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Optimization of Operational Cycle Time for Testing Of Filter Pop-Out Indicator for Helicopter Gearbox Application

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ABSTRACT

The present study deals with the optimization of operational cycle time for testing of filter pop-out indicator for helicopter gearbox application. The main aim of this work is to carry out Pre-Installation check of filter pop-out indicator in order to do that we have to install the filter on the Gear Box and then run gear box to raise the temperature upto 65ºC and then the filter tests were done, in doing so we are deviating from our main aim which by alternate method can be developed. Hence ALH MGB has to undergo functional test continuously for 1 hour to check the condition of the filter pop-out indication. As a consequence, the MGB queue up adding as bottleneck. Moreover, if there are any issues during the test like pressure drop, leak, chip warning, stalling of actuator etc., the test on other MGB cannot be taken up until resolving the issues on the MGB being tested. In view of this to check the filter functionality all other parameters has to concentrated which is unnecessarily time consuming various activities other than actual testing. Study of cycle time for the entire process is required, Design, Development of dedicated test rig for PI check of filter pop-out indicator had been taken up.

KEY WORDS: Optimization, Filter Pop-Out, Gearbox, Test Rig.

1. INTRODUCTION

The Advanced Light Helicopter is a twin-engine, lightweight, multi mission helicopter of 4 to 5 tons class. It is powered by TM 333-2B-turbomeca engines. The airframe is consists of cockpit mid fuse cage and rear fuse cage and tail boom with empennage[1]. The cockpit provides all round visibility, crashworthy seats for two pilots of crew entry /exist doors. The mid fuse cage provides for ten passenger it contains two sliding doors. Two main fuel tanks and two supply tanks are located in the crash worthy bottom structure. The rear fuse cage comprises of cargo comportment with two clamshell doors, rear fuel tank and avionics bay in the bottom structure[2]. A cowling covers the engine installation the tail boom supports the tail rotor with controls, vertical pins and horizontal stabilizer with end plates a tail bumper protects the tail boom. The helicopter fitted with skid landing gear consisting of a forward cross tube, a rear cross tube and 2-skid tube.

Main Features of ALH:

- Advanced engine with Full Authority Digital Electronic Control (FADEC).
- Hinge less Main Rotor offers good maneuverability and maintenance free Operation.
- Advanced blade profiles ensure low noise, high speed and efficient lift.
- Composites used over 65% of wet area ensure longer life, low life cycle
- Costs, high power to weight ratio.
- High reliability due to redundancy in critical systems.
- SIX degree of freedom isolation system.(ARIS)
- Easy maintenance due to modular design and bite facilities in major systems.
- Main rotor blade folding facility for restricted area parking.
- Under flow crash worthy fuel tanks.
- Skid type and landing gear for air force/army versions.

Transmission System: Power from the engines is combined in the main gearbox (MGB) and transmitted to the main rotor. The tail rotor drive shaft is driven from the MGB and transmits power through flexibly coupled shafts, an auxiliary gearbox, intermediate gearbox and a tail rotor gear - box to the tail rotor. The power from the MGB is also used for driving various accessories arranged in two distinct areas; LH & RH sides of MGB, which consists of Hydraulic - pump drive, an alternator drive and a lubricating pump drive[3].

Assemblies of Transmission System:

Transmission system consists mainly of:

- Main gear box
- Auxiliary gear box
- Intermediate gear box
- Tail gear box
- Tail drive shaftnti-resonance isolation system (ARIS)

Main Gear Box: The main gearbox – MGB (Fig.2) fulfills several functions in addition to its main function.

- Transmission of power and reduction of rotational speed between the engines and the rotors.
- Provision for the fixed anchoring of the flight servo controls.
- Driving various accessories such as hydraulic pumps, alternators, cooler fan.

It is designed to suit the integrated dynamic system and is supported in the airframe by an anti-resonance vibration isolation system (ARIS). The power taken off from the engines is transmitted through a flexible coupling shaft running at 6000 RPM. The MGB reduces the nominal 6000 RPM of engine output speed to a nominal 314.06 RPM of main rotor speed through a two stage bevel spiral gears system reduction[4]. The reduction ratio of the gearbox is approximately 19. Reduction ratio is defined as the ratio of engine output speed to the rotor speed.

Reduction ratio = 6000/314.06 = 19

The main gearbox is also designed to cater for tail rotor output, power take off for hydraulic pumps, alternators & oil pumps. In addition, the design permits housing of the upper controls inside the gearbox and attachment of the hydraulic actuators. Freewheels have been provided on both sides between main gearbox and engines to prevent rotor driving the engine, in case of engine failure and also during auto rotation as well as during single engine operation. The free wheels are roller cam type. The LH side free wheel has provision for selecting to actuate mode. In the actuated mode (with only the LH engine running) the drive to the rotor is disconnected while at the same time driving LH accessories of the MGB. This is useful for particular checks on AFCS and also to use the LH engine as an auxiliary power unit (APU).

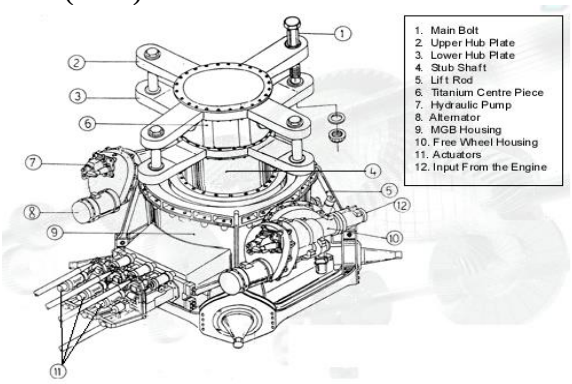

Figure.1. Main Gear Box

Power Train: The power train from the engines to the rotor shaft is achieved by a two-stage reduction system. The power output of both the engines is collected in the second stage (Collector Stage). This gives the transmission the best fail- safe qualities because the gears, shafts etc are designed and tested for the takeoff power (TOP) ratings of the engines[5]. In the normal twin-engine operation, each of the power trains is loaded with only the maximum continuous Power (MCP) ratings of the engines for major percentage of time.

Oil Pumps: The geo-rotor type of oil pumps are installed inside the gearbox. These pumps rotate at 5037 rpm, being driven by a quill shaft through the accessory power train of MGB. Two pumps provide redundancy and adequate lubrication even if one pump fails. For effective scavenging of the lubricating oil trapped in the center section of the main gear box, back to the oil sump, geo-rotor type of scavenge pumps have been installed, these scavenge pumps are integrated with the pressure pump. The pressure pump has a single suction and delivery of its own, the scavenge pumps have individual suction lines and a common delivery port.

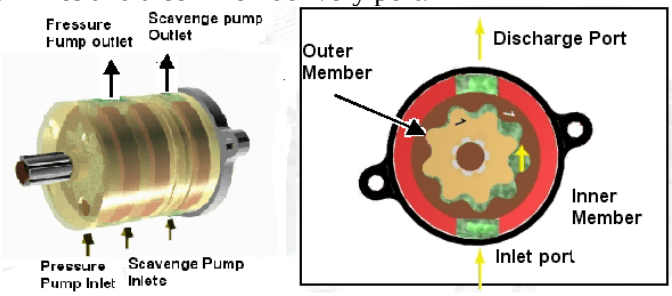

Figure.2. Oil Pump

MGB lube system uses a micro filter. In case of debris blocking the pores of the filter, the oil will by pass the filter and there will be apop-out warning (red button), which can be detected during the ground checks. In case of such warnings the micro-filters need to be checked for the debris and action to be taken as per maintenance manual. Figure.3, shows the Filter with Bypass & Pop out Indicator.

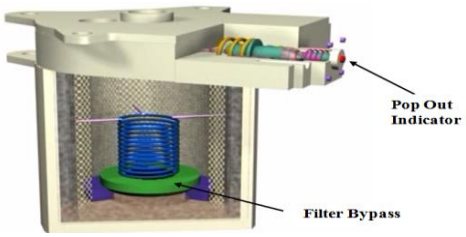

Figure.3. Filter with Bypass & Pop out Indicator

MGB Interfaces: MGB - STRUCTURE: The MGB is supported on the airframe via an anti-resonant isolation system (ARIS).MGB - ROTOR HEAD: The main rotor hub is directly attached through stub shaft to collector gear. MGB - ENGINE: The MGB is mounted independent of engine with only the input drive shafts connecting each engine with the MGB[6]. The input drive shaft employs flexible coupling at either end, which are designed to accept axial and angular misalignment. MGB - ACCESSORIES: Accessories such as Hydraulic pumps, alternators and lubricating pumps are driven by the accessory drive of the MGB along with the main rotor drive with the LH side having facility for actuated mode where only the accessories can be driven without driving the rotors.

2. METHODOLOGY

Lubrication system of a main gearbox assembly is a critical subsystem. The lubrication system of the Main Gear Box (MGB) of ALH and LCH employs two types of lube oil filters viz. course filter and fine filter (filter element size 3µ). These filters are required to maintain cleanliness of the lubricating oil required for smooth operation of the gearbox[7]. There are two fine filter assembly's located one each at LH & RH of the MGB. Each filter assembly consists primarily of filter element assembly and the filter element housing. Further, the filter element assembly comprises of top cover, bottom cover, and centre tube, filter element of 3 µ size & popout indicator. The Pop out Indicator is intended to show / indicate the condition of the filter in the lubricating system of Main Gearbox (MGB) of the Advanced Light Helicopter (ALH). & Light Combat Helicopter (LCH).

The pop out indication is a fore warning before opening filter by pass. The indicator is fitted on the filter body & operates on the differential pressure between oil entry to filter & exit from filter. Presently, the filter element is clogging at an average life of around 100 hours of flying. Hence, filter elements are replaced at around 100 hours[8]. These elements were replaced before total clog of the filter element because of the lower temperature setting of Pop out indicator (i.e. 27^0C during raise in temperature and 0^0C during lowering the temperature). To overcome the early indication of the pop out indicator, the design improvements were made to increase life of filter element by increased filter element length (i.e. 167mm from 105mm) and temperature setting changed pop out indicator (i.e. 60^0C during raise in temperature and 40^0C during lowering the temperature).

Functioning of the equipment: The Fig.1, shows pop-out indicator. The contaminated particles collecting outside the filter element cause the differential pressure to increase across the element. When this increased pressure reaches a specific value of pressure $P_{cracking} = 2.36^{-0.3}$ bar, inlet pressure forces the spring-loaded magnetic piston downward breaking the magnetic attachment between the indicator button and magnetic piston. This allows the red indicator to pop out.

Cracking pressure, $P_{cracking} = 2.36^{-0.3}$bar

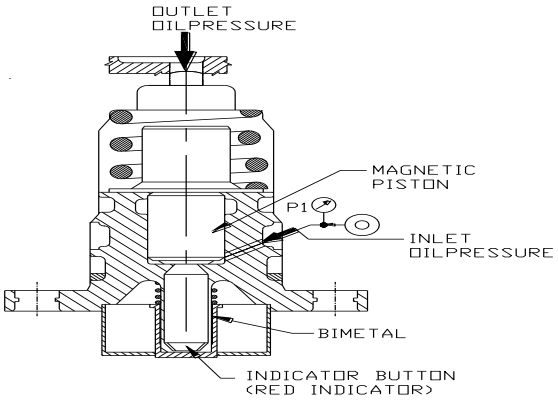

Figure.4. Cross-setional view of pop-out indicator

Research Methodology: Working experience was used to great extent, as we were aware that when we block the filter with dummy element, with the pressure differences the filter will pop out. Then the concept of heating the oil were thought of as when we run the Main gear box the oil will get heated up, So instead of using MGB a container with oil and heater of known capacity could be used to heat the oil. Then the idea of creating the pressure differences was thought of as the original filter was used on the Main gear box and the Main Gear Box speed was controlled to

get the required pressure. So the idea of controlling pressure came. By controlling the pressure, Pressure differences was created and the filter popped out at the required pressure.

As a trail filter was assembled on a flexible lines with motor pump assembly, oil was used in a bucket as tank, Valves was also connected to the flexible hoses to control the oil pressure, Pressure gauges was connected to the inlet and outlet lines, lot of leakages was observed and the unable to get the required pressure, then again all the leakages were arrested in the joints, then only we were able to control the pressure. Oil was separately heated with the help of heater and poured in bucket and also the pop out of the filter was sometimes coming on sometimes off, due the fine controlling of the pressure required. And also when trails was going on we observed that line experienced high pressure due to the absence of the pressure relief valve, again pressure relief was introduced in the line. After all this exercise. Then required materials list was prepared, instead of flexible hoses hard lines were thought of, Stainless steel tank was thought of, Precision quality gauges were brought and assembly carried out.

After all this we were unable to control the motor pump as we connected the motor directly to the main power, so the safety concern was No overload protection, single phase protection was not available, so we thought of using a starter, and also heating the oil outside was also a problem, so we thought of using heater integrated in the tank which can make the oil heat. Another problem was to control the temperature of the oil, Again Temperature indicator with relay outputs was thought of, via relay thermocouple was use d to control the temperature of the oil.

Cycle Time Reduction through Dedicated Test Rig: The various activities involved on the MGB test rig and the activities which can be done through dedicated test rig is shown in Table-1. From the Table, it can seen that that cycle time involved during installation ,test run & Removal of MGB from functional test rig is 220 Minutes. By using the dedicated test rig the time involved for Installation, Functional run & test is 35 Minutes. From the above. It can inferred that there is a reduction of about 185 Minutes by developing dedicated test rig forPI check of MGB lube oil filter pop-out/clog indicator of ALH/LCH.

Table.1. Cycle time involved in the assembly of MGB & dedicated test rig

SL. No.	**Major activity on th test rig**	**Activity performed**	**Activity to be performed**	**Time cycle**	
		on the PI check test rig	only on the test rig	If done on the rig (Min)	If done on the PI check test rig (Min)
1	Installation of MGB on to the base plate		□	20	
2	Instrumentation		□	20	
3	oil Slushing under static condition		□	30	
4	Oil filling / Draining		□	10	
5	Connecting the MGB to Drive shaft		□	10	
6	Brake converter connection		□	5	
7	Heating of the oil	□			20
8	Test Run	□	□	70	10
	Total time			**165 Min**	**30 Min**

About 135 Min (165 -30) of cycle time could be expected to be reduced.

Table 2: Cycle time involved in the dis-assembly of MGB & dedicated test rig

SL.No.	**Major activity on th test rig**	**Activity to be performed**		**During Removal (Min)**	
		only on test rig	**PI Check test rig**	**If done on rig**	**PI Check test rig**
1	Removal of MGB on to the base plate	□		20	
2	Removal of Instrumentation	□		20	
3	oil Slushing under static condition				
4	Oil filling / Draining				
5	connecting the MGB to Drive shaft or	□		10	
6	Brake converter connection	□		5	
7	Test Run schedule				
8	Hooking of the PI Check test rig		□		5
				55 Min	**5 Min**

About 50 Min (55 -5) of cycle time could be expected to be reduced.

Test rig for PI check of MGB lube oil filter Pop-out/clog indicator of ALH/LCH: The test rig. Developed in Transmission assembly of Helicopter division, which is used for the PI check of the Filter pop out/Clog indicator, is shown in Fig.2. It is assembled with filter housing with dummy cylinder (to simulate the clogged condition of filter) and temperature setting changed pop out indicator.

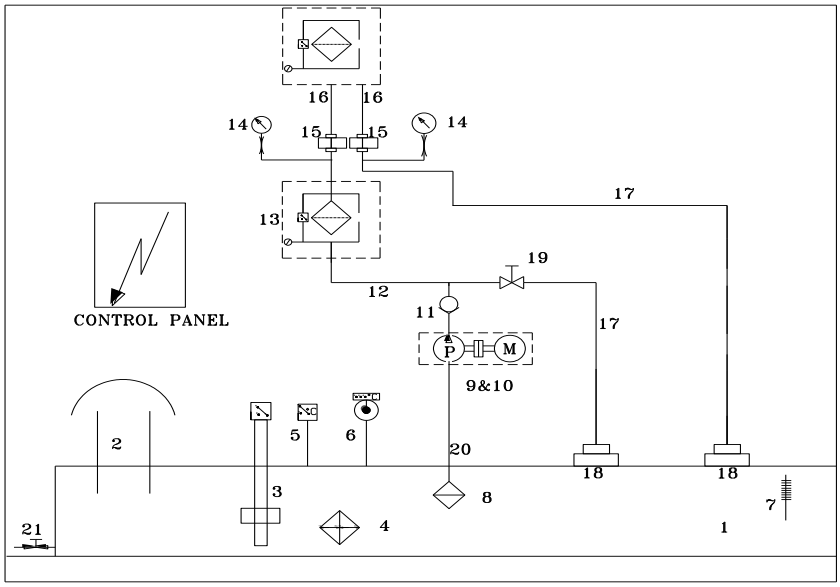

Figure.5. Schematic Line Diagram of MGB Lube Oil Filter Pop-Out/Clog Indicator

Description of the test rig: The above test rig circuit caters for pre-installation check of 3µm filter element with temperature setting changed pop out indicator (from existing (0°C to 27°C) to (40°C to 60°C)) for checking function and recording the characteristics. It consists of a fixed displacement gear pump (30 lpm) Sl No. 8 coupled to an electric motor Sl No.10 of capacity 0.5 hp, The pump suction line is fixed with suction strainer of 100 micron SS mesh, at the downstream of the pump is connected with pressure relief valve (Not shown in the fig.2). The check valve Sl No. 11 provided to prevent reverse flow of oil, Immediately after the output of the check valve oil branches out into two different paths, LH & RH .On the LH side, the circuit is having a return path of oil back to oil reservoir as a safety measure(closed loop) ,However in the closed loop, regulating valve Sl No. 19 is placed ,the regulating valve will be utilized as & when required to build a pressure on the RH side by partially operating the regulating valve.

On the RH side 3 micron filter Sl No.13 is placed immediately after the check valve Sl No. 11 which ensures clean & pure oil will pass through the filters under test, each of these filters are equipped with electrical clog switch which gives electrical indication/Alarm for immediate change of clogged filter with new ones & also trips loading circuit motor Sl No.10.

The clean/pure-filtered oil is sensed for temperature (Sl No.5) & pressure (Sl No.14) respectively. Thermostat constantly monitors the supply oil temperature & gives electrical indication/Alarm & trips loading circuit motor.

The oil reservoir (Sl No. 1) circuit is of capacity 100 ltrs & stores OX 38 aircraft lubrication oil. It also constitutes of accessories like filler breather (Sl No.2), oil level gauge(Sl No.7),, drain valve(Sl No.21), float switch, (Sl No.3), heater (Sl No.4), with temperature controller to maintain the oil temperature at greater than 60ºC & temperature gauge (Sl No.5), to visually indicate the reservoir temperature.

Conduction of test at Transmission Assembly / Ground test centre: Carry out differential pressure setting of pop out indicator as below.

- Assemble the filter assembly with blanking plugs.
- Introduce the pressurized lube oil (with 3 bar & 4 bar oil pressure in steps) by regulating the valve
- Switch on the heater to get different oil temperature i.e 30 ºC, 40 ºC , 50 ºC & 60 ºC in steps.
- Initially keep the oil temperature at 30 ºC and check for pop out indication for different pressure i.e for 3bar and 4bar. Ensure there is no pop-out indication.
- Repeat the test for 40 ºC and 50 ºC of oil temperature and ensure that there is no pop out indication.
- Introduce pressurized oil at temperature ≥ 60 ºC and increase the oil pressure slowly and note down the pressure at which pop out indicator actuates. The pressure should be at $2.06^{\pm 0.3}$ bar pressure.
- Repeat the by decreasing the temperature from 60 ºC, 50 ºC, 40ºC and 30 ºC and ensure that there is no pop out indication below 60 ºC.

- After ensuring the above, the blanking plug to be replaced with actual filter element part and assembly to be finalized.
- Install the above filter assembly on the MGB assembly.

Technical Specification ForPI Check of MGB Lube Oil Filter Pop-Out/Clog Indicator of ALH/LCH Test Rig.

Item specifications (refer drawing for item no. and quantities)

Item no.	Description	Specifications	QTY
1.	Oil Reservoir	50 litres reservoir of SS material. Mounting feet at 4 places below the reservoir / system, as shown in the drawing.	1
2.	Filler Breather	25 micron filler breather to be provided.	1
3.	Oil level float switch	Float switch for interlocking with the control panel to cut off the heater circuit and pump motor when oil level is low. M/s Sridhan make or equivalent.	1
4.	Heater	2.0 kW, controlled by the temperature controller, interlocked to the oil level float switch.	1
5.	Temperature controller	Temperature controller with digital indicator, to maintain the temperature at preset points of 100 +/- 2 deg. C, of M/s Digitherm or reputed equivalent make.	1
6.	Temperature gage	Globe type temperature gauge, 0 to 120 deg. C.	1
7.	Oil level gauge	Standard	1
8.	Strainer	100 micron strainer (M/s Hydroline or equivalent).	1
9.	Pump	Gear pump, 30 LPM, with suitable 3 phase AC motor, 400 V, 50 Hz along with a suitable coupling, check valve (0.5 bar cracking pressure), all mounted on the tank top. The pump should be of M/s Dowty/Rexroth/Parker/Vickers make or equivalent. The motor to be of M/s IEC make or equivalent.	1
10.	Motor	5000 rpm, with suitable 3 phase 0.5 HP, AC motor, 400 V, 50 Hz .mounted on the tank top. The motor to be of M/s IEC/ABB make or equivalent.	1
11.	One way valve	½ inch size, Standard	1
12.	Flexible hose- outlet from pump	1/2 inch ID, 20 bars, with end fittings of 1/2 inch BSP straight swivel nuts (both ends), of Aeroquip or reputed equivalent make.	1
13.	Filter	3 micron absolute filter, 20 bars, with mechanical clog indicator, of Hydac/Parker/Rexroth make or reputed equivalent.	1
14.	Pressure Gauge	0 to 4 bars, least count 0.1 bar, glycerine filled, of M/s Mass/Wika/Stauff/equivalent make, with push to lock gage isolators. Gages/isolators must be neatly mounted together on a common mounting plate with the required tubing / routing, near the control panel.	2
15.	QDC - Suction	Quick Disconnect Coupling, 5/8 inch size (steel), Aeroquip or reputed equivalent make.	2
16.	Adaptor - Tank inlet & outlet filter connection	Adaptor ending in M20x1.5 thread to be supplied by vendor along with suitable O-ring.	2
17.	Flexible hose- outlet from Filter	1/2 inch ID, 20 bars, with end fittings of 1/2 inch BSP straight swivel nuts (both ends), of Aeroquip or reputed equivalent make.	1
18.	Adaptor	Standard	2
19.	check valve	½ inch size, Standard	3
20.	Flexible hose- Suction	5/8 inch ID, 20 bars, with end fittings of 5/8 inch BSP straight swivel nuts (both ends), of Aeroquip or reputed equivalent make.	1
21.	Drain Valve	Standard	1
22.	Adaptor-Pressure sensor	Adaptor ending in M12x1.25 thread (Not shown in the dwg.)	2
23.	Pipes & fittings	Suitable	
24.	Control Panel	Standard	1

Extension of the Test Rig for Setting of Pressure Relief Valve (PRV): The pressure relief valves are employed in lube circuit of MGB assembly and AGB assembly, so that in case of over pressure in the lube line, oil is rerouted back to sump thus protecting the system from over pressure or bursting the lube circuit. The pressure relief valve is also employed in MGB filter assembly so that in case of over pressure due to clogging of the filter, oil bypass and unfiltered oil will be entered into the system thus provide the lubrication to the system. Pressure relief valve consist of a spring loaded valve along with number of washers, steel ball, pin ,guide valve, body bypass valve, static sealing ring ('o' ring) as shown in the figure.1. The number of washers is decided based on the requirement of pressure setting. If the pressure at inlet of the PRV exceeds the limit of the setting pressure of MGB or AGB, the valve will open & oil will bypass.

Earlier the setting of Pressure Relief valve was done outside the production shop which requires more cycle time and involves more logistics. PRV setting is very critical as far as Gearbox assembly is concerned since it prevents the over pressure in the lubrication circuit. Meanwhile if the PRV is set to a lower value than the Designed value, then sufficient pressure will not be developed in the lubrication circuit which may lead to low pressure warning in the helicopter. Considering these criticality of PRV, it was decided to fabricate a dedicated rig for carrying out the setting of PRV. The new test rig is designed such a way that it can be adapted for both pop out indicator testing and PRV setting.

Procedure to Carry out PI Check of the PRV Using Test Rig: Detailed procedure to carry out pressure setting of PRV is as below.

Ensure rig is in close loop (Inlet & outlet of the ports bridged with additional hose).

- Switch on the heater of the test rig and wait till oil temperature reaches specified temperature.
- Run the test rig for 5 minutes such that oil throughout the tank & circuit will have uniform specified temperature.
- Remove the bridging hose between inlet & outlet ports of the rig
- Assemble the PRV in the lube circuit i.e connect the out let of the rig hose to the inlet of the PRV.
- Ensure the temperature is stabilized. Record the temperature.
- Increase /Decrease the flow rate by opening/closing the throttle valve present in the lube circuit. Such that the oil pressure setting requirement is met.

Instrumentation: Following instrumentation to be carried out during above PI checks.

- Temperature sensor
- Pressure gauge at inlet of PRV assembly.

4. CONCLUSION

In the present study, optimization of operational cycle time for testing of filter pop-out indicator for helicopter gearbox application was done and the the following conclusions were made,

- Cycle Time reduction through dedicated test rig
- Manpower required is limited with comparison with earlier
- Cost is reduced as rig requires minimum items as compared to MGB test rig
- Power is saved as we use 0.5 HP motor-Pump set to carry out the test where unnecessary power is required to drive MGB is 45kW.
- Maintenance is easy due to 1 Motor-Pump set, few hard lines, less pressure gauges
- Time is saved in assembly, Testing and dis-assembly of the filter
- Total time reduction chart is available
- The same rig can be used for checking the filters of other Helicopters like LCH, LUH
- The same test rig can be used to check the pressure relief valves of all Gear boxes of ALH Helicopter
- If further developed with higher capacity Motor-Pump set, Lube Pumps of MGB can be checked with a canopy to hold the pump

REFERENCES

Aditya Polapragada A.S, Sri Varsha K, Pneumatic Auto Feed Punching and Riveting Machine, IJERT, 1 (7), 2012, 96-104.

Alfieri A, Tolio T, Urgo M, A project scheduling approach to production planning with feeding precedence relations. International Journal of Production Research, 49 (4), 2011, 995-1020.

Dossenbach T, Manufacturing cycle time reduction - a must in capital project analysis, Wood & Wood Products, 105 (11), 2000, 31-35.

Eckert C, Clarkson P, Planning development processes for complex products, Research in Engineering Design, 21 (3), 2010, 153-171.

Johnson J.D, A framework for reducing manufacturing through put time. Journal of Manufacturing Systems, 22 (4), 2003, 283-298.

Rahul Joshi R, Naik G.R, Reduction in Setup Time By SMED A Literature Review, International Journal of Modern Engineering Research (IJME), 2 (1), 2012, 442-444.

Suzic N, Stevanov B, Cosic I, Anisic Z, Sremcev N, Customizing products through application of group technology: A case study of furniture manufacturing. Strojniški vestnik - Journal of Mechanical Engineering, 58 (12), 2012, 724-731.

Herrmann J.W, and Chincholkar M.M, Design for production: a tool for reducing manufacturing cycle time, Proceedings of DETC 2000, ASME Design Engineering Technical Conferences, Baltimore, 2000, 1-10.