TECHNICAL NOTE

AIRCRAFT MAINTENANCE MANAGEMENT - AN ANALYSIS OF DEFECT TREND FOR MAINTENANCE OF AEROENGINE (ARTOUSTE III B)

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Abstract

Maintenance of Aeroengine plays a vital role in the ***Aircraft Maintenance Management****. In this paper. an analysis of defect trend for maintenance of aeroengine (Artouste III B) has been carried out on premature withdrawals of ninety - one aeroengines (Artouste III B) fitted in Chetak / Cheetah helicopters under operation for a period of five years in the various parts of India. Based on the analysis, the trend of defects occurred has been established and the remedial measures are suggested to the manufacturer, overhaul agency and operators to prevent occurrence of such defects. Some of them are implemented in the form of mandatory modifications issued by Director General of Civil Aviation(DGCA) based on the Service Bulletins issued by the manufacturer.*

Introduction

Aircraft Maintenance Management is an activity designed to keep the aircraft or its engine or its components/accessories in fully serviceable condition to optimum level [1]. Poorly maintained engine / item can be unsafe to operate and can create high costs in the form of **"Aircraft on Ground"** and delay time.

The defects are evaluated thoroughly by the defect investigation agency which will clearly reveal whether the defects have been confirmed or not. In this presentation of research, out of ninety one aeroengines (Artouste III B) prematurely withdrawn and sent to defect investigation agency, the study is carried out in depth about 58 confirmed investigation reports leaving aside the 33 cases, where the defects are not confirmed. The contributory factors are studied thoroughly and the remedial measures are suggested to prevent occurrence of such defects leading to the maintenance of the aeroengine to a higher order to enhance the aircraft maintenance management.

Findings

Total of 91 defects [2] have been reported and 91 defect investigation reports have been received from the defect investigation agency. (In 58 cases, defects have been confirmed and in 33 cases, defects have not been confirmed (Fig.1).

The study of 58 continued investigation reports reveals the following major contributory factors for the premature failure of the aero engines (see Fig.2).

Defects in Oil System

The defects occurred in **oil system** are further classified as stated below (see Fig.3).

- High oil consumption : 3 cases
- Oil and fuel mixing more than 10% : 6 cases
- Oil leak : 5 cases
- Oil discolouration : 5 cases

High Oil Consumption

In all the three cases, **the high oil consumption** was due to sticking of the axial compressor seal, which was found sticky.

Oil and Fuel Mixing of more than 10%

In 6 cases, premature withdrawals of the aero engines were due to the defect **oil and fuel found mixed more than 10%**. In four of the above cases, the defects were attributed to lack of sealing effect at the jet holder location. The investigation agency [3] states that the fuel and oil

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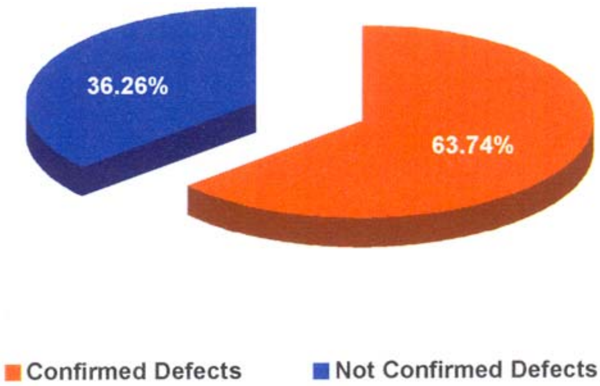

Fig.1 Defective investigation reports against total defects

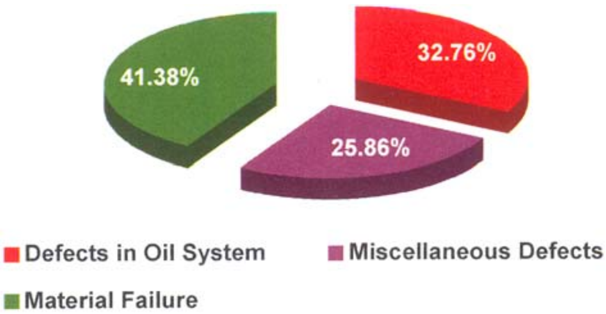

Fig.2 Nature of defects against confirmed defects

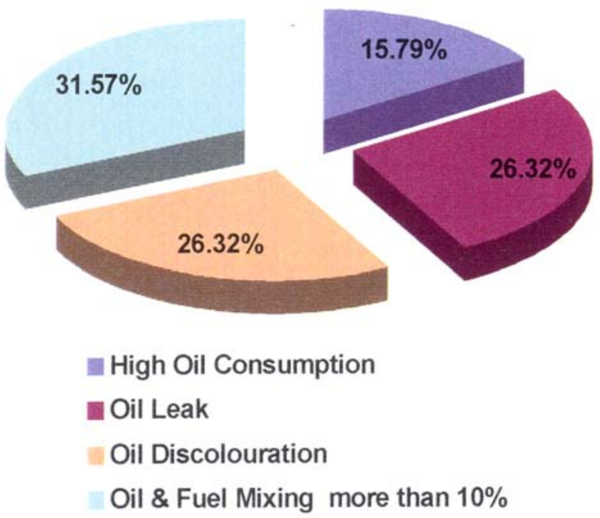

Fig.3 Nature of defects in oil system

mixing is a known defect and this can be rectified in field by changing jet holder assembly. Further it has been suggested that the defect can be cured by changing the spring or alakarite ring or graphite seal carrier. In the case of one aero engine the threads were found stripped on jet holder blanking plate leading to further leakage at the jet holder in addition to graphite seal. In the case of another aero engine, the defect was due to chipping of chrome plated area rendering the sealing of the injection wheel ineffective and also due to speed governor whose function was not satisfactory during rig test.

Oil Leak

Five overhauled engines were prematurely withdrawn at 24:30 hrs, 677:29 hrs, 17: 1 0 hrs, 467:40 hrs and at 1189:15 hrs due to the defect of **'Oil leak'**. Two of them were found to have the snag of **'Oil leak'** from rear overhauling. The former one had the leak through exhaust diffuser inner cone and the latter one had the leak from the locations of oil inlet and outlet tube connections. In the case of another aero engine the **'Oil leak'** occurred at the Sealol Seal which was probably due to sticky sealol. Further, excessive run out noticed on the parting face of the cover could have also contributed to the reported snag of **'high oil leak'**. Further in an aero engine, static leak checks on the turbine front and axial rear sealol seals revealed leaks across the sealol seals. Since the centre bearing breather is connected to the centrifugal compressor casing which accommodates the central bearing and the sealol seal housing, any leak across the two sealol seals mentioned above would lead to an oil leak through the breather pipe[4]. Besides, in another aero engine the' oil leak' was through the scavenge pump. The speed governor and fuel pump had been changed between 750 hrs and 1189:15 hrs. During the change of accessories and fitment of oil pipelines alight distortion of the pump body could have occurred causing oil leak.

Oil Discolouration

In five cases, the defects were attributed to **'Oil discolouration'**. Three of them were new ones and were prematurely withdrawn at 459:20 hrs, 758:25 hrs and 992:10 hrs and the other two were overhauled ones and were withdrawn prematurely at 659:30 hrs and 781:05 hrs. The reported defect of **'discolouration of oil'** is due to the presence of ferrous oxide (brown paste) which is the result of frettage noticed between the layshafts and their corresponding gears and hubs. The frettage had released minute powdery metal particles which had gone into the oil stream. This was due to low interference between layshafts and gears.

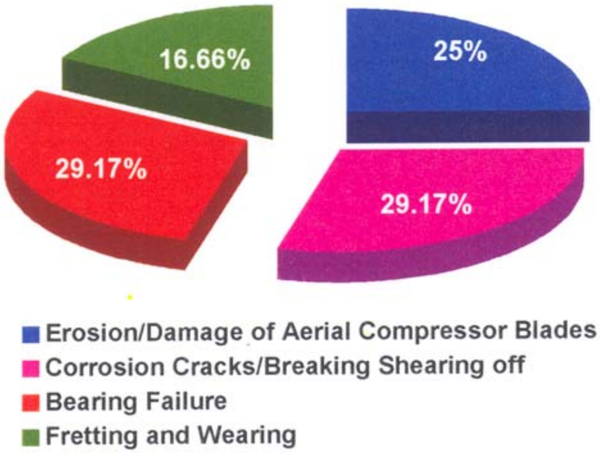

Fig.4 Nature of defects material failure

Material Failure

24 aero engines were prematurely withdrawn due to the defect of **"Material Failure"** Ten of them were new ones and fourteen of them were overhauled ones. This defect of material failure is further classified under the following headings (see Fig.4).

- Erosion / Damage of axial compressor blades : 6 cases
- Bearing failure / Excessive rear arm play : 7 cases
- Corrosion / Cracks / Breaking / Shearing of parts : 7 cases
- Fretting / Wearing : 4 cases

Erosion / Damage of Axial Compressor Blades

Two overhauled aero engines were prematurely withdrawn at 1035:25 hrs and 1057:30 hrs respectively and two new aero engines at 727:45 hrs and 1067:27 hrs respectively due to the defect of excessive erosion on axial compressor blades. This defect occurred due to operating the engines in sandy atmosphere. Another new aero engine was prematurely withdrawn at 409:15 hrs due to the defect of having dents and nicks on axial compressor blades during 400 hrs inspection. The damage observed were due to ingress of foreign object, probably small stones sucked in during engine operation near ground. Further, one more new aero engine was prematurely withdrawn at 827:10 hrs due to the failure of compressor in flight. This failure of the axial compressor blades was due to flexural strength.

Bearing Failure /Excessive Rear Arm Play

Two overhauled aero engines were withdrawn prematurely at 164:05 hrs and 1292:55 hrs respectively with the defect of excessive metal particles found on magnetic drain plug of engine oil system. Laboratory test revealed that the defect was due to the failure of bearing. Three new aero engines and two. overhauled aero engines, were withdrawn prematurely at 857:00 hrs, 420:20 hrs and 507:35 hrs and at 521:30 hrs and 447:00 hrs respectively due to the defect of excessive rear arm play. This defect was due to **"heavy frettage"** noticed on the face of the arm at pin location in aero engines and also due to **"excessive wear of bush and pins"** resulting in **"bowed"** turbine shaft assembly in the case of one of the aero engines. In the case of two aero engines the defect of **"excessive rear arm play"** was due to attempting to put back the bush by hitting it hard that resulted in bulging and deformation of the bush with part of it protruding out with hit and slightly spread.

Corrosion / Crack / Breaking / Shearing of Parts

Two overhauled engines were prematurely withdrawn at 242:20 hrs and 243:15 hrs due to the defect of crack found in engine rear bearing feed pipeline and on exhaust diffuser near weld joints on No.2 and No.3 respectively. In the former case the defect was due to **"improper welding technique"** and in the latter case, it was considered as normal by Messrs Turbomeca. An overhauled aero engine was withdrawn at 429:35 hrs due to the defect of **"pipeline broken"** near the welding joint of the front nipple. This defect had occurred due to high engine vibration. Another new aero engine was withdrawn at 830:05 hrs due to the defect of "combustion chamber burst". This burst was due to the development of combustion high temperature in flight. An overhauled engine was withdrawn prematurely at 209:25 hrs due to **"Turbine outer casing corroded over a large surface area"** accompanied by pitting marks. This was due to moisture laden atmosphere to which the engine casing was exposed. Another new aero engine was withdrawn at 1023:49 hrs due to diffuser assembly found externally damaged during acceptance check of aero engine. This defect was due to **"the bolt (foreign object) that was sent with the engine from the unit"** found damaged and deformed. Another new aero engine was withdrawn at 1000:20 hrs due to defect of diffuser casing front flange and turbine casing rear flange attachment bolts getting loosened / missing at 6,7, 8, and 9'O clock position viewed from rear internal threads damaged at 9'O clock position. The reported defect was attributed to the butting / fouling of the dowels fitted onto the front flange of the exhaust diffuser and on the first stage of NGV.

Fretting / Wearing

Three overhauled aero engines were withdrawn at 09:25 hrs, 828:25 hrs and 633:00 hrs respectively due to the defect of **"threads worn out"**. In the first case, the stripping of the internal threads on the casing was due to **"overtorquing"**. In the second case, the defect of **"excessive wear in the couplings sleeves and drive sleeves"** was due to the slight misalignment evidenced by the co-axial checks. In the third case, the wearing of thread of clutch unit stud on engine R.G. casing front flange was due to **"over-tightening"**. Another overhauled engine was withdrawn at 895:45 hrs due to the defect of **"metal particles found on magnetic plug"**. This defect was the result of **"loosening of fretted metal particles"** due to heavy fretting observed on the lay shafts and related hub/gear. The frettage is due to low interference between the lay shaft and hub/gear which is within limits.

Miscellaneous Defects

Following are the miscellaneous defects due to which fifteen aero engines were prematurely withdrawn for defect investigation (see Fig.5).

- Fuel leak : 2 cases
- RPM fluctuation : 1 case
- Engine vibration : 3 cases
- Engine cutting off/flame out : 2 cases

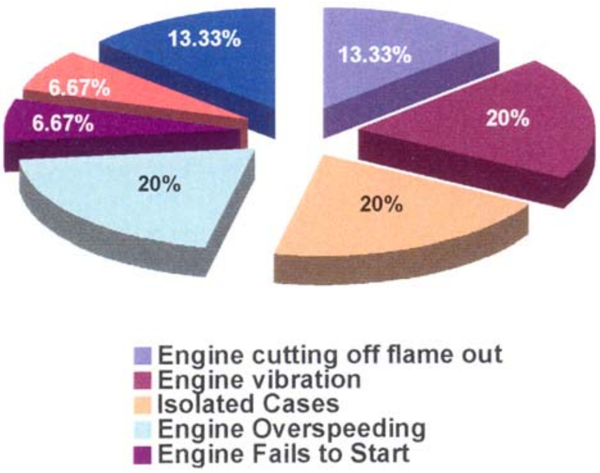

Fig.5 Miscellaneous defects

- Engine overspending : 3 cases
- Engine fails to start : 1 case
- Isolated cases : 3 cases

Fuel Leak

One new aero engine was withdrawn at 669:20 hrs due to the defect of **"fuel leak from bottom of axial compressor front end"** when booster pump was put 'ON'. This leak was due to the **"dislodged and protruding condition of the simirit seal"** noticed on the fuel pump. Another overhauled aero engine was prematurely withdrawn at 7:40 hrs due to **"fuel leak noticed through oil pipe line"**. This leak was also due to dislodging of the Simirit seal from its location on the fuel pump.

RPM Fluctuation

One overhauled aero engine was prematurely withdrawn at 588:50 hrs due to engine RPM fluctuation. This reported defect of **"rpm fluctuation"** was attributed to over dampening of speed governor's scroll since RPM fluctuation to an extent of 100 to 200 was noticed during loading and unloading of engine [5].

Engine Vibration

Two new aero engines and an overhauled aero engine were withdrawn at 1027:10 hrs and 796:00 hrs and 1237:50 hrs respectively due to engine vibration. In the cases of two aero engines the defect was due to the **"bowing of the turbine assembly"** noticed during a detailed strip examination of the individual components of the engines. In the case of the other aero engine, the vibration was due to incorrect installation of the gasket which was blocking the port of idle bypass valve.

Engine Cutting Off/Flame Out

An overhauled aero engine was withdrawn at 481:05 hrs with defect of engine switching off at 23,000 to 24,000 rpm. The reported snag of engine switching off is due to flame out as a result of snarl and combustion instability. Another overhauled engine was also prematurely withdrawn at 64:30 hrs due to the defect of engine cutting off at 30,000 to 31,000 rpm. The defect was attributed to starter generator.

Engine Over Speeding

One overhauled aero engine and a new aero engine were withdrawn prematurely at 872:30 hrs and 818:45 hrs respectively due to the defect of **"overspeeding"**. The defect was due to the failure of quill shaft. Another overhauled aero engine was withdrawn at 244:05 hrs due to the defect of **"overspeeding"**. The defect was due to momentary malfunctioning in the speed governor [6].

Engine Fails to Start

An overhauled aero engine was prematurely withdrawn at 401:00 hrs due to the defect of **'not attaining self sustained rpm'**. This defect was due to the failure of the fuel pump's quill shaft as a result of torsional overloading condition in service.

Isolated Cases

The first isolated case was in connection with an overhauled aero engine which was withdrawn prematurely at 941:25 hrs due to the defect of **'reduction of run down time to more than 20 seconds"**. The defect was due to sluggish rotation of the starter generator.

Analysis

Pattern of Defects

Pattern of defects as revealed from the study of 59 confirmed investigation reports is shown in Fig.1. It may be seen that two major defects e.g. **"Defects in oil system"** and **"Material failure"** together account for approximately 74:14% of the confirmed defects.

Defect in Oil Systems

19 defects have occurred in oil system and the percentage of each defect works out as stated below (see Fig.3) :

- High oil consumption : 15.79%
- Oil and fuel mixing more than 10% : 31.57%
- Oil leak : 26.32%
- Oil discolouration : 26.32%

High Oil Consumption

All the three aero engines had the defect of **'high oil consumption'** due to sticky axial compressor sealol seal. Proper precautions if taken during assembly to fit sealol seals after ensuring its full serviceability would have obviated this problem.

Oil and Fuel Mixing more than 10%

Four out of six cases had the above defect which was attributed to the lack of sealing effect at jet holder location. This defect could have been easily rectified by changing jet holder assembly or the spring or alakarite ring or graphite seal carrier as applicable by the operation unit.

Oil Leak

The **'Oil leak'** in two cases was due to sealol seals being ineffective. If proper precautions had been taken by the overhaul agency to fitment of serviceable sealol seals, this defect could have easily been prevented [8]. In another two cases, the operating units should have ensured proper tightening of oil transfer tubes after carrying out rear bearing arm's play check, and no distortion of the fuel pump body had taken place during the change of accessories and fitment of oil pipelines to prevent occurrence of oil leak.

Oil Discolouration

The above defect in two cases out of all the five cases can easily be prevented, if the overall agency takes proper measures to avoid too low interference between gear and layshaft. Though the torque value of layshaft retaining nuts is increased to 7/8 mdons from 4/5 mdons and the limit of interference is increased to 0.012 / 0.028 mm from 0.001 / 0.012 mm by the order of modification, defect still persists.

Material Failure

In 24 cases, the defect of **'Material Failure'** has occurred and the percentage of each category of defect is as mentioned below (see Fig.4) :

- Erosion / Damage of axial compressor blades : 25%
- Bearing failure / Excessive rear arm play : 29.17%
- Corrosion / Cracks / Breaking / Shearing of parts : 29.17%
- Fretting / Wearing : 16.66%

Erosion / Damage of Axial Compressor Blades

The defect of **'excessive erosion on axial compressor blades'** had occurred in four cases. It was due to operational environment of sandy atmosphere. Fitment of anti-sand filters and erosion check at every 25 hrs interval could prevent the occurrence of this defect. Another defect of **'damage to the blade'** due to ingress of foreign object could have easily been avoided if the operating unit had adhered to the laid down instructions for engine operation near ground.

Excessive Rear Arm Play

The above defect in five cases was due to either a heavy frettage on the face of the arm at pin location or excessive wear of bush and pins leading to **'bowed'** turbine shaft. In the case of the former, overhaul agency may adopt a measure to prevent frettage. In the latter case, the cause of defect was due to overheating specially during starting with low voltage battery by the operation unit. Had the concerned operating unit taken adequate precaution to avoid low voltage battery during starting, the occurrence of the defect could have been easily prevented [7]. Further, in two other cases, the defect occurred due to the attempts made by the operating units to put back the bush by hitting hard, that resulted in bulging and deformation of the bush with part of it protruding out with hit and slightly spread. If the operating units had exercised proper care while removing the bolt for the purpose of carrying out this check, this defect could have been easily avoided.

Corrosion / Cracks / Breaking / Shearing of Parts

One aero engine had the defect of crack found in engine rear bearing feed pipeline due to improper welding technique. In order to avoid recurrence of such a defect, the manufacturing agency has to replace the welding technique. In the case of another aero engine, the defect of **'corrosion'** on turbine outer casing exposed to moisture laden atmosphere, could have been easily avoided by the operating unit, had the operating unit protected the engine with cover when helicopter was not in use and also followed the instructions given in maintenance manual. Further, in one more aero engine the defect would have been easily prevented, if the overhaul agency had checked the proper fitment of the dowels and ensured correct stand out of dowels within drawing tolerance preferably on the lower limit.

Fretting /Wearing

Defects of **'threads wearing out'** occurred in aero engines could have been prevented if the overhaul agency and user units had ensured correct torque - tightening.

Miscellaneous Defects

Following seven different defects have occurred in fifteen aero engines. The percentages of each defect has been studied and stated in Fig.5.

- Fuel leak : 13.33%
- RPM fluctuation : 6.67%
- Engine vibration : 20%
- Engine cutting off/flame out : 13.33%
- Engine over speeding : 20%
- Engine fails to start : 6.67%
- Isolated cases : 20%

Fuel Leak

The defect of dislodging of the simirit seal, has been studied by the manufactures and modifications will be issued to prevent the seal from dislodging.

Engine Vibration

All the three cases of the above defect could have been easily avoided, had the operating units strictly followed the quick lines of starting procedure stated in maintenance manual and properly positioned the gasket whenever fuel pump was disturbed.

Engine Cutting Off

It is evident that proper cleaning of injection wheel if carried out as per maintenance manual by the operating unit the would have totally prevented the above defect.

Engine Over Speeding / Engine Fails to start

The above defects had occurred in three cases and the cause was established as the failure of quill shaft. Modification has been introduced to improve the mechanical properties of quill shaft with thicker cross section. This introduction of modification will reduce the possibility of failure of quill shaft and thereby avoid engine over speeding or not attaining self sustained r.p.m.

Defect Occurrence Against Engine Hours

Defect arising against engine hours is shown in Fig.6 and the following facts are evident from the figure.

i) Defect arisings in overhauled engines are predominant in first 200 hrs and in new engines from 601 hrs to 800 hrs. This occurrence may be a subject of study of concerned agencies and overhaul procedure and quality control checks need to be revised.

ii) Twenty out of fifty eight defects occurred within 600 hrs of engines overhauled life. This accounts for 34.5% of defect arisings within 600 hrs, which only points out to the overhaul efficiencies. This also proves an overhaul efficiency point that once the quality of overhaul is better (confirmed by trouble free service of engine for 600 hrs). the changes of components giving trouble at later stages are minimized.

Calendar-wise Defect Distribution / Trend of Defects

Calendar wise defect occurrence and its trend are shown in Figs. 7 and 8 that the defect arisings during second year is predominant. It is seen out of sixteen defects occurred in second year, twelve of them are from overhauled engines which works out to 75%. This fact points out that the overhaul lapses may be one of the major contributory factors towards defect arisings which is apparent from the trend of defects reflected in Fig.8.

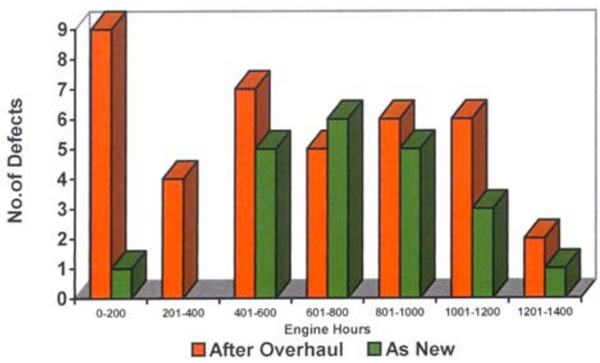

Fig.6 No. of defects vs engine hours

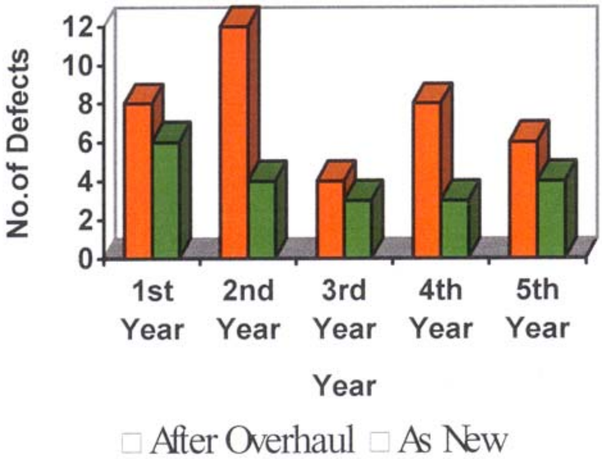

Fig.7 Calendar wise defect distribution

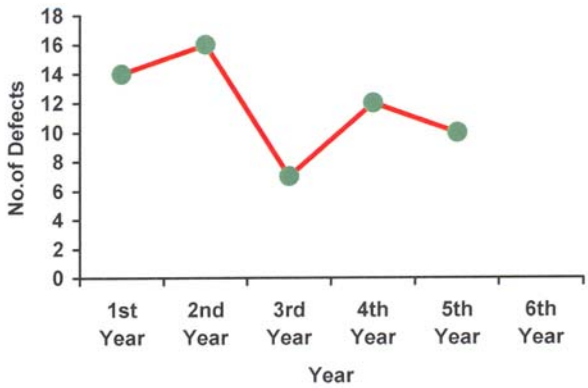

Fig.8 Trend of defects calendar wise

Conclusions

It is seen that this study has established the trend of defects occurred. Based on the above evaluation, the following remedial measures are suggested to prevent occurrence of such defects.

For Manufacturer

- Improvement in the material of sealol seal may be reviewed in consultation with the manufacturer.
- Increment in the torque valve of layshaft retaining nuts from 7/8 mdons and in the limit of interference between layshaft and gears from 0.012/0.028 mm may be examined in consultation with the manufacturer.
- Fitment of anti sand filters on all engines operating in sandy areas may be introduced.
- Improvement in welding technique for manufacturing rear bearing pipe line may be devised.

For Overhaul Agency

- To explore the possibility of finding the indigeneous substitute for the sealol seal.
- To ensure fitment of serviceable sealol seals during assembly.
- To examine the possibility of fitment of anti-sand filters on those engines operating in sandy areas.
- To check the proper fitment of the dowels fitted onto the front flange of the exhaust diffuser and on the 1st NGV during assembly and ensure correct stand out of dowels within drawing tolerance preferably on the lower limit.
- To issue modification to prevent the Simirit seal from dislodging.
- To ensure despatch of modification to all operating units.

For Operators

- Cure the defect **'Oil and fuel mixing more than 10%'** by change of spring or alakarite ring or graphite seal carrier.
- Ensure proper tightening of oil transfer tubes after carrying out rear arm's play check.
- Make sure that no distortion of fuel pump body takes place during the change of accessories and fitment of oil pipe lines.
- Carry out axial compressor blade check at 25 hours interval as per maintenance manual on those engines operated in sandy areas.
- Take adequate precaution to avoid low voltage battery during starting as advised in helicopter maintenance manual.
- Exercise proper care during the removal of bolt while carrying out rear arm play check. If the bush comes out, do not attempt to hit hard to put it back resulting in bulging and deformation of the bush with part of it protruding out with hit and slightly spread.
- Protect the engine with cover when helicopter is not in use [8], and strictly adhere to the instructions given in maintenance manual for engines operated in Saline atmosphere and for protection of engines in installed condition.
- Ensure strict compliance with instructions laid down in maintenance manual [9] for replacement of Simirit seal.
- Carry out proper cleaning of injection wheel as per maintenance manual if the defect **'engine cutting off'** occurs.

The above suggestions were well appreciated by all the three agencies and most of them had been implemented. Operators implemented religiously the salient instructions in the form of Technical Orders issued to aircraft mechanics,/engineers working on the engines. Overhaul agency were instructed by the manufacturer to replace Sealol seals while assembling the engine during overhaul. Further, modification is issued by DGCA [10] to implement modification on engine / Air - Air intake assembly for inspection of filters to prevent accumulations of sand, and fuel pump / pipe (PN 0202-12-800-0) to prevent fuel leak during overhaul as per mandatory modification list published by Director General of Civil Aviation (Refer DGCA / ALOUETTE III / 23, DGCA / ALOUETTE / 52, DGCA / ALOUETTE /53 and DGCA / ALOUETTE III /54).

The trend of defects was considerably reduced in subsequent years and the maintenance of the aero engines made a significant progress and the helicopters were extensively used without any incident / accident with a high level of maintenance.

Acknowledgements

The authors wish to sincerely thank Pawan Hans Helicopters Ltd., Air Works India Engineering Pvt. Ltd and Indian Air Force for using their defect reports for our research and the defect investigation agency, Hindustan Aeronautics Ltd. for their defect investigation reports for evaluating the defect trend analysis.

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BOOK REVIEW

FLUID MECHANICS AND MACHINERY

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The book under review, namely Fluid Mechanics and Machinery, deals with one of the very important subjects that is, Fluid Mechanics and its Applications. In this book, the subject matter is introduced gradually in a traditional manner but goes on to include some advanced topics such as aerodynamics and boundary layer theory. In addition quite a number of practical examples, ranging from nature to sports and in different fields of engineering, are given for better appreciation of the subject. Appropriate diagrams are placed at apt, locations to facilitate clear grasping of the theoretical treatment. This is followed with worked examples, gradually increasing in complexity to drive home the subject matter under discussion. Review questions along with answers are added at the end of each chapter which could further improve the comprehension. The chapters on aerodynamics and boundary layer theory are interesting and could motivate students to know more about these specialized fields. Also, quite a few special topics in various fields of engineering and technology are included which highlight the applications of fluid mechanics and are quite informative and add value to the contents of the book. Some of the details provided in the special topics on wind tunnel and flow visualization may be useful for setting up test facilities in Engineering Institutions. This book also contains syllabus of fluid mechanics and machinery applicable for different undergraduate courses and typical university question papers to make it more useful to undergraduate students.

The book has been carefully edited and has been published in paper back edition costing of Rs. 295/- which is a reasonable price by any standard.

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