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Failure Mode Analysis Of Torsion Shaft In Garrett-5 Engine Using Two Test Pieces

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ABSTRACT

This work deals with *"**Failure Analysis of Internal splines in Torsion Shaft**"* of "TPE 331-5-252D - GARRET ENGINE" which is used in Dornier aircraft. Garret Engine is a type of air breathing engine. It comes under the category of Turboprop engines of Gas turbine engine. As separate shafts are used for propeller and turbine, this aids them to rotate at different RPM. A torsion shaft is used to transmit the torque from main shaft to propeller shaft. Torsion shaft is used to give a deflection which is also used to measure the torque of the engine. This torsion shaft is internally connected with the main power transmission shaft and its other end is coupled to a coupler shaft with engagement of its internal splines to the external splines of coupler shaft. Further this coupler connects to the gearing system and transmits power to the propeller shaft. Due to Continues variable load over internal splines, it is subjected to high rate of wear and tear. This problem can be rectified by *Failure Mode Analysis Method*, in which heat treatment process of torsion shaft is being carried out. Two test pieces are heat treated separately at different temperatures of 580^{0}C and 540^{0}C at variable time durations. Tuffriding which is a Liquid nitriding process is done with this two test pieces and results are analyzed. The hardness of the material is increased to desired values and its life time is also increased which overcomes the problem.

Keywords- Coupler, Splines, Torsion Shaft, Tuffriding, Wear.

I. INTRODUCTION

Torsion shaft is one of the power transmitting device in Garret Engine. Its left end is coupled with main shaft and right end is coupled with coupler shaft. One of its end with external teeth is engaged with internal splines of main shaft and other end is coupled to a coupler shaft with engagement of internal splines to the external teeth. Further this coupler connects to the gearing system and transmits power to the propeller shaft. The source of power is from turbine which rotates at 41,730 rpm connected to the main shaft. This high power low torque of main shaft is to be converted into low power high torque of propeller shaft by reduction to 1,591 rpm. So due to Continues variable load over internal splines, torque occurs on the torsion shaft and subjects to high rate of wear and tear of the splines. Analysis is done on two sample pieces of torsion shaft by heat treatment process at various temperatures which increases the hardness of the inner splines. This problem has been analyzed with the support of Concerned Methods Engineering in Aero Engines Division of HAL, Bangalore which aid us with materials and test equipment.

II. MATERIAL COMPOSITION OF TORSION SHAFT

The material specification used for torsion shaft is AMS 5743 and its composition is as follows.

15%-chromium
4.5%-nickel
2.9%-molybdenum
0.10%-nitrogen solution and rest iron

Table 1: Number of teeth and splines

Torsion shaft	Inner splines	18
	Outer teeth	25
Coupler shaft	HSP teeth	31
	Outer teeth	18

Internal splines data

Standard involute : 18 teeth
Pitch : 32/64
Pressure angle : 30°
Type : Flat root side fit
Major diameter : 0.5938-0.601
Measurement between 0.054dia pin : 0.488max
Circular space width with gauge : 0.0491
Involute diameter : 0.5875

After completion of internal splines cutting, the test piece will be sent for Liquid Nitriding (Tuffriding).

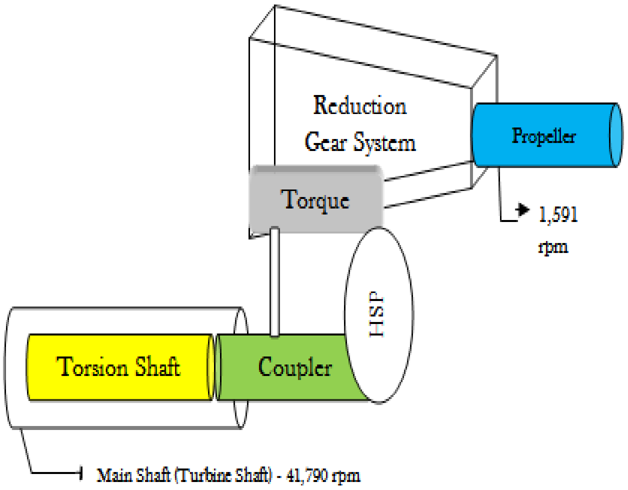

Fig 1: Schematic diagram of torque sensing system

III. TORSION SHAFT ASSEMBLY

CATIA is *Computer Aided Three dimensional Interactive Application*. Fig 2 show the isometric view of the torsion shaft designed in CATIA V5 software.

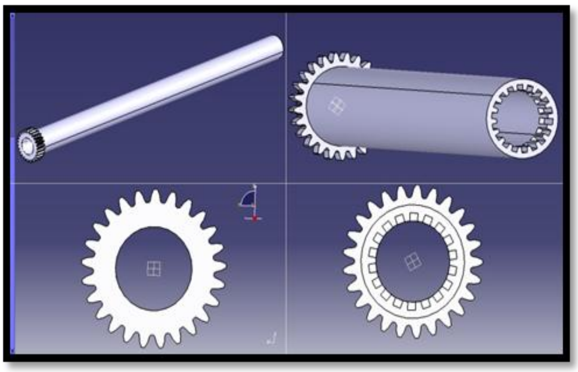

Fig 2: Torsion shaft

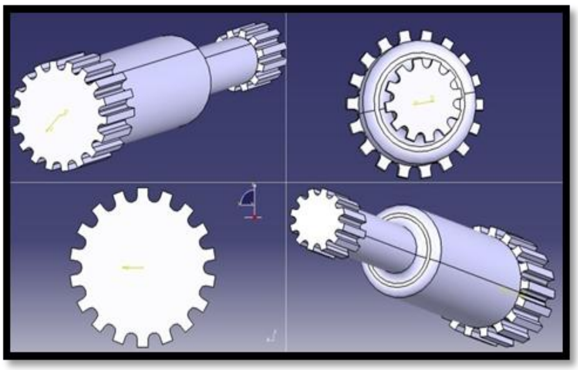

Fig 3: Coupler shaft

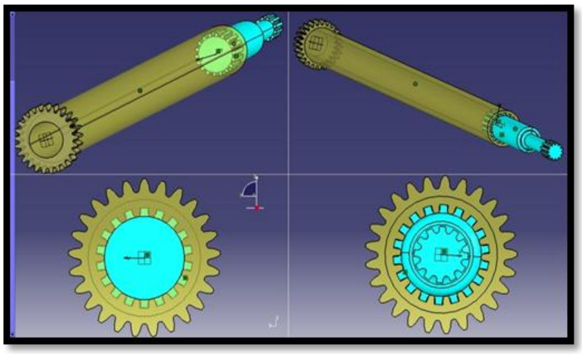

Fig 4: Torsion system assembly

Liquid Nitriding

Liquid nitriding or nitriding in a molten salt bath employs the same temperature range as gas nitriding, which is 510 to 580°c. The case hardening medium is a molten nitrogen-bearing. Fused salt bath contains either cyanides or cyanates. Unlike liquid carburizing and cyaniding which employ baths of similar compositions, Liquid nitriding is a sub-critical casehardening process. Thus processing of finished parts is possib1e because dimensional stability can be maintained. Also liquid nitriding adds more nitrogen and less carbon to ferrous, materials than that obtained through higher-temperature diffusion treatments. The liquid nitriding process has several proprietary modifications and is applied to a wide variety of carbon, low-alloy steels, tool steels, stainless steels and cast irons.

Torque Sensor

Torque sensor is a mechanical instrument which is used to sense the torque occurring on the torsion shaft of the Garret Engine. The torque sensor is placed just above the coupler shaft. The wheels provided inside the torque sensor rotates at 41,790 rpm as it is directly coupled with the main shaft. It is also coupled with the reduction gears which rotate at lesser rpm. So a difference in rpm is detected inside the torque sensor and it is signaled to the cockpit through a transducer provide externally to the torque sensor. Transducer is a device used to convert change in oil pressure of the torque sensor to electrical signals. Oil is used as the medium of transferring the signals inside the torque sensor system. A cam wheel is used inside the torque sensor which is engaged with other gears of the torque sensor. Due the difference in the rpm of main shaft and propeller shaft this cam wheel will be induced to '*rotating'* motion and *'to and fro'* motion regarding to the positive torque and negative torque.

IV. FAILURE MODE ANALYSIS OF TORSION SHAFT

Analysis is done on Return To Shop Engine (RTS). Since the Torsion shaft is subjected to all the torque generated in the Garret engine, the Torsion shaft is exposed to greater wear and tear. As the Torsion shaft connects two moving components inside the engine, greater torque came to play on the Torsion shaft. There are internal splines inside the Torsion shaft that couples the Torsion shaft with the coupler of garret engine, this coupler is connected to the high speed pinion gear and reduction gear, so the Torsion shaft have very great importance in the garret engine and inside the torsion shaft than the internal splines bear the greater responsibility of coupling, so this internal splines are the vital part in the torsion shaft. This leads to the major efficiency of the garret engine is being reduced.

Reason

- Torsion shaft is always subjected to variable load, the tear and wear happens on the torsion shaft is always higher than any other mechanical component in the Garrett engine, which decreas the life span of internal splines.
- May be because of improper Tuffrided case depth and Surface Hardness which causes to quick spline profile wear.

Analysis

Considering the above two reasons and viewing 1st point is design factor and we may not alter at this stage. So, we had considered 2nd reason and we had carried out some analysis. Analysis is carried out as follows by taking two identical test pieces of “AMS 5743”.

- Done Initial Turning of dia “2.0”
- Drill a deep hole to dial 0.975”.
- Drill a hole of dia 0.533” to a length of 0.840+/-0.002 inch.
- Then two test pieces are carried out heat treatment operations in sequence as mentioned above, but for analyzing one is done aging at 540deg (Test Piece-1) centigrade and another one at 580 deg (Test Piece-2) centigrade .
- Broach internal splines as per the internal splines data mentioned above.
- Two test pieces are sent for Liquid Nitrading (Tuffriding) and the annexure gives the details.

Table 2: Tuffriding Parameters

Sl No.	Process	Required Value	Test Piece-1	Test Piece-2
1	Aging	540+/- 5 deg C for 3hrs Air cool - Air Circulating Furnace.	540+/- 5 deg C for 3hrs Air cool - Air Circulating Furnace.	580+/- 5 deg C for 3hrs Air cool - Air Circulating Furnace.
2	Core Hardness	36-44 HRc	38HRc	37HRc
3	Duration	1-2 hrs	1hr 30min	2hrs
1	Case Hardness	>900 VPN	1131-1142 VPN	1168-1182 VPN
2	Case Depth	0.0006"-0.001" as per Specification "AMS 2755".	0.0009"-0.001"	0.001"

V. CONCLUSION

The test pieces were sectioned and the case depth was measure through microscopic inspection on all the spline surfaces including the angular side surfaces which undergone more wear. Hardness on both the test pieces were measured and tabulated as shown in the above table. The actual assigned life of the Torsion shaft is 3820 hrs service. Before this investigation the Torsion shafts were getting rejected by 900hrs. By increasing the Tufriding duration from 1 hr to 1hr 30 min and keeping the aging temperature at 540°C and tufriding temperature at 580°C, the recommended result is able to be achieved and it is assumed that here after the life of the torsion shaft also will be equivalent to 3820 hrs. One Torsion shaft value is approximately Rs.6.5 lacs. Three time shaft replacement is being avoided. So the saving per engine is Rs.19.5 lacs. Thus the desired result is achieved by liquid nitriding process which is a surface hardening process. Earlier Torsion Shafts used to keep cyanide bath solution only about 1 hr. As we increased duration time (1hr 30min for Test Piece-1 & 2hrs for Test piece-2), consequently case hardness and case depth are increased marginally. Thus the wear and tear of the inner splines of the torsion shaft is retained within the specified limits and can withstand the applied torsion occurring on it.

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