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Landing Gear Shock Strut Heat Damage

RATIONALE

Landing Gear Shock Strut Heat Damage has been recorded as a problem for at least three decades. Airline experience has shown that, under certain load conditions heat damage can occur between high-strength steel, chrome-plated or bare, surfaces and aluminum-nickel-bronze bearing materials. This has resulted in the generation of severe thermal spikes over small discrete areas that have caused cracking of the high-strength steel. Although there have been only a handful of component failures, that have been catastrophic, repairing the damage has been time consuming and expensive. Sometimes the damage is deep enough to warrant scrapping an expensive landing gear component. All of this adds greatly to the cost of ownership. This report describes a specific design change as a solution to this long time problem.

1. INTRODUCTION

The purpose of this report is to outline the type of damage referred to as "Ladder Cracking". Discuss how it is being repaired and describe the use of a bearing material that has resolved this problem without introducing other problems.

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LIST OF FIGURES

2. REFERENCES

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of the other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

AIR5883 Landing Shock Struts Bearing Selection

AIR5885 Landing Gear Common Repairs

ARP4915 Disposition of Landing Gear Components Involved in Accidents/Incidents

AIR1594 Plain Bearing Selection for Landing Gear Applications

2.2 Other Publications

AD-D127069 CONSIDERATION OF MECHANICAL, PHYSICAL, AND CHEMICAL PROPERTIES IN BEARING SELECTION FOR LANDING GEAR OF LARGE TRANSPORT AIRCRAFT. Author: Fewtrell, H. E. published 1983. http://ammtiac.alionscience.com/ammt/iacdocs.do?B119661

3. BACKGROUND

3.1 Airline experience has shown that, under certain load conditions, Aluminum nickel bronze bearings operating on bare and chrome plated high strength steel, has resulted in the generation of severe thermal spikes over small discrete areas which have caused cracking of the steel with in some cases, resulting in catastrophic failures.[1]

3.2 Landing Gear Configuration

A typical landing gear that encounters this type of damage is shown in Figure 1 these are of the cantilever design.

[1] See Reference Para 3.5 for other testing.

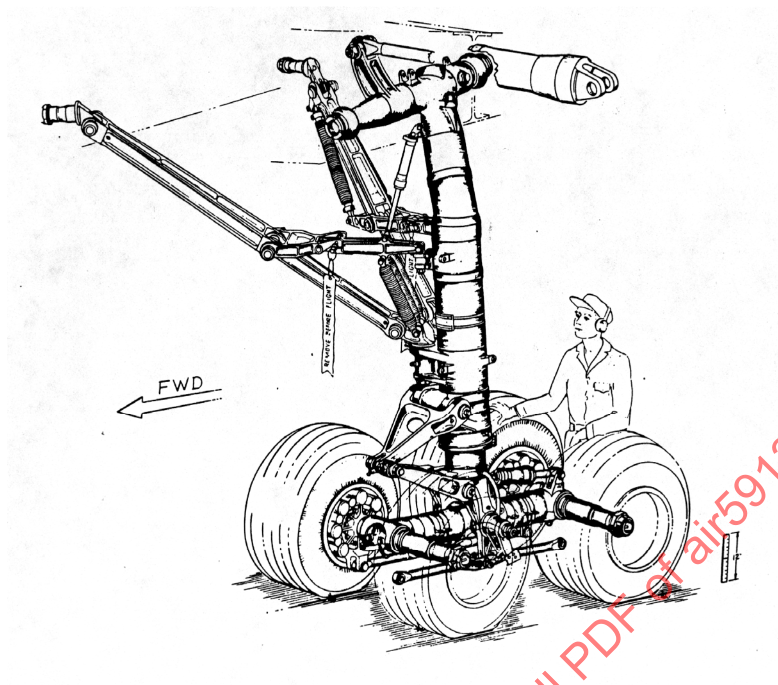

FIGURE 1 – 767 MAIN GEAR

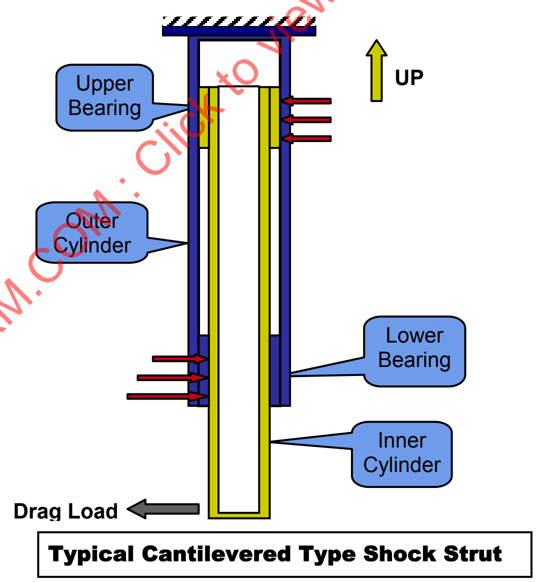

FIGURE 2 – SHOCK STRUT SKETCH

The type of strut illustrated in Figure 2, comprises of a piston/inner cylinder supported by and able to slide inside the outer cylinder. Drag and side loads exert a considerable force on each of the sliding bearings which are usually have a designed projected area bearing pressure of around 6000 psi. However, due to deflections the bearing loads are concentrated at the open end of the lower bearing and they can be considerably higher than 6000 psi.

There have been many different design concepts to alleviate the problem of high bearing pressures. Self aligning, bell mouthed, non-metallic and others have met with some success.

3.3 Heat Damage

The type of heat damage that is encountered in landing gear shock struts reveals itself as streaks or travel marks on chrome plated pistons. It is usually not detectable by the naked eye until it is evidenced by plating breakdown in the form of “Ladder Cracks” (see Figure 3). These cracks sometimes penetrate into the substrate material and have led to a structural failure or rejection of the part.

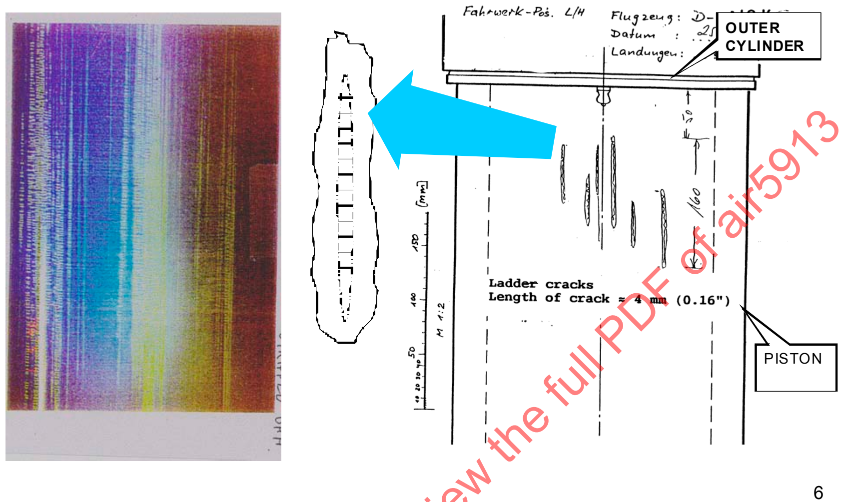

FIGURE 3 – LADDER CRACKS

This damage is caused by rapid motion accompanied by high bearing pressure in a localized area. This type of action generates a localized high temperature sufficient to produce over-tempered and un-tempered martensite in the low alloy steel that most shock strut inner and outer cylinders are made from. The cracking occurs in the un-tempered areas. The cracks do not usually propagate out of this area as in most cases the damage is in the compressive area of the inner cylinder. A forward raked gear is a concern as the cracks may propagate in tension areas of the cylinder.

3.4 Discovery

The heat damage is usually discovered during overhaul. The general method of detection is Magnetic Particle Inspection and/or Dye Penetrant inspection of the plated piston. Detection through the chrome is often difficult and the damage is not detected until the chrome plate has been stripped and the part has been Nital Etched. Heat damage has also been found on the inside of steel outer cylinders in the area where the upper bearing slides.

3.5 Repair

Repair is usually accomplished by a general reduction of the piston outside diameter followed by local grinding in the areas of most damage. If, after this operation, the part is still capable of being returned to service, it receives plating. The depressed areas are filled with nickel plate up to the diameter of the surrounding area. The piston is then chrome plated and ground to the original finished diameter. It has been observed also that parts that are repaired with sulphamate nickel plating and re-chrome plated do not usually exhibit ladder cracking after return to service. The common belief is that the nickel acts as a heat sink, between the chrome and the metal substrate.

Engineering usually assesses any removal of damage on the inside of outer cylinders. How it will affect the shock strut performance is considered.

It is unfortunate that repairs of this nature have become woven into the fabric of landing gear overhaul and are taken for granted. Considerable savings can be realized if this type of damage could be eliminated.

4. SOLUTION

4.1 Design

Almost all cantilever type shock struts use metallic upper and lower bearings such as Aluminum Nickel Bronze. These bearings slide on chrome plated and ground (inner cylinders or pistons) and bare steel inside diameters of outer cylinders. The use of these materials has been the norm since the 1960's and in some cases airlines specified the use of Al-Ni-Bronze bearings. A non-metallic material called "MICARTA" [2] a phenolic resin laminated material was used but it had a problem in as much as it became swollen when immersed in hydraulic fluid and instead of working like a bearing it became a good brake. Numerous other materials are also used for the upper and lower bearings applications with various degrees of success. It is believed that Dacron lined bearings were less problematic than fiberglass woven bearings.

As airplanes got larger and more complex, landing gears got larger and truck beams were added to provide good floatation. Overhauls revealed heat damage.

It was apparent that a bearing material was needed that produced a lower friction value and reduced the friction-generated heat. As well as reducing the friction, the bearings needed to be durable so that it would last at least to the first overhaul.

4.2 Solution Research (The search for a bearing material)

A series of tests were run using low alloy steel plates, with 16 micro-inches finished bare steel, chrome plated or Tungsten Carbide coating on each side. A clamping fixture was used to apply a force to both sides of the plate through bearing pads of a known area. The plate was then pulled through the clamped pads at 3-10 fps velocities with pad pressures up to 60 kpsi. This was done with the pads immersed in MIL-PRF-5606 with additives and dry. Figure 4 illustrates the test set-up.

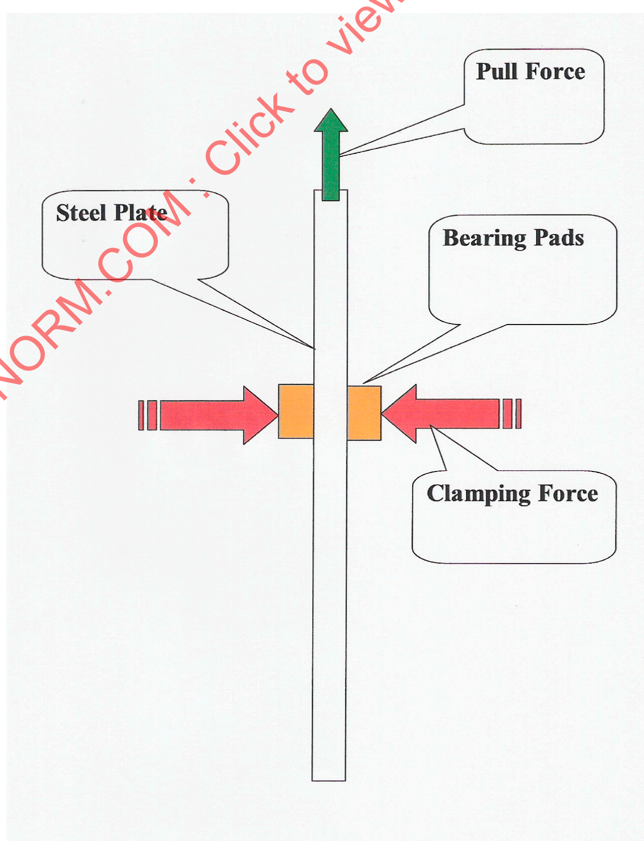

FIGURE 4 – TEST SETUP

[2] www.norplex-micarta.com

The first objective was to reproduce the heat damage encountered in landing gear shock struts using the same combination of bearing materials and cylinder finishes that was aluminum nickel bronze running on chrome plate and bare low alloy steel.

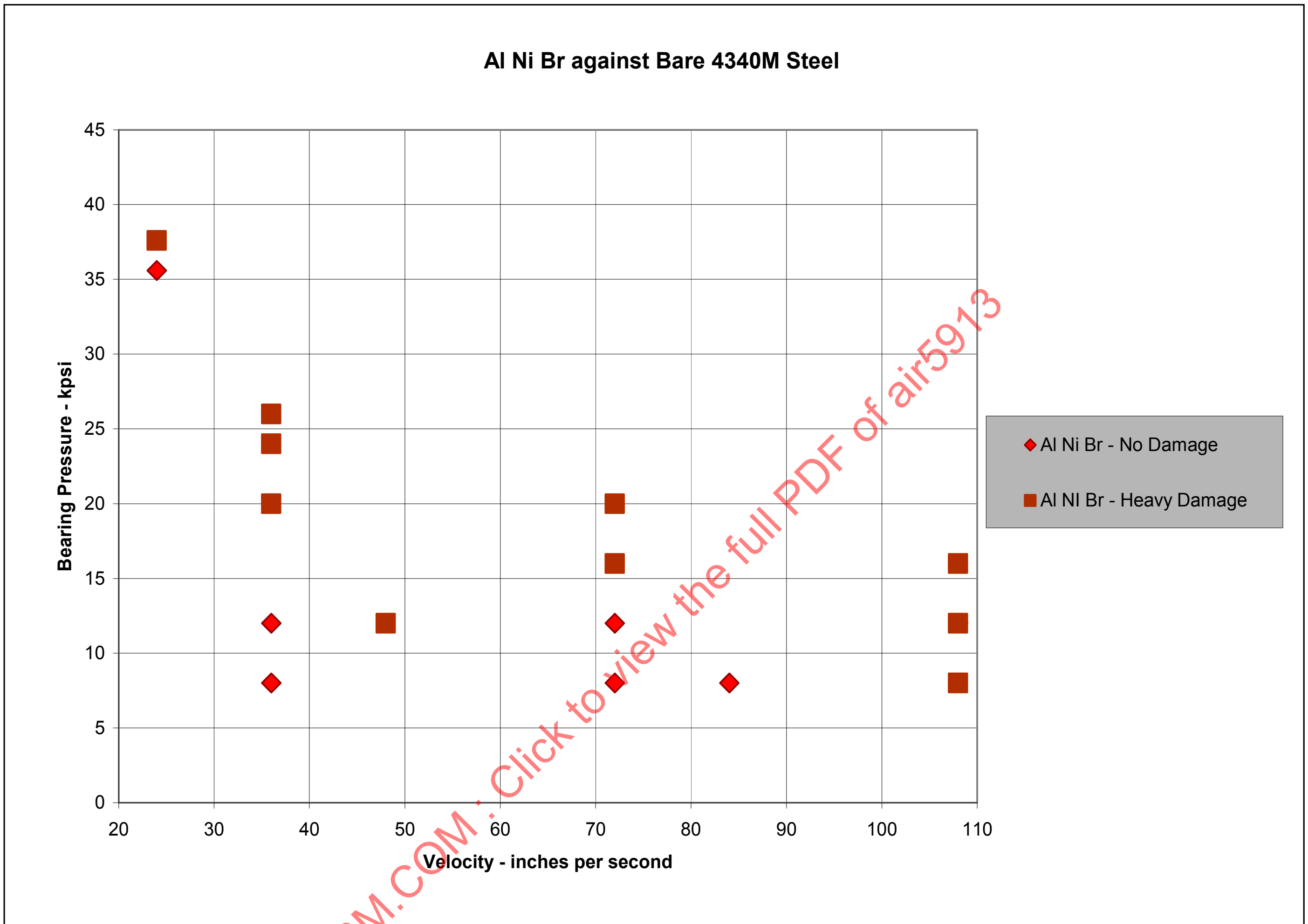

FIGURE 5 – BASELINE TEST

The heat damage was reproduced using this test method. Ladder Cracking was not produced in this test. Having established the heat damage threshold (see Figure 5), various other bearing materials were tested at the same settings. The results are shown in Figure 6. Figure 7 shows data obtained from some other materials that were tested. Copper Beryllium did not perform well. Dyflon [3] and Kentlon [4] were non metallic coatings which showed little durability.

Heat damage was also produced with chrome plated steel plates. Inspection of the plates for heat damage entailed stripping the chrome plate and nital etching the base material. This, at the time, was time consuming and expensive. Limited funds and time led to concentrating on bare steel plates. There was also very limited testing of tungsten carbide coated steel plates.

[3] Southwest Products, AHR Aerospace Bearing Division. www.ahrinternational.com/ahr_aerospace.htm
[4] Southwest Products, AHR Aerospace Bearing Division. www.ahrinternational.com/ahr_aerospace.htm

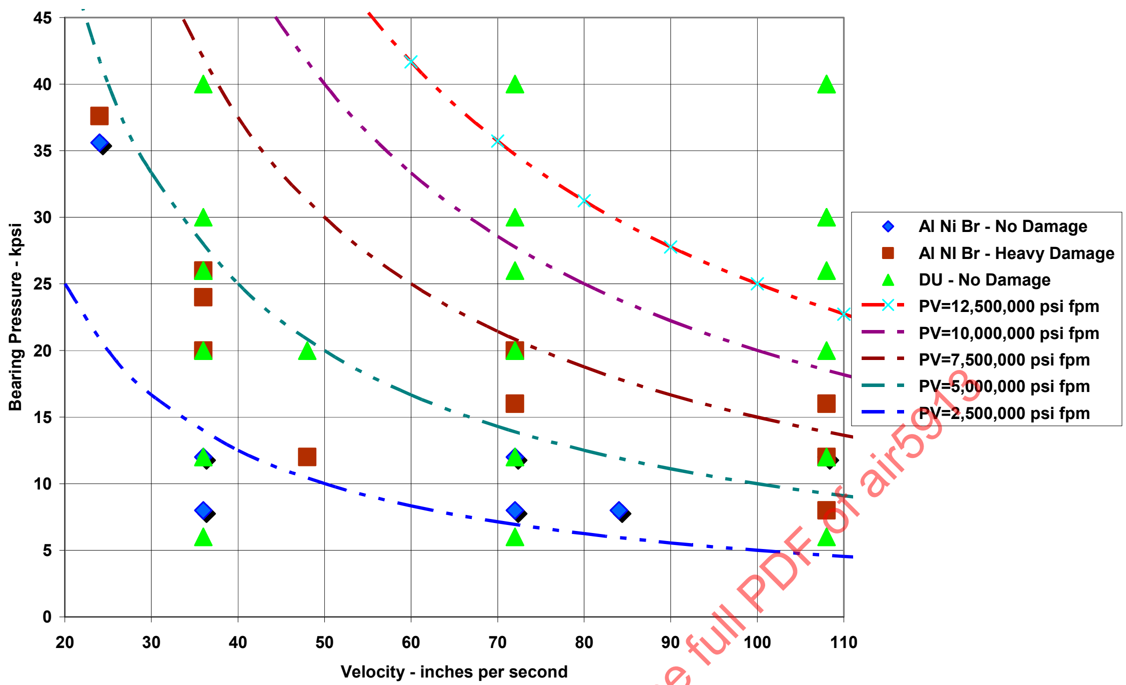

FIGURE 6 – HEAT DAMAGE COMBINED RESULTS

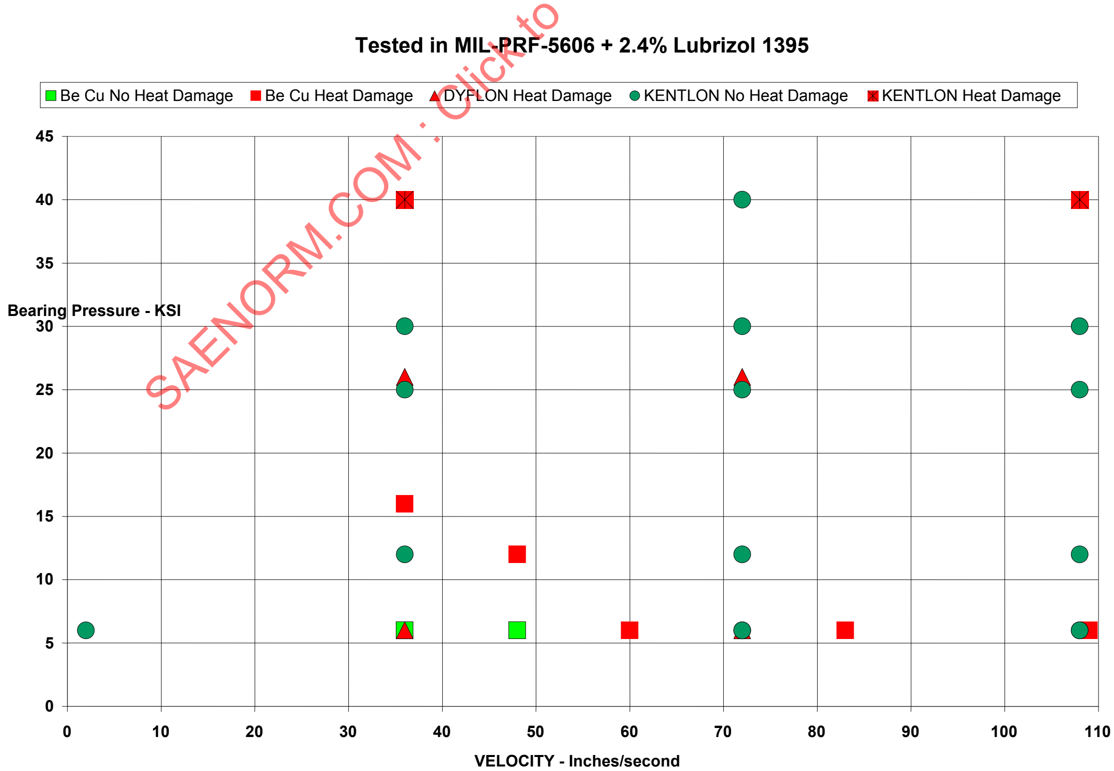

FIGURE 7 – OTHER MATERIAL TESTING