercial alloys available indicated that the material is a micro alloyed Vanadium steel [4].Forensic engineering identifies precautions to be taken in aircraft design and manufacture in order to avoid future failures. It therefore became necessary to carry out an investigation of the failure of the nose wheel strut.

MATERIALS & METHODS

Undamagedand failed nose wheel strut samples (Plates 2 and 3) designated as U and F respectively was obtained as shown.

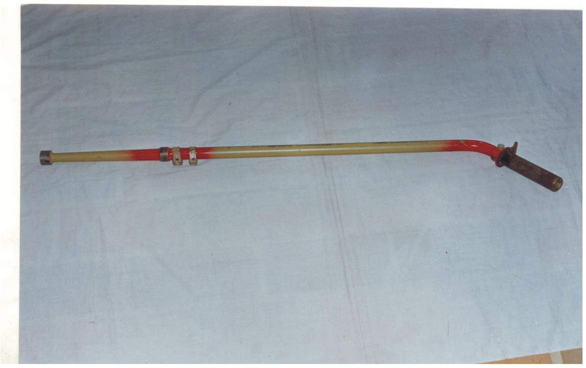

Plate 2: As-Received Undamaged Sample, U

Plate 3: As-Received Failed Sample, F

In this study, the samples were subjected to various tests. The experimental investigations performed include visual inspection with the unaided eye and fractography using a Leica M400 microscope.Hardness tests were carried out to determine the Brinell hardness number of the specimens.The universal tensile/compression testing machineHarrison M300was employed for the hardness test.

The measurements were replicated on two different surface areas for each sample.In this case, the ability of the material to resist plastic deformation under indentation was used to evaluate hardness.Also, the chemical compositions of the specimens were determined using the atomic absorption spectrometer while microstructural examination was achieved using a metallurgical optical microscope.

RESULTS & DISCUSSIONS

Visual Inspection

Visual inspection via unaided eyeshowed a buckled and fractured strut material with V-shaped markings (Chevrons) on the fracture surface. It showed that the markings converge to the origin of the fracture.

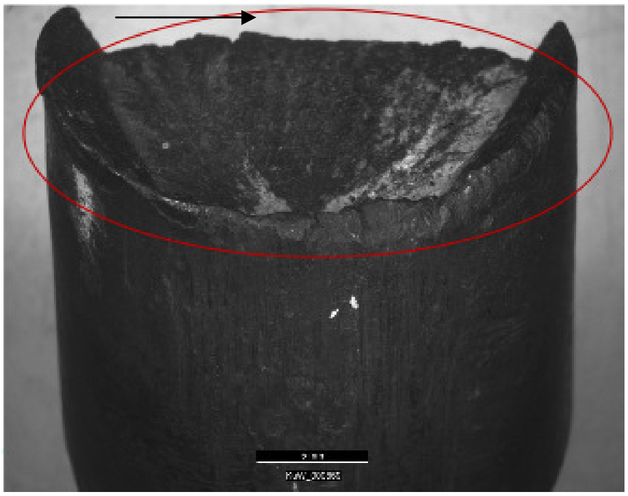

Plate 4: The Fracture Surface

The fractograph ispresented in Plate 4. It showsincidence of a ductile pull and high energy fracture.This is evident by the cone shape of the fractograph and the observed tear, depicted by the circled part.Further investigation of plate 4 reveals no evidence of hole. This nullifies the assumption that a hole may be the cause of failure. However, it is worthy of note that a hole is not seen, the presence of micro-pores might beassociated with the high energy fracture. More so, the presence of chevrons is characteristic of brittle fracture associated with fatigue.This kind of failure produces no gross but very little mass deformation. Such a fracture is sudden, thus produces disastrous consequences [5].

Hardness Tests

The results of the hardness tests are presented in Table 2.The percentage discrepancy between the failed and undamaged samples is a bit high. The loss in hardness, according to [6] may be a result of fatigue behaviour which is marked by loss of strength and loss of ductility in sample F.

Table 1: Hardness Values (HBr) of Undamaged & Failed Nose Wheel Strut Samples

HBR				
		1	2	Mean
Sample U		524	524	524
Sample F		432	432	432
% Discrepancy				17.6

Chemical Analysis

Chemical analysis was carried out on both failed and undamaged samples for the purpose of comparism. The strut material ought to have been spring steel since the aircraft was designed without a shock absorber.The spring properties are to enable the materials absorb shock on impact. Thus, chemical analysis was done in order to ascertain if the material was of the desired composition.The results obtained are shown in Table 2.

Table 2: Chemical Analysis of Undamaged & Failed Nose Wheel Strut Samples

Composition(%)		
Element	**Undamaged Sample**	**Failed Sample**
Fe	96.8	96.82
C	0.4	0.426
Si	0.319	0.074
Mn	0.75	0.931
P	0.005	0.015
S	0.035	0.021
Cr	0.887	0.917
Mo	0.01	0.026
Ni	0.055	0.208
Al	0.013	0.007
Co	0.013	0.007
Cu	0.299	0.129
Ti	0.007	0.004
V	0.191	0.177
B	-	0.002
Nb	-	0.015
Sn	-	0.001
Mg	-	0.008

It has been shown that carbon steel with carbon content between 0.3 and 0.6% is termed medium carbon steel [7]. While those with lower and higher carbon contents are respectively classified as mild and high carbon steel. Likewise, AISI classified steel whose carbon content ranges between 0.29% - 0.54% (for example AISI 1040 steel) to be medium carbon steel [8].

The carbon content of the strut is lower than 0.65% – 0.85% which is adequate for springs.

The strut material contains Cr, V and Mn in sufficient amounts which cause the hardened structure to be quite tough and corrosion resistant. However, the percentages of Silicon in both samples are lower than 1.90% - 2.40% required for spring steel.

This is a deficiency in material property since it is Silicon that produces spring property in materials. At least 0.50% Ni and 0.60% Mo is needed for springs. The Nickel will improve the hardenability of the steel while Molybdenum will increase the strength and toughness of the steel. Based on these findings, the nose wheel strut material can be classified as medium carbon steel of the tough grade withspecification number 0050 [9].

Based on the aforementioned, it can be concluded that inconsistent design details and improper material specification may be the cause of the variations present in the chemical composition of both samples. The buckling may have occurred as a result of the insufficient shock absorbing property of the nose wheel strut material.

Microstructural Examination

Results of microstructural examination at magnification of X200 are shown in Plates 5 and 6.

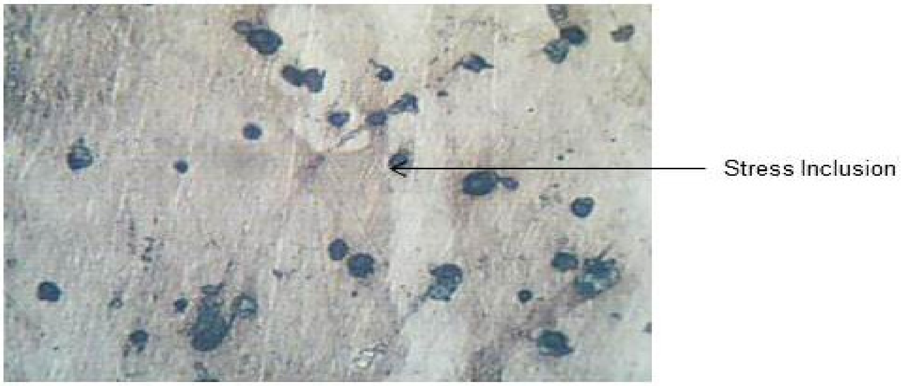

Plate 5: Optical View of Undamaged Strut Sample at X200

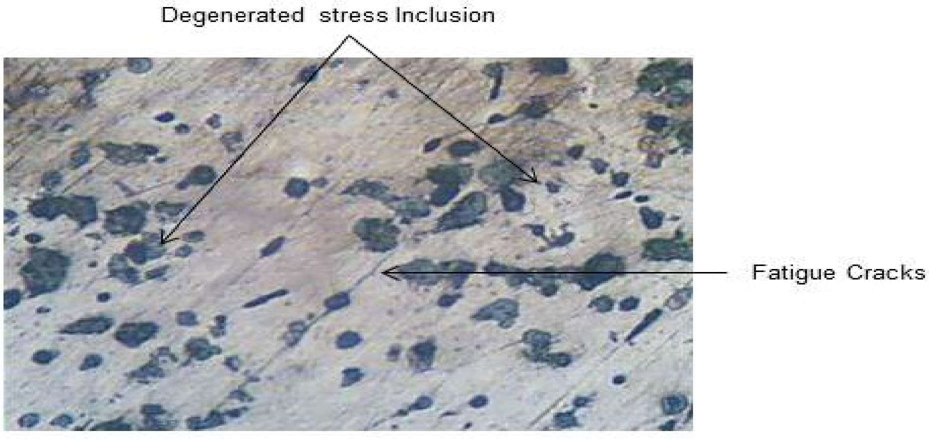

Plate 6: Optical View of Failed Strut Sample at X200 Showing Fatigue Cracks

Microstructural examination of the both samples at magnification of X200 shows pearlite in ferrite matrix and the presence of inclusions, which are more predominant in the structure of the failed strut, hence; resulting into pitting. Some of them are seen as degenerated inclusions. The inclusions acted as stress raisers and fatigue initiation sites which eventually culminated into fatigue cracks and final fracture.

CONCLUSIONS

Based on the Investigations & Experiments the following conclusions can be drawn

1. The nose wheel strut failed by brittle fracture associated with fatigue failures.
2. The loss in strength and ductility of the failed sample material was due to the failed state of the material and not a difference in materials.
3. Compositional analysis revealed medium carbon steel of the tough grade instead of the required high strength spring steel.
4. The main reason for the sudden buckling of the nose wheel strut can be linked to wrong material specification for the nose wheel strut. This is also backed by lower strength, toughness, hardenability and a lack of spring property of the material employed for the nose wheel strut.
5. Inclusions present in the microstructure of both gears acted as stress raisers and fatigue initiation sites which led to the failure of sample F.

REFERENCES

1. Carosena M, Giovanni MC, Squillace A, Vitiello A (2006) Non-Destructive Evaluation of Aerospace Materials With Lock-in Thermography, International Journal on Engineering Failure Analysis, Vol. 1, Pp 380-381.
2. Graham C (2005) Failures in Military Aircraft, International Journal on Engineering Failure Analysis, Vol.12, Pp755- 771.
3. Pitt C, Symonds N (2006) Military Helicopters: Have the Seeds of future Accidents Already Been Sown", International Journal on Engineering Failure Analysis, Vol. 1, P 493.
4. Franco LAL, Lourenco NJ, Graca MLA, Silva OMM, De Campos PP, Von DoIIinger CFA (2006) Fatigue Fracture of A Nose Landing Gear in a Military Transport Aircraft, International Journal on Engineering Failure Analysis, Vol. 13, Pp 474-479.
5. Khana OP (1995) Materials Science and Metallurgy Part 1.
6. YuWZ,XuXI (2005) Failure Analysis of Diesel Engine Rocker Arms, Abstract on Engineering Failure Analysis.
7. Lindberg RA (1977) Processes and Materials of Manufacture, 2nd Ed, Allyn and Bacon, Boston MD, USA.
8. Smith WF, Hashemi J (2006) Foundations of Materials Science and Engineering, 4th Edition, McGraw-Hill, P388.
9. American Foundry men's Society (1957) Cast Metals Handbook, Fourth Edition.