International Journal of Advanced Research in

Mechanical and Production Engineering and Development

Volume: 1 Issue: 2 08-Apr-2014,ISSN_NO: 2320-7256

A Novel Approach for Altitude Performance of Gear-box Filter

B. Arul Jothi[1] and A. M. Junaid Basha[2],
Somashekhar S. Hiremath[3] and M. Singaperumal[4]

Scientist, Combat Vehicles Research and Development Establishment,
Avadi, Chennai-600054 Tamil Nadu. INDIA[1].

Additional Director, Manufacturing Division and Centre of Excellence for Filters
Scientist, Combat Vehicles Research and Development Establishment,
Avadi, Chennai-600054 Tamil Nadu. INDIA[2].

Associate Professor, Department of Mechanical Engineering,
Indian Institute of Technology Madras, Chennai-600036, Tamil Nadu. INDIA[3].

Professor Emeritus, Department of Mechanical Engineering,
Indian Institute of Technology Madras, Chennai-600036, Tamil Nadu. INDIA[4].

aruljothicvrde@gmail.com, junaidbashaam@yahoo.com,
somashekhar@iitm.ac.in, msingam@iitm.ac.in.

ABSTRACT— *The combat aircrafts are designed to perform at different altitude conditions with high reliable control systems. The control systems include hydraulic system operating the aircraft control surfaces. At high altitude reduction in atmospheric air pressure and temperature leads to the reduction in the performance of the aircraft. An accessory gearbox connected to the aircraft engine, operates the hydraulic pumps required for hydraulic system. The hydraulic pressure across the lube filter plays a vital role for operating the lubrication system of the accessory gearbox connected to the engine. The high speed gearbox has a self contained lube system. The accessory gearbox is designed with fine jets located in the core of the gear casing. A 10 micron filter is used in the accessory gearbox to ensure contamination control for lube oil to maintain flow through the jets. The performance of the accessory gearbox in different altitude position affects the performance of lube pump. The present paper describes the test setup and performance of the lube filter of the accessory gear box at different altitude conditions using an altitude test rig.*

Keywords— Altitude performance, Accessory gear box, Lube filter, lube pump, Inlet pressure, Outlet pressure, Flow

1, INTRODUCTION

Fighter aircraft has to manoeuvre different altitude conditions. Performance of the Aircraft depends on density altitude of air at different altitude conditions. W. B. Herbst [1980] opinioned that density altitude is the appropriate term for correlating aerodynamic performance in the nonstandard atmosphere, expressed in terms of the altitude in the standard atmosphere corresponding to a particular value of air density. Density altitude is pressure altitude corrected for nonstandard temperature. At high altitude reduction in atmospheric air pressure and temperature leads to the reduction in the performance of the aircraft. During manoeuvring at different altitude positions, the high speed accessory gearbox has to perform efficiently to ensure operation of the hydraulic pumps for control system assisting the aircraft manoeuvring. Also the accessory gearbox with stack of gears needs efficient lube system for optimum performance during manoeuvring at high altitude. Therefore the performance of the lube filter is important for controlling the contamination and smooth oil flow through the fine jets inside the accessory gearbox. Oil viscosity depends on temperature of the oil and extreme low temperature conditions leads to reduction of oil flow and induces severe pressure drop of oil flowing through a filter. To minimize this increase in flow resistance filters are equipped with a high-pressure actuated bypass.

Some of the main literatures on hydraulic oil filters are elaborated in the following section:

Verdegan et al (1992) have proposed standardized filter test methods, which facilitates comparison among different filter products. The multi-pass filter test is the basis for many oil filter test standards and its reproducibility has been continually improved through better specification of the test conditions and improvements in particle counting methods. Particle counting is a major source of inter-laboratory variability. In response, ANSI/ (NFPA) T2.9.6R1-1990, a particle counter calibration method utilizing latex spheres suspended in oil, was recently adopted by the USA. The new method provides traceability to internationally accepted definitions of the meter unobtainable by the old method of AC fine test dust calibration. However, the new method is sensitive to subtle instrumental differences. A hybrid method is needed to improve agreement between laboratories and instruments. Other ways of improving reproducibility and communicating test results are also discussed.

L.G.I. Bennett et al. (1996) discussed various condition monitoring techniques are used collectively to monitor the health of aircraft engines and transmissions, a concept known as Integrated Health Monitoring (IHM). A well-established quantitative technique is Aircraft Oil Analysis (AOA) in which spectroscopic techniques such as Rotating Disk Electrode Atomic Emission Spectroscopy (RDE-AES) is employed to analyze periodic oil samples for wear debris. A technique that quantitatively analyses the wear debris caught on the filter has been developed and is termed Quantitative Filter Debris Analysis (QFDA) was discussed in the paper. Moreover, trending of the data for sequential samples has demonstrated the capability of QFDA for condition monitoring.

Richard K. Tessmann and Ing T. Hong (1998) have conducted study on contamination and maintenance associated with the hydraulic systems on aircraft. They reported that contamination induced failures reduced with contamination control strategies in the design and maintenance activities. They have done a brief study on modern contamination control theories to explore practical contamination problems through component sensitivity tests.

C. Van Netten and V. Leung (2001) studied the pyrolysis products of jet engine oil and two hydraulic fluids at a higher temperature. They found that of carbon monoxide from engine oil in ventilation ducts, accounted for mid-flight incidents. The authors recommended that carbon monoxide data should be monitored continuously and controlled to avoid accidents in flights.

Myounggu (2002) has investigated the in-service failure of a hydraulic filter installed on a combat aircraft. Cracking had occurred at the filter head and no sign of plastic deformation was found. Chemical examination and micro-hardness measurement revealed that the filter head material was Al 6061-T6. But the base material of the randomly chosen filters from the field was Al 2024-T4. So the wrong material selection was confirmed. Metallography showed micro structural anomalies which contributed to the early fracture of hydraulic filter head. A surface examination of the fracture region revealed striations, and it was confirmed that the fracture mode was fatigue. At the initiation site there were corrosion pits providing initiation sites for fatigue cracks. The corrosion pits and micro structural anomalies might be generated by applying the manufacturing processes designed for Al 2024 to the wrong material (Al 6061). It was verified by fatigue analysis that with pre-existing defects and/or flaws, the fracture should occur far earlier than the expected cyclic life. The right selection of the material can be the most important remedial action in this case.

Parker Arlon (2003) has introduced another new system designed to prevent breakdowns in hydraulic systems, the MGSB filter. The company claims that approximately 80% of hydraulic system breakdowns are caused by oil contamination and that efficient filtering processes will help to cut the cost of maintenance and ownership for end users. The higher capacity MGSB filter can handle a maximum flow of 250 lt./min. at 250 bar of pressure. It is intended for use primarily on drive transmissions in the industrial sector. The filter head is made from aluminium, and the bowl from steel. The more versatile MGSB filter can be equipped with 3, 6, 10 micron or 20 micron glass fibre elements, unlike the SR2 filter. The MGSB filter incorporates the so-called ‘third port’ concept into its design. Essentially, this means that a pressure relief valve is integrated into the filter head. When the valve opens the majority of the oil volume flows unfiltered, via the third port, safely back into the tank. The pressure relief valve is only initiated when the filter element needs replacing or is malfunctioning. It displaces the more traditional by-pass valve.

As well as protecting hydraulic systems from contaminated oil, the MGSB filter also acts to prevent insufficient lubrication of system components during cold starts, and holds back a small amount of filtered oil for emergency operation, for example, if certain components become too hot.

Allison M. Toms and Karen Cassidy (2008) had developed an automated filter debris analysis system for oil filtering in aircraft engine gear box. An automated filter debris analysis system was developed and analyses are conducted. The filters are automatically cleaned; the particles are counted and sized utilizing a quantitative oil debris sensor; and the debris is deposited on a patch for automatic analysis by an integral energy dispersive X-ray fluorescence spectrometer (XRF).This determined the engine condition and was successfully applied in aircraft operational conditions.

The aim of this study is to establish test method for aircraft hydraulic filter of accessory gearbox and evolve the behavior of aircraft filter in different altitude condition. This paper describes the altitude test setup and performance of the lube filter of the accessory gear box at different altitude conditions using an altitude test rig.

2, CONSTRUCTION OF ACCESSORY GEARBOX LUBE FILTER

The typical aircraft lube filter considered for the present work is designed to withstand the maximum collapse pressure of 25 bar. The specifications of the filter are shown in Table.1

Table 1: Specifications of Lube Filter

Filtration rating	10 microns
Flow rate	20 lpm
Working pressure	10 bar
Working Temperature	-40 ^{0}C to 135 ^{0}C
Clean element pressure drop at rated flow	0.7 bar
System oil	MIL-L-23699
Element type	Disposable

The filter assembly consists of an aluminum alloy head with an in-built by-pass valve system, filter bowl, a differential pressure indicator, inlet and out let ports as shown in Fig.1. The bypass valve is of spring loaded non return valve as it opens and closes according to the pressure differential across the filter element.

The lube filter element along with a sealing ring is mounted inside the housing. The total filter assembly is fitted in to the aircraft accessory gearbox as shown in Fig.2. The purpose of the filtration in a hydraulic system is to achieve the reliable system operation and an acceptable operating life for components and equipments by controlling the quantity and the size of particulate contaminant which circulates within the system

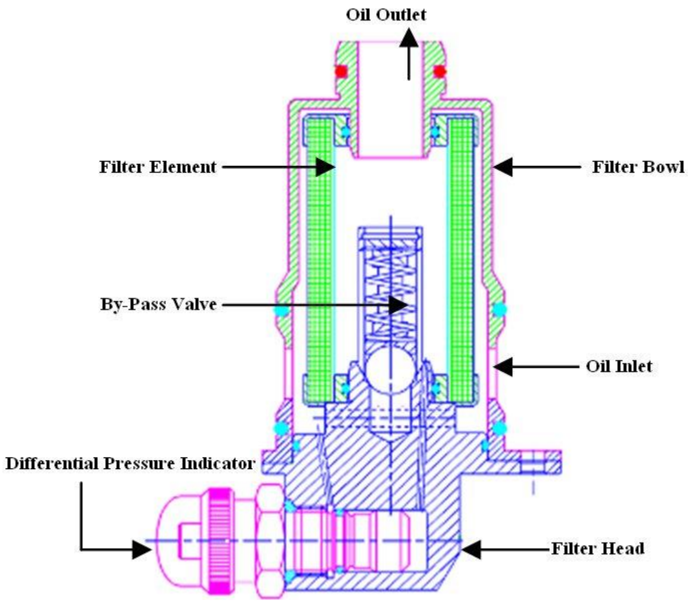

Figure 1. Schematic diagram of accessory gearbox lube

The hydraulic filter unit installed must caters and retain sufficient number of particles considered potentially harmful to the system operation so as to effectively control the contamination to the acceptable levels. Its size and the glass fibre media have been selected for the given application. The total lube filter assembly has been tested as per MIL-F-8815E standards and mounted on to the accessory gearbox.

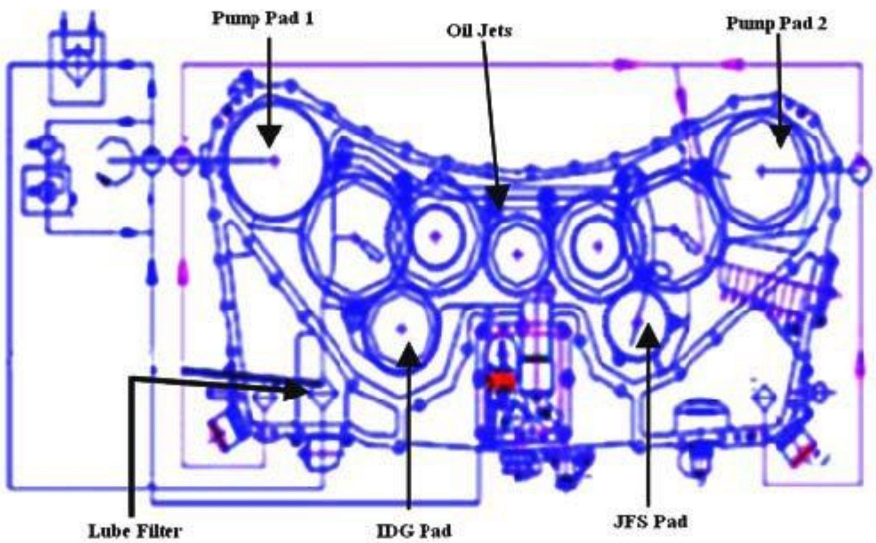

Figure 2. Schematic diagram of aircraft accessory

The accessory gear box consists of two hydraulic pump pads- Pump pad 1 and Pump pad 2, Jet Fuel Stator (JFS) pad used for starting the engine, Integrated Drive Generator (IDG) pad used for generator drive system, lube filter which controls the oil from contamination.

3, ALTITUE TEST

The performance of the aircraft gear box filter is greatly depends on the atmospheric air pressure and temperature. So at high altitude, reduction in atmospheric air pressure and temperature leads to the reduction in the performance of the aircraft gear box filter. Hence it is essential to carry out an altitude test to simulate altitude conditions inside a chamber to observe the behavior of a gear box. Hence an attempt has been made to build the altitude test setup to simulate the performance of the gear box during landing and descending of aircraft at different altitude conditions. The various process parameters like flow, pressure across the filter are monitored at different altitudes and presented in the paper. Study of the parameters at different altitude conditions reveals behavior of gear box.

3.1 Altitude Test Setup

The developed altitude test facility consists of an absolute pressure chamber capable of simulating atmospheric conditions from 2 km to 16 km. Absolute pressure chamber consists of a vacuum pump unit and houses connections to heat exchanging unit, and sensing unit. It provides facility to measure various parameters like input speed, inlet pressure, outlet pressure, differential pressure, flow passing through the gearbox filter. Test facility has 50 channel data acquisition system and it houses various sensor elements like thermo couples, piezo resistive pressure sensors, magnetic pick up, turbine flow meter and vibration accelerometer pick up. The developed altitude test setup is as shown in Fig. 3. Table 2 shows the altitude test conditions used for the study.

3.2 Altitude Test Procedure

Accessory gearbox mounted on mounting pad of attitude chamber is driven by an external hydraulic motor. The filter to be studied is initially fitted inside a gear box which is mounted in an altitude chamber as shown in the Fig. 3. Altitude chamber door is closed and subsequently the vacuum pump is started to create a vacuum inside the chamber which in turn simulates the altitude condition at which the filter needs to be examined. Starting from 2 km to 16 km altitude condition is simulated for takeoff and descends conditions. The altitude test is carried out at input speed of 16,800 rpm. Various process parameters like upstream and downstream pressures across the filter, the flow rate during the flight take off and descend conditions are carefully recorded at different altitude conditions.

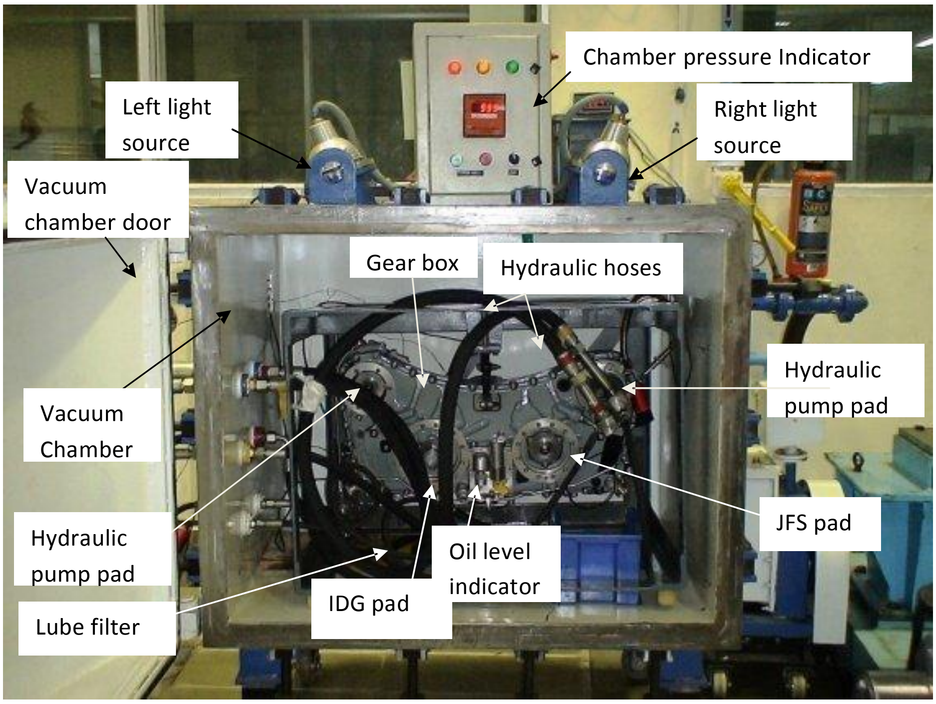

Figure 3. Experimental setup of aircraft gear box

Table 2: Test Conditions

Test Fluid	MIL-H-5606
Cleanliness level	NAS Class 4
Oil temperature	32 °C
Gear box speed	16,810 rpm
Flow rate	20 lt/min.
Inlet pressure	10 bar

4, RESULTS AND DISCUSSIONS

The performance of the accessory gearbox lube filter at various altitude conditions are monitored and recorded. Figure 4 shows the variation of inlet pressure at different altitude conditions and it was observed that inlet pressure across the lube filter drops from 10 bar to 6 bar during takeoff conditions.

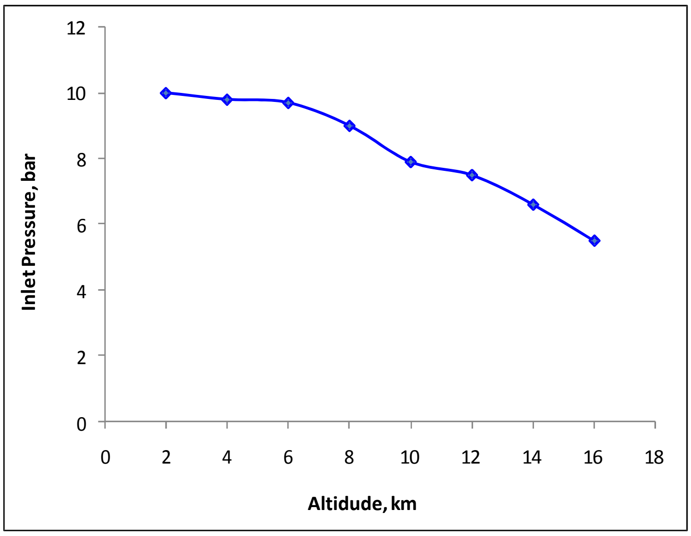

Figure 4. Variation of inlet pressure at different altitude conditions during takeoff conditions

Figure 5 shows the variation of differential pressure at different altitude conditions and it was observed that differential pressure across the lube filter drops from 0.7 bar to 0.6 bar during takeoff conditions.

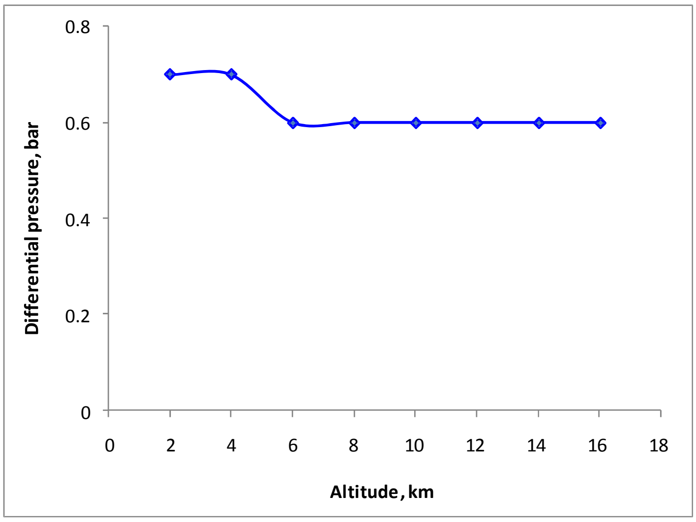

Figure 5. Variation of differential pressure at different altitude conditions during takeoff conditions

Similarly Fig. 6 shows the variation of flow at different altitude conditions and it was observed that flow across the lube filter drops from 17.7 lt./min to 12.9 lt./min during takeoff conditions.

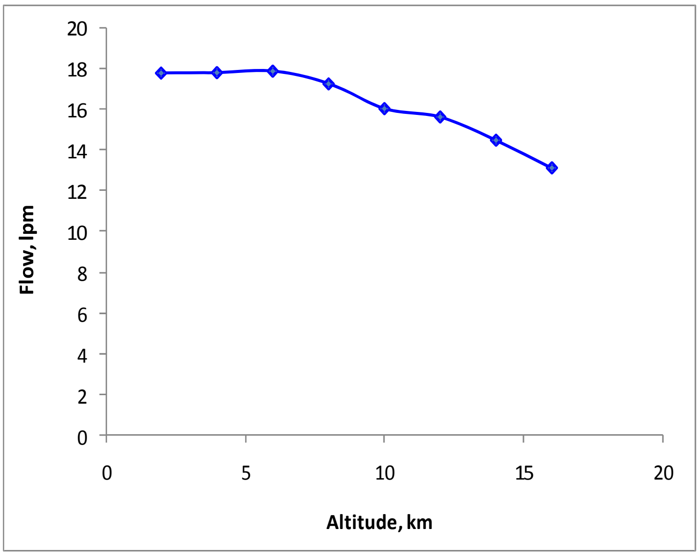

Figure 6. Variation of flow at different altitude conditions during takeoff conditions

Figure 7 shows the variation of inlet pressure at different altitude conditions during the descend conditions. The oil inlet pressure varies from 10 bar to 5 bar during the descend conditions. Pressure drop across the oil filter is in the order of 0.6 bar to 0.5 bar as shown in Fig. 8, with the flow rate in the order of 18 lt./min to12 lt./min as shown in Fig.9.

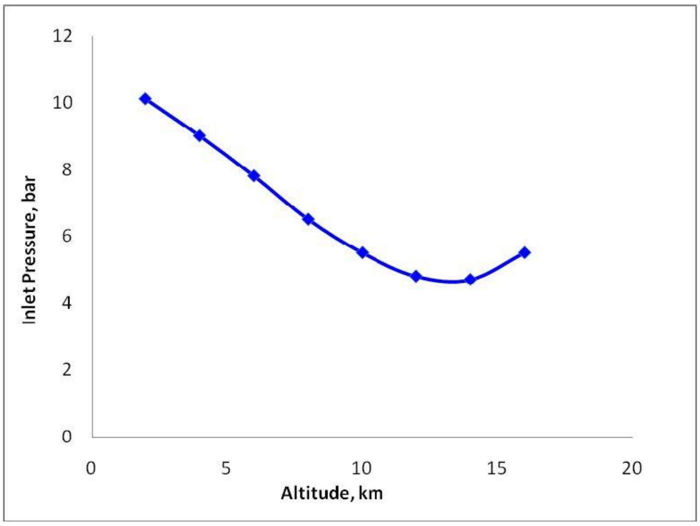

Figure 7. Variation of inlet pressure at different altitude conditions during descend conditions

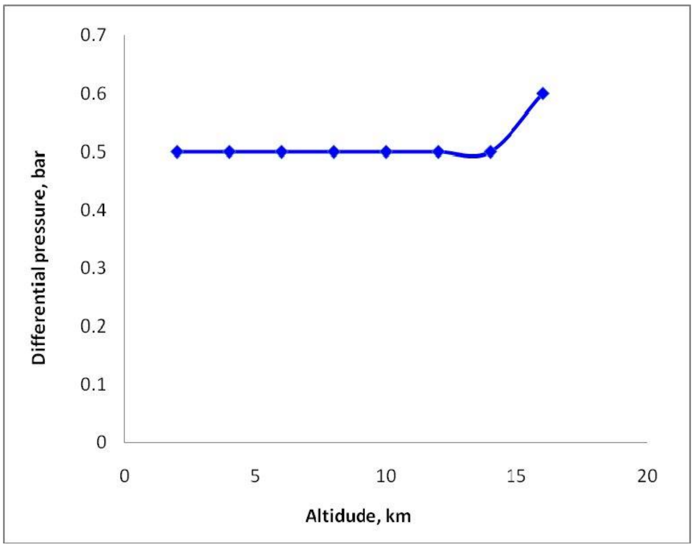

Figure 8. Variation of differential pressure at different altitude conditions during descend conditions

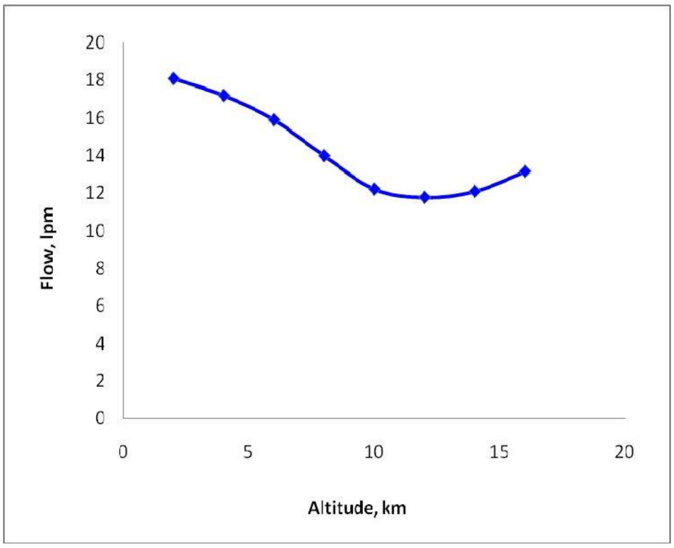

Figure 9. Variation of flow at different altitude conditions during descend conditions

4, CONCLUSIONS

- The simulated altitude conditions of the flight during the take-off and descend conditions, performance of the lube filter of an accessory gearbox has been evaluated and the results are presented.
- During different altitude positions, the inlet lube filter pressure is found to decrease in descend motions.

- The temperature of the lube oil across the filter within limits during the altitude cycle.
- Pressure drop across the lube filter within the limits indicates safe lubrication to the gears and its efficiency and life during altitude conditions.
- The higher inlet pressure and flow is noticed at an altitude of 10 to 12 kms across the lube filter, however pressure drop a/c the filter is 0.5 bar within the design limits, due to stabilization of pressure relief valve of the gear box. Therefore the altitude test simulating the high altitude maneuvering of the flight has significant effects on the lube filter performance.

REFERENCES

[1]. W. B. Herbst. "Future fighter technologies", Journal of Aircraft, 17(8), pp. 561_566, 1980.

[2]. Verdegan B.M., K. McBroom, L. Liebmann, Recent developments in oil filter test methods, Journal of Filtration & Separation, Volume 29, Issue 4, July–August 1992, pp. 327_331.

[3]. L.G.I. Bennett, Sarah Swanson, F.D. Koza and J.S. Poland “Condition monitoring of aircraft by Quantitative Filter Debris Analysis (QFDA)”, DTIC, Information for defense Community. This paper is a part of Technology Showcase: Integrated Monitoring.Diagnostics and Failure Prevention. Proceedings of a Joint Conference, Mobile, Alabama, April 22-26, 1996.

[4]. Richard K. Tessmann and Ing T. Hong, “Contamination control of aircraft hydraulic systems", An FES/BarDyne Technology Transfer Publication, 1998, pp.1_15.

[5]. C. Van Netten & V. Leung, "Hydraulic Fluids and Jet Engine Oil: Pyrolysis and Aircraft Air Quality”, Archives of Environmental Health: An International Journal, 2001, pp.181_186.

[6]. Myounggu Park, Fatigue failure of a hydraulic filter head, Engineering Failure Analysis, Volume 9, 2002, pp. 435_450.

[7]. Parker Arlon, Another addition to in-line hydraulic oil filter offering, Journal of Filtration & Separation, Volume 40, Issue 5, June 2003, pp. 10.

[8]. Allison M. Toms and Karen Cassidy, “Filter Debris Analysis for Aircraft Engine and Gearbox Health Management", J Fail. Anal., and Preven., 2008, pp.183_187.

BIOGRAPHY

B. Aruljothi currently working in aerospace division of Combat Vehicles Research and Development Establishment (CVRDE), Avadi as a scientist. He has completed Bachelor of Engineering in mechanical Engineering in 1983 and Master of Engineering (IC Engineering) in 1990 from Anna University, Chennai. He has developed sub-systems for Armour fighting vehicles and working on development of Aircraft subsystems. His area of interests includes hydraulic systems for aircraft applications. He has **published many papers** in **National and International level**.

A. M. Junaid Basha currently Additional Director heading the Manufacturing Division and Centre of Excellence for Filters of Combat Vehicles Research and Development Establishment (CVRDE), Avadi . He has completed Bachelor of Engineering in Mechanical Engineering from Anna University, Chennai. He pursued Master of Science and **Ph.D. from IIT Madras**. His Doctoral work was related to **Hydrostatic Steering System for Armoured Fighting Vehicles**. He has developed several hydraulic and lube filters for fighter aircrafts. His interest includes study of portable ultrafine filters to aid human renal failure cases. He is handling important Defence projects related to filters. He is the Secretary of Fluid Power Society of India, Madras Chapter. He is currently guiding many Ph.D. scholars in the areas of filters, hydraulic systems, Aircraft transmission systems and Active suspension systems. He has **published many papers** in **National and International level**.

Somashekhar S. Hiremath works as an ***Associate Professor and Head,*** **Precision Engineering and Instrumentation Laboratory** of Department of Mechanical Engineering at Indian Institute of Technology Madras, Chennai, Tamil Nadu, India. He received the **Doctoral Degree in 2004** from Indian Institute of Technology Madras, Chennai, Tamil Nadu, India. As an academic credential he received **Two National Awards**: **Innovative Student Project Award 2005** (**Best PhD Thesis of the year 2004–2005 in the Department of Mechanical Engineering**) from the Indian National Academy of Engineering (INAE), New Delhi and **Prof. K. Arumugam National Award** for *Innovative Research Work in Engineering and Technology* from Indian Society for

Technical Education (ISTE), New Delhi. He has **published many papers** in **National and International level**. More than 100 papers in his credits. He was delivered more than **60 Invited talks** on various topics of his research areas at Engineering Colleges, Universities, Research centres, Industries and conferences. Currently he has handling many **Consultancy and Sponsored Projects** of various industries and R&D institutions of Defence, Government of India. His **Current Research Areas are** Mechatronic System Design-System Simulation and Modelling, Robotics, Finite Element Modelling **-** basically Fluid Structure Interactions, Micromachining, Advanced machining processes – basically Hybrid Processes. He was guided 1 Ph. D. and 2 MS Thesis. Currently **5 Ph.D. Scholars** and **2 MS Scholars** are working under his guidance. Last but not the least he is a **Member of Many Professional Bodies** like Fluid Power Society, American Society for Precision Engineering and European Society for Precision Engineering and Nanotechnology (EUSPEN), Indian Society for Technical Education.

M. Singaperumal received his **BE degree in Mechanical Engineering** in 1969, **M.Tech degree in Machine Design** in 1976 and **Ph.D. in Fluid Power** from Indian Institute of Technology Madras in 1984. Currently, he is an ***Emeritus Professor* in Precision Engineering and Instrumentation Laboratory**, Department of Mechanical Engineering at the Indian Institute of Technology Madras, Chennai, India. He has published **many papers in international journals** and **guided many MS and Ph.D. scholars** in the field of fluid power, oil hydraulics, robotics, and Mechatronics. His current research interest includes hydraulic hybrids, underwater robotics, networked robotics, robot calibration, mechatronics, MEMS, micromachining, and oil hydraulics.