STUDY OF FILTER MEDIAS UNDER COLD CONDITIONS

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Abstract

The combat aircrafts are designed to perform in cold conditions at high altitude field areas with high reliable control systems. The control systems include hydraulic filters operatingin extreme cold conditions. The design ofsophisticated aircraft filters involve strict compliance to the International standards for higher reliability and efficient performance of the hydraulic systems. Generally the glass fibre and stainless steel mesh medias are used in aircraft hydraulic filters. The hydraulic filters are subjected to high differential pressures during cold environment operating conditions. The present work describes the comparative performance of hydraulic filters with glass fibre and stainless steel mesh under cold environment conditions.

Key words: Glass fibremedia, stainless steel mesh media, flow, pressure drop.

I.INTRODUCTION

The combat aircrafts are designed to operate at high altitude field areas. The extreme cold environment conditions at high altitudes affect the aircraft hydraulic systems. The sophisticated filters used in the aircraft hydraulic systems normally operate with filtration rating ranging from 3 microns to 30 microns. Generally glass fibre and stainless Medias are used in the aircraft hydraulic filters[1]. The glass fibre media filters are used where absolute filtration is required for operating precision hydraulic control valves. Whereas the stainless steel mesh medias are used for nominal filtration required for operating hydraulic pumps, motors and direction control valves [2]. The filters are subjected to severe differential pressures at cold conditions due to increase in oil viscosity. Hence the aircraft hydraulic filters have to be carefully designed with proper support to the filter media to withstand the severe differential pressures. The filter designer has to compromise between the major factors like dirt holding capacity, minimum initial clean filter element pressure drop and media support to withstand the high differential collapse pressure[3].

The aircraft filters have to be designed to cater for high reliability and stringent environmental conditions and qualified for the cold start test and bubble point test as per International standards conforming to MIL- F-8815E [4].

The present work describes the cold condition performance of aircraft hydraulic filters with glass fibre and stainless steel mesh medias. The comparative results during cold start conditions and media integrity bubble point test are presented and the conclusions are drawn.

II. GLASS FIBRE AND STAINLESS STEEL MEDIA FILTERS

Normally the glass fibre and stainless steel media types of filters are used in the hydraulic systems of a combat aircraft. The glass fibre media filters operate in the range of 3 micron to 25 micron filter rating.The glass fibre filters are used for absolute filtration of finer contaminations required for operating precision control servo valves and actuators. The stainless steel media filters operate in the range of 10 to 30 micron filter rating. The stainless steel mesh filters are used for nominal filtration of contaminants for less precision hydraulic valves, pumps and motors etc.

The construction of a galssfibre filter involves a central perforated stainless steel tube wound over with pleated glass fibre media of requisite filter rating along with supporting rayon fabric and course stainless steel mesh. The pleated media structure is glued at both ends with end caps as shown in Fig.1 TypeI and Fig.2 Type II filters. In the case of stainless steel mesh filters, the stainless steel media of requisite filter rating is supported with course stainless steel mesh pleated and wound over a perforated central steel tube. The pleated structure is welded with end caps at both ends as shown in Fig.3 Type III and Fig.4 Type IV filters. While designing the filters, care is taken to maintain the clean element pressure drop to the minimum at the same time provide proper support to the filter media against collapse pressures during cold start and clogging build up pressures.

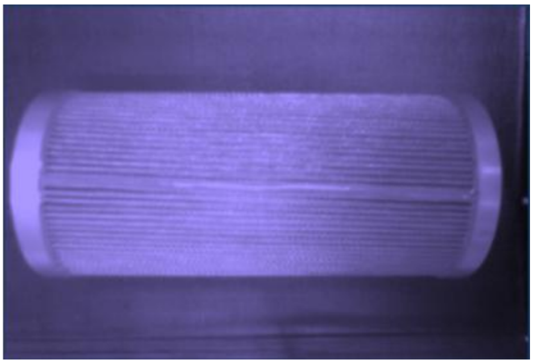

Fig. 1. Type 1 Glass fibre filter

Fig. 2. Type II Glass fibre filter

Fig. 3. TypeIII stainless steel mesh filter

Fig. 4. TypeIV stainless steel mesh filter

For the present work two different filter rating glass fibre and stainless steel mesh filters have been selected as shown in Table 1. The aircraft filters are subjected to rigorous qualification tests as per International MIL-F-8815E Std. After satisfactory test results, the filters are certified for aircraft flight trials by the authorised certifying agencies.

Table 1.Specifications of selected filters

Type of Filter	Filter rating, micron	Flow, lpm	Pressure, bar	Filter media
Type I	3μ	40	7.5	glass fibre
TypeII	25μ	34	7	glass fibre
TypeIII	16μ	40	3.5	wire mesh
TypeIV	30μ	40	4.5	wire mesh

In the present work the selected four filters are subjected to cold start test and the differential pressures experienced across glass fibre and stainless steel mesh filters are compared. The Bubble Point test is also conducted to ascertain the integrity of the filters before and after the cold start test [5]. The Bubble point test and the cold start test are described in the following.

III. BUBBLE POINT TEST

Bubble point test is performed to check the fabrication integrity of the filter element. The bubble point test is non-destructive testing for detecting defects in the media, seals, and the bonding at the joints and damage from handling. The pressure required to open the pore of the filter media can be calculated using the following equation [6].

[1]

Where
dX = pore diameter (m)
δ = surface tension (N \ m)
cos φ = wetting angle
ΔP = pressure drop at filter (Pa)

For all the above filters, the bubble point value is calculated and used as reference value for acceptance or rejection of the manufactured filter element.

A. Bubble point Test procedure

The bubble point test is performed by fully wetting and then mounting the filter element horizontally in the bath of Iso Propyl Alcohol (IPA). The Bubble point test facility is shown in Fig. 5. The IPA level is maintained at approximately 15mm above the top of the filter element. The filter element is then connected to a compressed air supply of about 1bar through a manometer. Slowly the air pressure is increased by the control valve and the filter element is rotated by 360° about the longitudinal axis and the entire filter area is scanned for the appearance of any bubble. The pressure in terms of water column in the manometer at which the first stream of bubble emerges from the filter media is observed as the bubble point value. The bubble point pressure obtained should be higher than the calculated value as per equation (1).

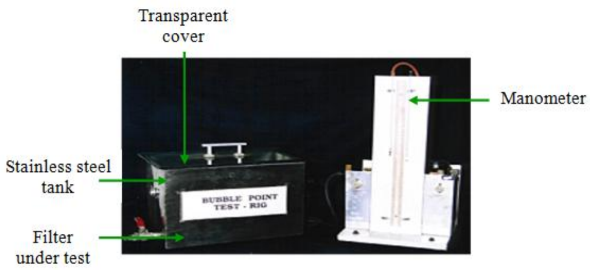

Fig.5. Bubble point test facility

IV. COLD START TEST

The four types of selected filters have to qualify cold start conditions at -40◦c for 75 cycles with a frequency of 2 cycles per second. This test ensures performance of the filter element at highly viscous oil condition creating high differential pressure with low flow across the filter [7].

B. Cold start test set up

The cold start test chamber is shown in Fig.6. In the cold chamber two transfer cylinders circulate the cold oil in the test filter for the specified number of cycles. The pump flow is connected to the two hydraulic cylinders through solenoid direction control valve operated by the electrical controls. At the end of the stroke of each cylinder a limit switch alternates the energizing of solenoid. The flow meter is connected to tank line of the directional valve. Necessary accessories like return line filter, pressure gauge and isolator have been provided to power pack, mounted on the mobile trolley outside the cold chamber.

Fig. 6. Cold start test chamber.

C. Cold start test procedure

The filter element is installed in a housing filled with specified oil and soaked at the temperature of -40˚C for four hours. The element is subjected to 75 flow cycles with a cycle time of 2 seconds. During the test, the differential pressure and the flow across the filter element are recorded. There shall be no evidence of filter damage for each filter element tested as observed by satisfactory completion of the subsequent bubble point test[8]. Table 2 shows the pressure drop, flow rate and bubble point results during cold start test

IV. RESULTS AND DISCUSSION

Fig.7 to Fig.10 shows the cold start test characteristics of the glass fibre and stainless steel mesh filter elements. From Fig.7 and Fig.8 it is observed that in the case of Type I finer 3 micron glass fibre filter pressure drop increases from 1 bar at 10˚C. to 7.5 bar at -40˚C. The corresponding flow reduces from 11.8 lpm to 7.8 lpm. Whereas for Type II 25 micron glass fibre filter the pressure drop increases from 1 bar at 10˚C to 6.5 bar at -40˚C. The corresponding flow reduces from 11.5 lpm to 7.5 lpm.

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Table.2 Cold start test results

No	Type of Filter	Temperature(˚C)	Pressure Drop (bar)	Flow (lpm)	Bubble point (mm of w/c)	
					Before	After
1	Type-I	-40	7.5	7.8	460	430
2	Type-II	-40	6.5	7.5	240	220
3	Type-III	-40	1.8	11	260	250
4	Type-IV	-40	2.2	10.2	120	110

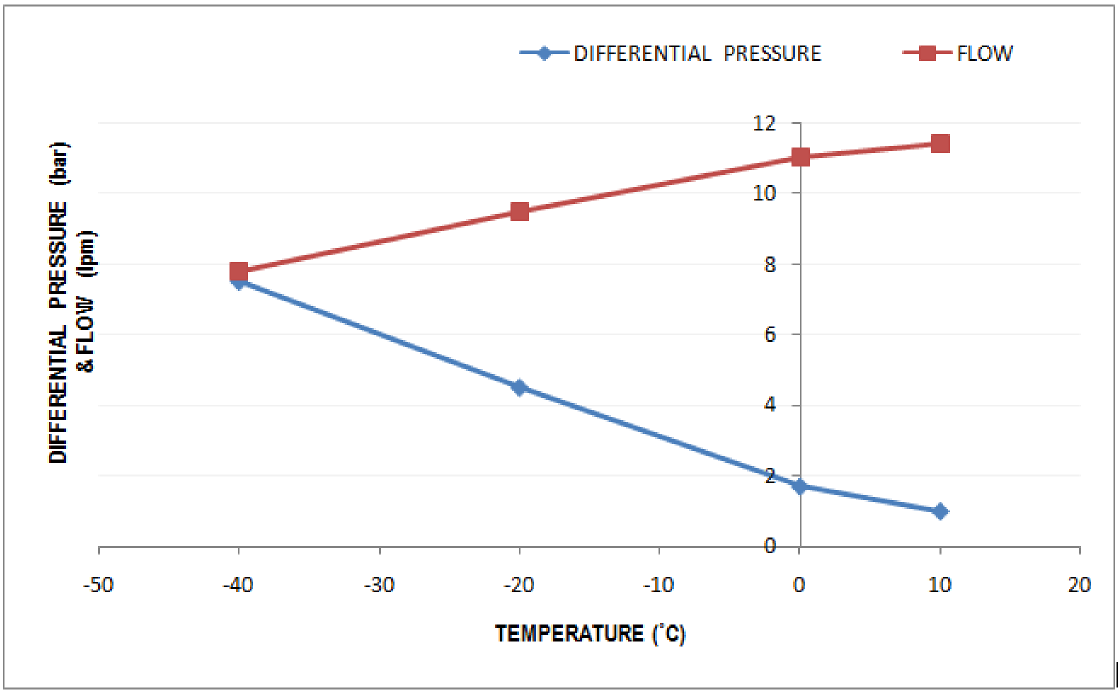

Fig 7.Cold start performance of Type I Glass fibre filter

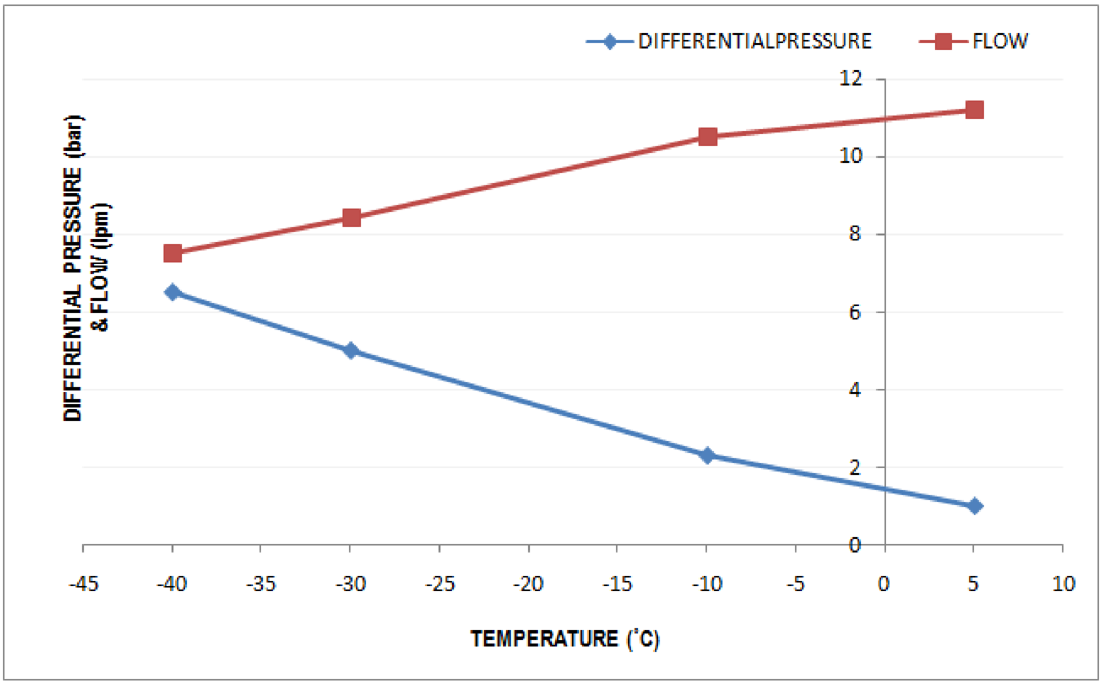

Fig 8.Cold start performance of Type II Glass fibre filter

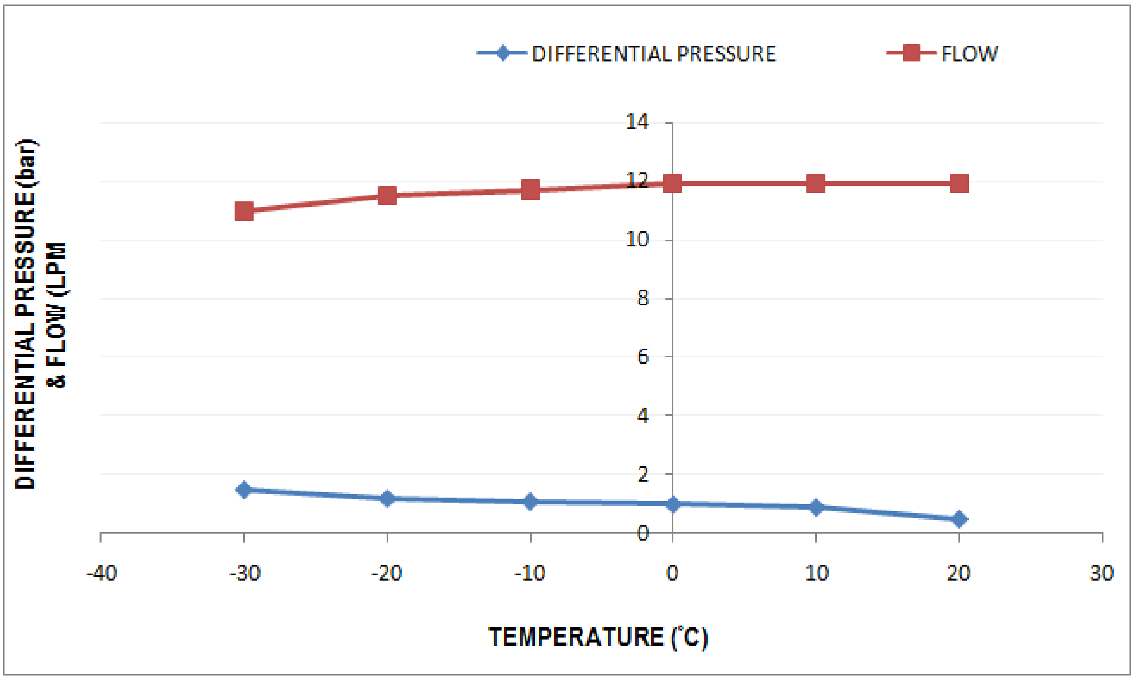

Fig 9.Cold start performance of Type III Stainless steel filter

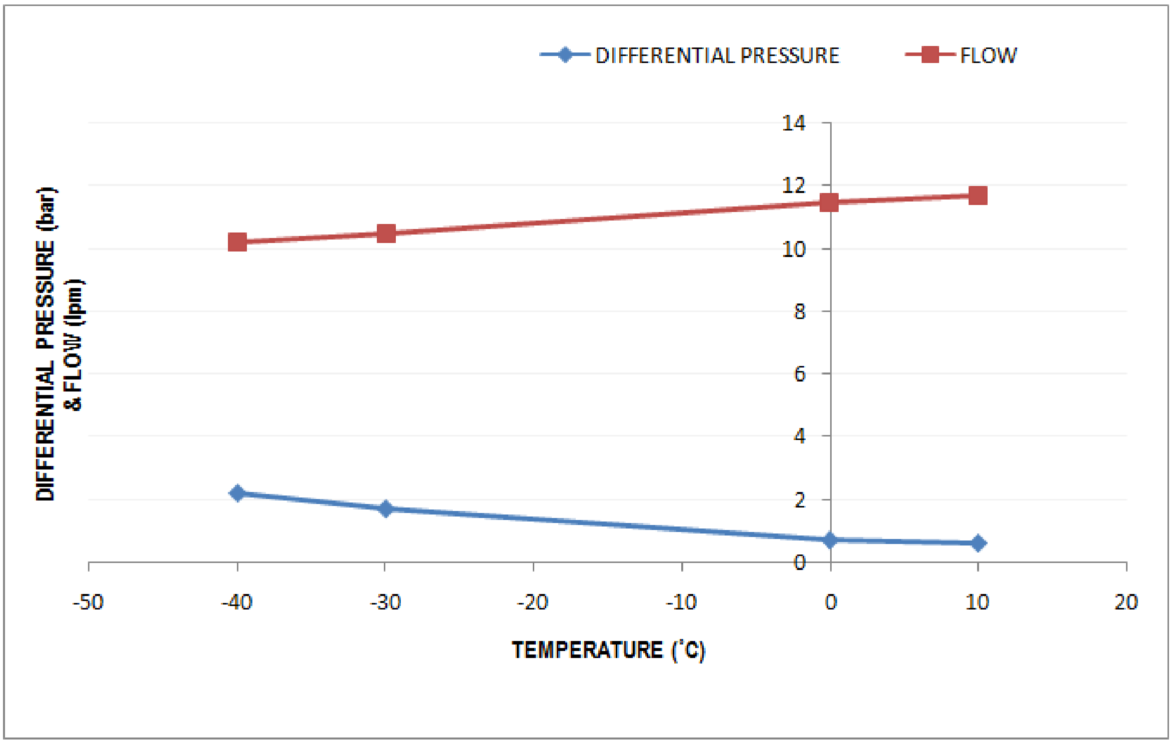

Fig 10.Cold start performance of Type IV Stainless steel filter

In both cases the pressure drop losses and reduced flow. will affect the aircraft transmission systems during the cold operating conditions Hence care must be taken while designing the size of the filter to ensure sufficient pressures for reliable aircraft operation. The pressure drop is higher in the case of 3 micron filter as compared to 25 micron filter due to more flow resistance in the finer pores of 3 micron filter media. The bubble point test during the pre and post cold start test reveals a marginal reduction of bubble point value for both Type I and Type II filters. This confirms the structural integrity of the filters.From Fig.9 and Fig.10 it is observed that in the case of Type III 16 micron stainless steel filter pressure drop increases from 0.5 bar at 20 ˚C to 1.8 bar at -40 ˚C. The corresponding flow reduces from 12 lpm to 11 lpm. Whereas for Type IV 30 micron SS filter the pressure drop increases from 0.8 bar at 10 ˚C to 2.2 bar at -40 ˚C. The corresponding flow reduces from 11.8 lpm to 10.2 lpm. Marginal variation in bubble point value ensures the integrity of the filters during cold start test. In both cases the pressure drop losses and reduced flow during the cold conditions are less as compared to the glass fibre filters. This is due to less flow resistance in the SS mesh filter media. This implies that where nominal filtration of contaminations is sufficient, glass fibre media filters can be selected for efficient hydraulic transmissionsystems.

However for hydraulic systems using precision servo control valves and precision cylinders, carefully designed absolute glass fibre filters are recommended [9].

V.CONCLUSION

Two types of glass fibre and stainless steel mesh filters have been subjected to cold start test for comparative study of the pressure drop characteristics. The pressure drop losses are more in the case of glass fibre media filters as compared to SS media filters. Hence wherever nominal filtration is sufficient, the SS mesh filters can be used for efficient operation of hydraulic systems. The finer 3 micron glass fibre filter offers higher pressure drop losses due to more flow resistance in filter media. Therefore sizing of the finer glass fibre filters have to be carefully designed to ensure sufficient pressure in the system beyond filters for efficient operation of hydraulic actuators.The bubble point test reveals that with sufficient supporting construction of the filter media, the filters withstand the higher differential pressures during cold environment conditions.

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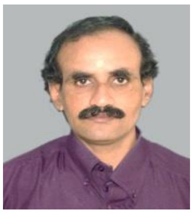

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