FLOW ANALYSIS OF LUBE SYSTEM OF A GAS TURBINE ENGINE

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Abstract : Lubrication is the property to reduce the friction in the engine components by applying a lubricant such as oil to minimize the friction and provide smooth movement to the engine components. During our investigation , the properties of the lubrication oil is being observed with the change in temperature of the engine box and the bearings used in the turbine engine. For the analysis of the lubrication oil we are using the LMS AMESim software. It is a simulation software which gives us a virtual platform to construct and modify the different types of system and test under the different condition. The results will be validated with the experimental data and the change in the properties of the lubricating oil will seen.

If the analytical results match with experimental results then the system can be used for the incorporation of new components in the model, prepared in the software, this will lead to the reduction in the cost of testing and also the time involved in the testing.

I. INTRODUCTION

Most of the present day aircraft gas turbine engines use closed loop lubrication system. This type of closed loop system is selected due to a very small loss of the lubricating oil through the system during engine run. Thus, the oil to be carried over the engine casing will be significantly less.

The closed loop lubrication system has three characteristic sections. The first section covers pipelines between the supply pump and the engine bearings. This is referred as supply line section. In this section, the oil after being filtered and cooled, is then supplied to lubricate the main shaft bearings, gear drives and gearbox. The second section is called scavenge pipeline section and that covers pipelines between bearing sumps and scavenge pumps. In order to safeguard positive suction of oil during the different altitudes of the engine in flight usually several scavenge pumps are installed in this section. Each suction line is fitted with a coarse filter and chip detector. The third section is between scavenge pumps to supply pump through Common scavenge Filter, IDBP & Oil tank. The oil from scavenge pumps passes through Common scavenge Filter and goes to IDBP where oil gets separated from air before falling back in the oil tank.

The gas turbine rotating components move at high speed and these parts undergo friction during motion which results in power loss. The bearings undergo wear and high temperature exposure which reduces the life of bearings. Therefore, this brings a need to supply lubrication oil to the bearings. In this analysis we check the lubrication oil supply parameters at different speed of the engine. Choice of the lubrication oil must be made carefully so that it should retain all its properties for the operating condition of the engine and should meet the requirement.

This analysis helps us in determining the pressure, temperature variation & flow distribution during the course of supply of lubrication oil to various parts. If the analytical values match with the experimental values this system can be used to predict the oil system performance for the incorporation of new components/modification in existing components which reduces the overall cost & time of testing.

1.1 Requirement of Lubrication

Lubrication is necessary to lubricate the various components of a gas turbine engine so that there is a smooth movement between the parts of the machine. The lubrication oil should have adequate viscosity so that it provides the proper lubrication. Higher viscosity can cause high oil temperatures due to higher power loss while shearing of oil film during lubrication and lower viscosity can cause lack of lubrication due to lower load capacity of the oil film causing oil film rupture.

The lubrication oil must carry the heat away from the gas turbine engine components such as bearings and seals to maintain the proper temperature so that overheating of the components can be avoided.

The choice of the lubrication oil depends on the requirement of the machine. A gas turbine engine requires a lubrication oil that can perform the function of both lubrication and heat removal. The lubrication oil used in a gas turbine engine should have a good viscosity index because the temperature attained in the gas turbine engine is very high and the lubrication oil should not lose its property when the temperature is increased inside the engine. The engines that are used in aircraft are exposed to higher altitude therefore the engine should have the lubrication system oil which can perform at varying temperature and pressure ranges.

II. LITERATURE REVIEW

2.1 Gas Turbine Engine and its Lubrication

A gas turbine is an internal combustion engine. It works on Brayton cycle. The gas turbine engine used in the aerospace industry has a problem of heat generation due to the parts moving at high speed. To reduce the generated heat, the lubrication oil is supplied to the parts which have relative motion between them.

The lubrication oil consumption sometimes increases due to the leakage of oil through various jets and seals. After every engine test, reduction of oil in the oil tank is noticed. Oil collection in bell mouth, bypass casing and in compressor drums were observed. When the engine was disassembled traces of oil were observed around shaft location and it seen that the oil which is found is troubling the smooth run of the engine. So proper care should be taken at the time of manufacturing the supply line of a lubrication system.

Matthew D. Teicholz et al (2018), the gas turbine engine consists of various components so it requires a lubricant to lubricate and remove the heat. The gas turbine engine includes a fan drive gear, pump, storing tank and the scheduling valves are included for varying the flow of the lubrication between the tank and the engine components depend on the conditions. It is noted that while lubricating the lubrication oil carries air with it and it changes the properties of the lubrication oil and after a period of time lubrication oil losses its property completely [1].

Thomas Ory Moniz et al (2018), this paper talks about the various pressure and temperature that a gas turbine engine goes through its running period. A gas turbine engine includes a fan section and a core turbine engine operated with the fan section. In this, a first duct in airflow communication with the valve and the first pressurized air source and second duct in airflow communication with valve and a second pressurization air source. The pressurized air flowing inside the turbine mixes along with the lubrication oil and changes the property of the lubrication oil so therefore the life of the lubrication oil decreases and there will be a need for change of the lubrication oil before the actual time period of changing [2].

Hermann Doell et al (2018), the auxiliary circulatory circuit with its lubricant supply tank and its pump is operatively connected to main circulatory circuit for supplying lubricant into the main circuit. The auxiliary circulatory circuit is effective during the engine start up and for replenishing lubricant into the main circuit during normal flight condition [3].

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III. Gas Turbine Engine Lubrication System

3.1 Basic need of lubrication in gas turbine engine

The requirements of lubrication system in a gas turbine engine is:

- To reduce friction between two solid bodies in relative motion, also called solid sliding friction.
- Retarding wear of engine parts.
- Minimizing temperature rise.
- Decreasing power requirement.
- In gas turbine engines, lubrication system is close looped and has the following objectives apart from the above: -
- Heat removal from:
- Engine Front and Rear Bearings.
- Bearing chamber seals.
- Power transmission Bevel Gears.
- Gearbox gear trains and bearings.
- Splines of engine accessories.
- Clean the engine and remove worn out particles.
- Prevent corrosion of parts.

3.2 Types of Lubrication Systems

Lubrication System: -

- Pressure Relief Valve System
- Full Flow System

3.2.1 Pressure Relief Valve System

Oil supplied to the bearing chambers is limited to a design value. On pressure exceeding design value, oil returned to pump inlet/outlet through valve. Valve opens at pressure corresponding to engine idling speed is greater than or equal to constant feed/delivery pressure all over.

Pressure relief valve system is used for engines with low bearing chamber pressure.

3.2.2 Full Flow System

No Pressure relief valve (PRV) are used and it allows the pump delivery pressure directly to oil jets.

Smaller size of supply and scavenge pumps, large oil spill by pressure valve relief system at maximum engine speed is obviated.

Pressure relief valve (PRV) are fitted to prevent damage to filters and coolers due to high oil pressure due to cold operating conditions or blockage.

Full flow system can be used for high bearing chamber pressures.

3.3 Classification of Lubrication oil

Mineral Oils produced from hydrocarbons by distillation and refining processes.

Fixed Oils extracted from animals, vegetable matter and fish.

Synthetic Fluids such as silicon polyglycol and ester based synthetic oils.

IV. MODELING OF LUBRICATION SYSTEM USING AMESIM

4.1 LMS AMESim Software

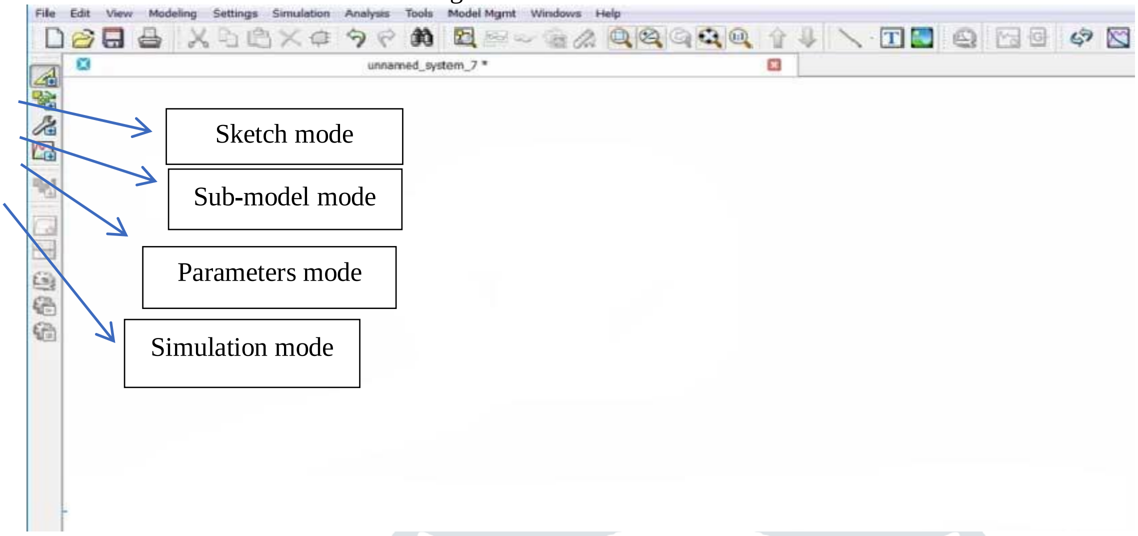
The full form of AMESim is Advanced Modelling Environment for performing simulations of engineering systems. AMESim is a 1D lumped parameter time domain simulation platform. AMESim uses symbols to represent individual components within the system which are either:

• Based on the standard symbols used in the engineering field such as ISO symbols for hydraulic components or block diagram symbols for control systems.

• Symbols which give an easily recognizable pictorial representation of the system.

4.2 Software Window

The AMESim software has the following modes:



4.2.1 SKETCH MODE

With LMS AMESim, you can build a sketch, affect submodels to the components and lines, set up the parameters of the submodels and then launch a simulation. Each step is performed in a specific working mode in LMS AMESim.

In Sketch mode we can: -

Build a new system

Modify or complete an existing system

Remove a component submodel

Designing the supply line of a lubrication system requires various number of components such as injectors, oil tank, pipeline, filter etc. These components are used based upon the requirement of the supply line. The components mentioned above are available in the library we can use them based on the requirement of each component. These components have some pre-defined values and these can be altered based on the system requirement.

4.2.2 SUB MODEL MODE

When your system is complete, you can enter Submodel mode to select submodels for the components of the system.

If the circuit is not complete, you cannot enter Submodel mode.

In Submodel mode we can:-

Select a submodel for each component.

Use the Premier submodel button so that the simplest submodel is automatically assigned to each component or line which has no submodel.

The sub model setup is the one where the properties of each component can be changed. In case of a thermal hydraulic pipeline we can use the pipeline which will consider both the friction factor plus the compressibility factor, in the same pipeline we have the option of using a pipe which will consider only friction factor. Therefore, the model which we are making will have no surface roughness and we can use a pipe with only compressibility effect.

In the sub model setup, we can change the specification of each component based upon the supply line specification.

4.2.3 PARAMETER MODE

In Parameter mode we can: -

Examine and change submodel parameters.

Copy submodel parameters.

Set global parameters.

Select an area of the sketch and show common parameters in this area.

When we enter Parameter mode, LMS AMESim compiles the system. The compilation creates an executable file. This executable file makes the simulation possible. Normally before we perform a run we adjust the parameters of the model.

Parameter setting is the phase in the modelling of a component, in this phase the input to each component can be given based on the requirement. Here the properties of fluid which is entering into the pipeline can be changed by changing the thermal hydraulic index of the fluid.

In the parameter setting before changing the dimensions of the components the system has to validate the model and check whether the system is perfectly closed or not.

4.2.4 SIMULATION MODE

In Simulation mode we can: -

Initiate standard and batch simulation runs

Create plots of results

Store and load the configuration of all or some of your plots

Initiate linearization of the current system

Perform various analyses on the linearized systems

The aim of the simulation mode is self explanatory, this is used to run and check the model, it is done after giving all the inputs to the model based on the requirement. It gives the system response when the fluid will flow through the pipeline, the pressure change of the fluid, its temperature variation and many other parameters. The results help us in knowing the system variation with respect to time without testing the model experimentally.

This helps us in reducing the time and cost that is involved in designing of the component.

V. TURBONYC 600 OIL PROPERTIES

5.1 Turbonyc 600 Lubrication Oil

Turbonyc 600 oil is a lubricating oil with its viscosity around 5cSt at about 100°C. It is a lubricating oil which is mainly used at high temperature application. Turbonyc 600 oil is mainly used for the lubrication in gas turbine engine.

5.2 Application of Turbonyc 600 Oil

The turbonyc 600 oil has many applications today in the industrial sector, a few of them are listed below: -

Used as a lubricating oil for aircrafts and helicopters.

It is used in aero derivative gas turbine

5.3 Benefits of Turbonyc 600 Oil

The benefits of using Turbonyc 600 are listed below: -

It has excellent non coking performance.

It shows low volatility at higher temperature range.

Turbonyc 600 has a higher flash point.

It shows low foaming tendency.

VI. SUPPLY LINE OF A LUBRICATION SYSTEM

6.1 SUPPLY LINE

The high pressure oil is sent to various parts of the engine to lubricate and carry away the heat. The supply line is also called as pressurized line.

The supply line consists of various number of components such as oil tank from where the lubrication oil is supplied, the supply line has a positive displacement pump. The supply line has a filter which is used to remove the impurities from the lubrication oil. However, each component that is involved in it act as a restriction to the flow which results in the back pressure, so the pressure after each component gets reduced in the flow line. After the filter, there is a Fuel cooled oil cooler (FCOC) heat exchanger where the fuel comes in thermal contact with the hot lubrication oil and thus the temperature of the lubrication oil is decreased, but due to a lot of bends in the oil flow it exerts a back pressure and it also acts as a restriction to the flow so the pressure at the outlet of the pump increases and pressure after the heat exchanger decreases. So the total pressure at the outlet of the pump is the combined effect of the back pressure due to each component that is assembled in the supply line.

The pressure and temperature in the supply line are inter-related indirectly. Since, viscosity decreases with the increment in the temperature and pressure decreases with the decrement in the viscosity, when the temperature of the fluid is higher the viscosity decreases and the pressure of the fluid will decrease and vice versa.

Pipelines: -

The pipelines to be designed keeping the following points in mind:

It should have leakproof joints.

The pipeline should have minimum numbers of bends for minimum pressure drop.

It should withstand the working pressure with the appropriate margins as per safety standards.

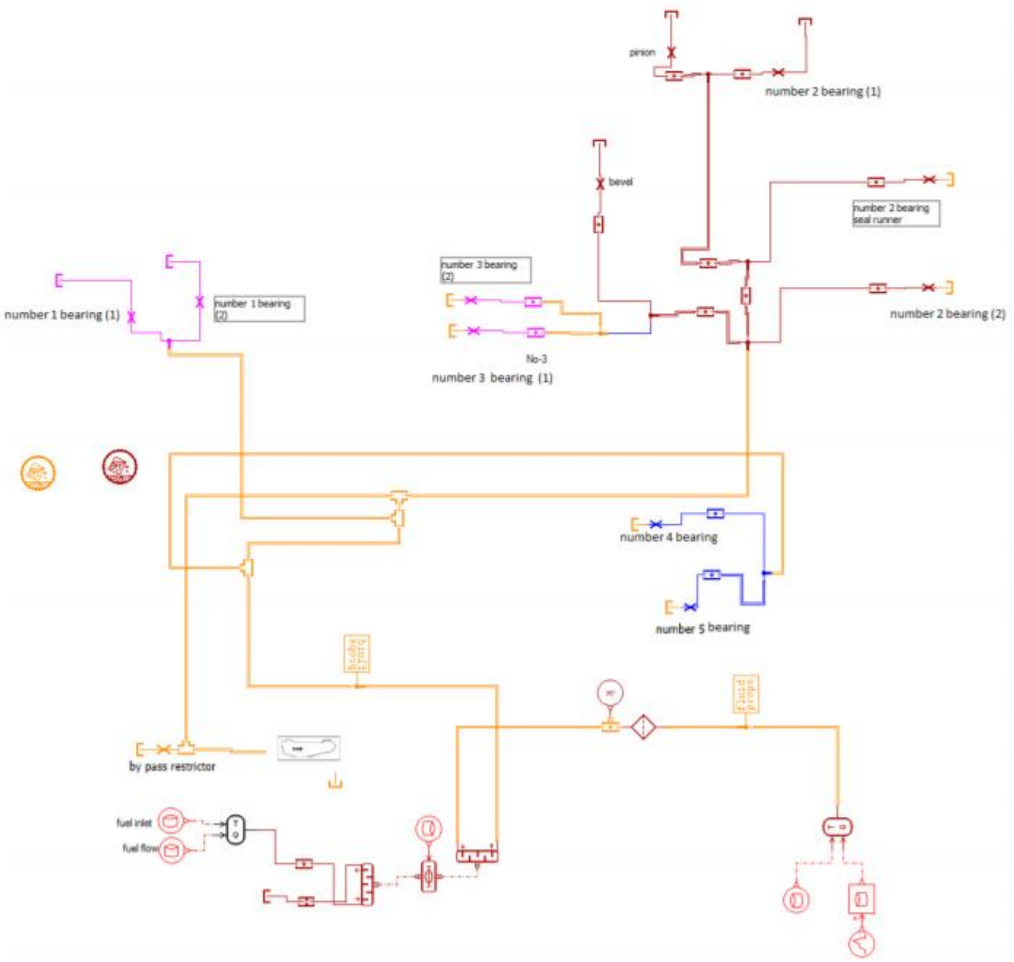
6.2 SUPPLY LINE DIAGRAM

The oil from the tank is pumped through a positive displacement pump which varies the flow rate of the fluid according to the speed of the engine.

The oil from the oil pump is passed through a filter which has a pressure drop the filter removes the unwanted particles and purifies the oil, it also acts a restriction to the oil flow.

The oil from filter is sent through a FCOC (Fuel Cooled Oil Cooler) heat exchanger where the fuel is supplied from the pipes whose temperature is lower than the lubrication oil temperature so the heat from the lubrication oil is removed and the temperature of the oil is reduced. At the inlet of the heat exchanger the fuel temperature is given at various intervals of time and also the flow rate of the fuel at those time periods.

The supply line of a gas turbine engine carrying a lubrication oil:



The oil from the heat exchanger goes to the pipe where the pipe is branched to send the oil to different injectors. The pipes have both friction and compressibility factor which causes a back pressure in the flow of the fluid. The injector diameter is taken based upon the amount of cooling required at that particular place in the engine, the diameter of the injector also has an effect on the speed of the injection of lubrication oil.

The supply line designed here has eleven injectors, the velocity of the oil is high at the injectors. The oil from the injector goes through the bearings to reduce the friction and to reduce the temperature of the bearings, the oil after this goes back to the oil tank and before entering into the oil tank it goes to a de-aerator unit which helps in removing the air that is carried along with the lubrication oil from the different bearing chambers, if this air is not removed it will increase the chamber pressures which will cause the vent to release more oil along with air causing high oil loss. The oil after the de-aerator unit is sent to the oil tank once again and the process repeats.

VII. SIMULATIONS

7.1 Simulation of Supply Line

The supply line of lubrication system has eleven injectors and each of the injector has different diameters because of the different cooling requirement of each part.

Table 7.1 Injector Diameter

Engine oil wetted component	Injector nomenclature	Injector diameter (mm)
number 1 bearing	number 1 bearing (1)	0.87
	number 1 bearing (2)	0.87
number 2 bearing	number 2 bearing (1)	0.95
	number 2 bearing (2)	0.95
number 2 bearing seal runner	number 2 bearing seal runner	0.85
number 3 bearing	number 3 bearing (1)	1.55
	number 3 bearing (2)	1
Bevel	Bevel	1.3
Pinion	Pinion	0.85
number 4 bearing	number 4 bearing	1.626
number 5	number 5 bearing	1.796

bearing		
By Pass Restrictor	By Pass Restrictor	2.7

7.2 Input to piecewise linear signal source

The input at the piecewise linear signal source is speed at different time intervals. The speed is varied in eight stages. The maximum speed that can be obtained by the engine is 5650 rpm. So keeping the maximum speed as reference the engine speed is varied at each time interval.

Table 7.2 Time v/s speed input table

TITLE	VALUE	UNITS
Number of stages	8	Null
Time at which duty cycle starts	0	Sec
Output at the start of stage 1	0	Null
Output at the end of stage 1	3745	Null
Duration of stage 1	41	Sec
Output at the start of stage 2	3745	Null
Output at the end of stage 2	3745	Null
Duration of stage 2	314	Sec
Output at the start of stage 3	3745	Null
Output at the end of stage 3	4547.5	Null
Duration of stage 3	64	Sec
Output at the start of stage 4	4547.5	Null
Output at the end of stage 4	4547.5	Null
Duration of stage 4	187	Sec
Output at the start of stage 5	4547.5	Null
Output at the end of stage 5	5082.5	Null
Duration of stage 5	69	Sec
Output at the start of stage 6	5082.5	Null
Output at the end of stage 6	5082.5	Null
Duration of stage 6	310	Sec
Output at the start of stage 7	5082.5	Null
Output at the end of stage 7	5403.5	Null
Duration of stage 7	14	Sec
Output at the start of stage 8	5403.5	Null
Output at the end of stage 8	5403.5	Null
Duration of stage 8	68	Sec

While starting a engine the speed of the engine not directly increased to its maximum speed, the speed of any engine is gradually increased for the better performance of the engine. In case of a gas turbine engine in the supply line it has a positive displacement pump which increases the flow with the speed of the engine. The speed of the engine here has been increased in eight stages.

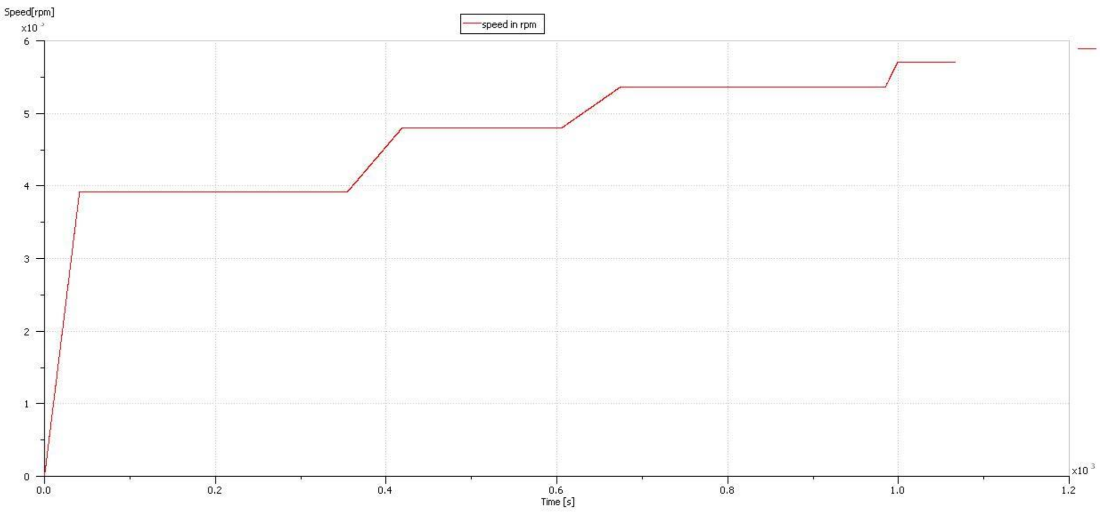


Fig 7.1 Time v/s speed graph of a supply line

7.3 INTERPOLATE 1D OR XY TABLE WITH RESPECT TO X

Table 7.3 Speed v/s flow rate inputs

SPEED(rpm)	FLOW RATE(LPM)
0	0
535	0
3691.5	29
3718.5	30
4440.5	36
4601	35
5029	38
5136	39
5162.75	40

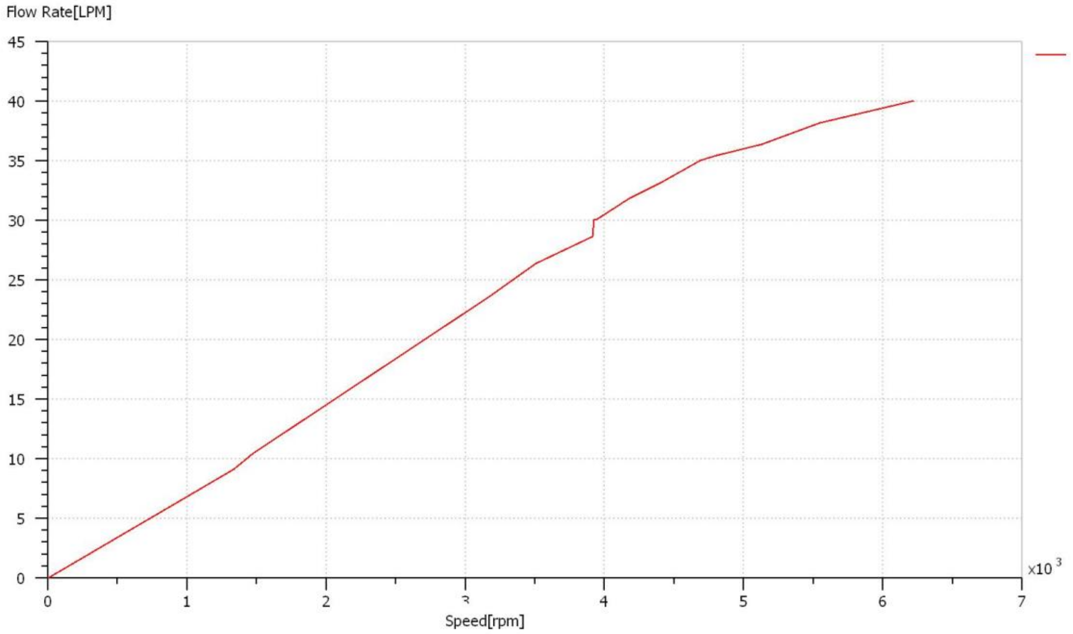


Fig 7.2 Speed v/s flow rate graph of a supply line

The speed of the engine continuously increases until it reaches the desired speed, when the speed of the engine is increased the components of the engine starts rotating at higher speed so the flow rate of the lubrication oil also must be increased to do so we have used a positive displacement pump which increases its flow with respect to speed. Therefore, the flow rate changes according to the speed linearly.

7.4 INTERPOLATE 1D OR XY TABLE WITH RESPECT TO TIME

Here the input to component is given with respect to time. The temperature of the engine is given as input at various interval of time during the run time of the engine. As the temperature of the engine is increased because of increase in the speed the flow rate of lubrication oil also need to be increased.

The temperature here is obtained from the engine test at various speed because adding thermocouple will make the engine design complicated.

Table 7.4 Time v/s Temperature Inputs

TIME(sec)	TEMPERATURE (°C)	TIME(sec)	TEMPERATURE (°C)
0	25.2	70	29.4
2	25.2	72	30
5	25.2	75	30.5
10	25.2	76	31.1
14	25.2	81	32
18	25.2	84	32.6
27	25.3	85	33.1
28	25.4	87	33.5
39	25.6	59	34
42	25.5	95	35
43	25.6	121	40
49	25.7	154	45
50	25.8	204	51
51	25.9	284	59

52	26.1	297	60
53	26.3	391	68
54	26.4	428	72
57	26.7	670	89
58	26.9	886	101
59	27.1	1044	106
64	28	1270	109.4
65	28.2	1276	109
66	28.5	1472	107.9
69	29	1590	108.4

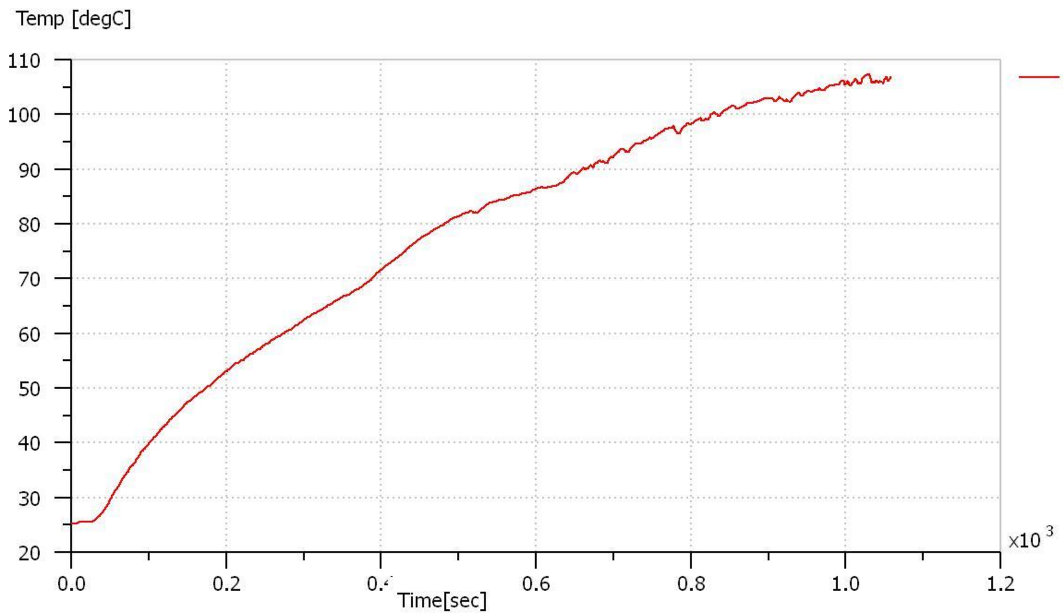


Fig 7.3 Time v/s Temp graph of a supply line

The heat exchanger is used to transfer the heat from the lubrication oil to the fuel of the engine. The lubrication oil is cooled by this process. The temperature of the lubrication oil keeps on increasing because the same lubrication oil is recirculated again and again during the engine run, due to this the heat inside the lubrication oil also gets added up and temperature keeps on increasing with time to reduce the heat in the lubrication oil fuel cooled oil cooler heat exchanger are used.

7.5 Time v/s Flow Rate for heat exchanger (fuel flow)

Heat exchanger is used to cool down the lubrication oil, so that the properties of the lubrication oil should not change very much as the engine liberates a large amount of heat at higher loads.

Table 7.5 Time v/s Flow Rate heat exchanger (fuel flow)

TIME(sec)	FLOW RATE(LPM)	TIME(sec)	FLOW RATE(LPM)
0	0	366	11.83
2	0	368	12.285
5	0	372	13.195
7	0.455	373	13.195
8	5.66	375	14.105
10	5.46	377	14.105
17	5.915	379	15.015
20	6.37	381	15.47
23	7.28	383	15.925
30	9.1	384	16.38
31	9.1	387	17.29
32	9.1	390	18.2
33	9.1	391	18.655
34	9.555	392	19.11
35	9.555	393	19.565
38	10.01	395	20.02

39	9.555	396	20.475
40	9.555	397	20.93
45	9.1	398	20.93
46	9.1	402	22.295
47	9.1	403	22.295
50	9.1	406	23.205
51	9.1	409	24.57
53	9.1	416	24.57
56	9.1	426	25.025
60	9.1	427	24.57
62	9.1	461	25.025
65	9.1	493	25.025
66	9.1	610	27.755
68	9.1	611	28.21
70	9.1	614	29.575
80	9.1	622	32.76
102	9.1	628	35.49
135	9.1	634	38.25
151	9.1	637	40.495
185	9.1	638	41.405
265	8.645	639	41.86
276	8.645	654	50.05
281	9.1	656	53.235
315	8.645	661	57.795
328	8.645	668	60.97
356	10.01	671	61.88
357	10.01	677	63.7
359	10.465	1025	83.265
362	10.92	1251	83.24
365	11.83	1276	83.24

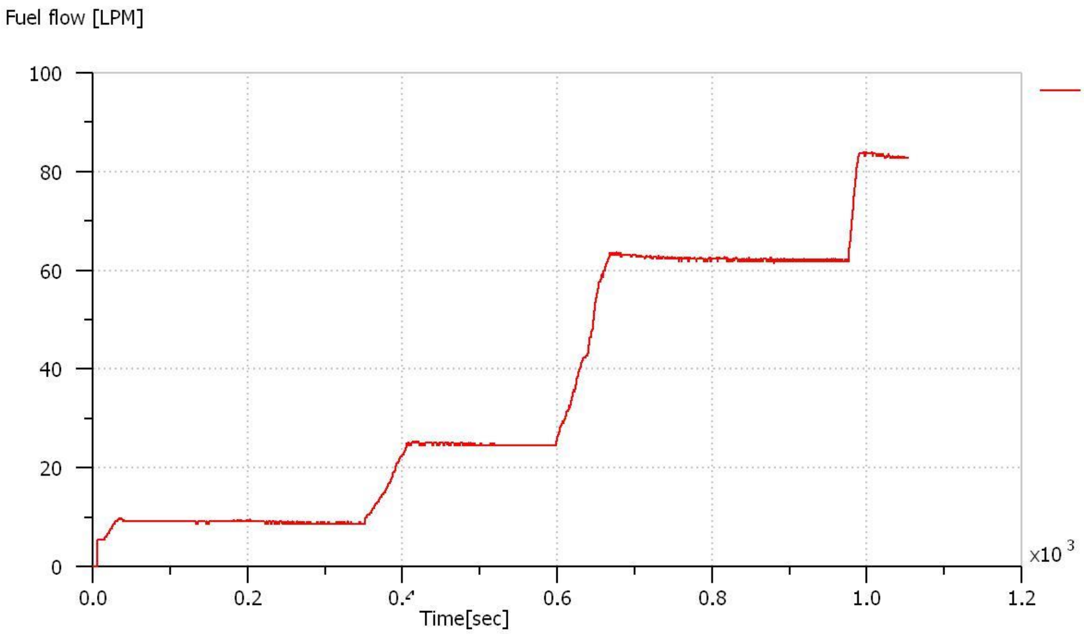


Fig 7.4 Time v/s Flow rate of a supply line

7.6 TIME V/S TEMPERATURE FOR HEAT EXCHANGER

Table 7.6 Time v/s Temperature for heat exchanger

TIME(sec)	TEMPERATURE (°C)	TIME(sec)	TEMPERATURE (°C)
0	24.8	86	45.9
2	24.8	87	46
5	24.8	88	46.4
7	25.1	90	46.9
8	26	91	47
20	27.8	93	47.5
23	28.4	95	47.8
24	28.6	96	48
30	30.1	98	48.4
31	30.4	101	49
32	30.6	102	49.2
33	30.8	106	49.9
34	31.4	107	50
35	31.6	109	50.5
38	32.5	112	51
39	32.8	115	51.5
40	33.1	118	52
45	34.3	123	52.7
46	35.1	125	53
47	35.4	129	53.6
50	36.4	132	54
51	36.7	134	54.3
53	37.2	135	54.5
56	38.1	185	60.1
58	38.4	265	65.8
62	39.9	278	66.5
65	40.7	372	69.9
66	41.1	409	65.3
68	41.6	651	50.1
70	42.1	867	43.6
76	43.6	1025	41
78	44.1	1030	45.2
82	45	1045	43.2
84	45.5	1067	42.8

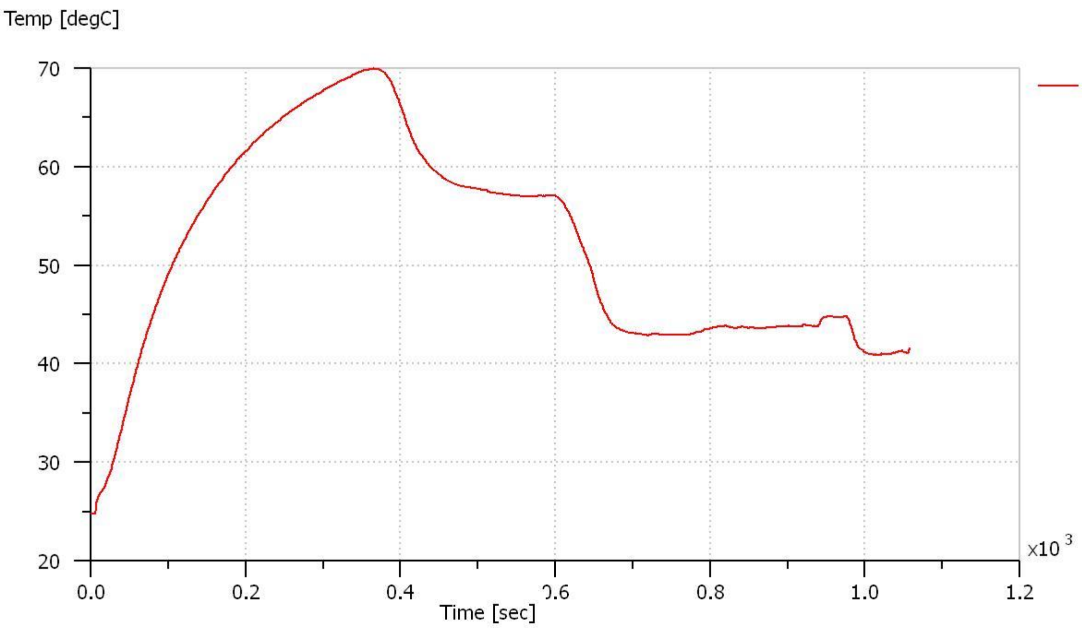
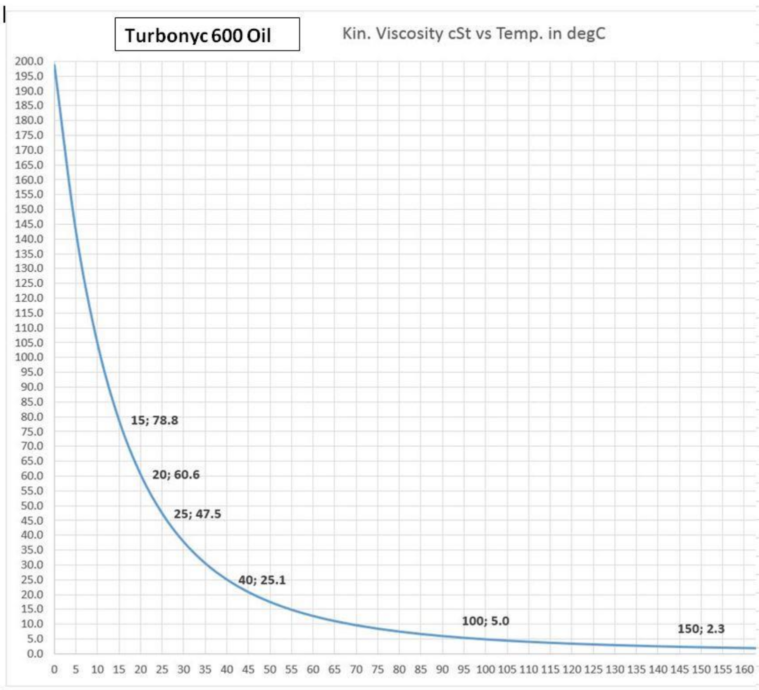


Fig 7.5 Time v/s Temperature of a Supply Line

7.7 TEMPERATURE V/S VISCOSITY EXPERIMENTAL DATA

Experimental data of temperature versus viscosity of lubrication oil.



Temp. degC	Kin. Viscosity cSt
0	198.7
5	142.4
10	104.7
15	78.8
20	60.6
25	47.5
30	37.8
35	30.6
40	25.1
45	20.9
50	17.6
55	15.0
60	12.9
65	11.2
70	9.7
75	8.6
80	7.6
85	6.8
90	6.1
95	5.5
100	5.0
105	4.6
110	4.2
115	3.8
120	3.5
125	3.3
130	3.0
135	2.8
140	2.7
145	2.5
150	2.3
155	2.2
160	2.1
165	2.0
170	1.9
175	1.8
180	1.7
185	1.6
190	1.5
195	1.5
200	1.4

Fig 7.6 Temperature v/s Viscosity Experimental Data of Gas Turbine Engine

The graph shows the experimental results of variation of kinematic viscosity with temperature, these results have been obtained during the test run of the engine.

VIII. RESULTS AND DISCUSSIONS

8.1 TIME V/S PRESSURE OUTPUT

In the supply line we have added two fluid properties components, one after the pump and one after the heat exchanger. These helps in checking the fluid properties at each stage of the fluid flow. The pressure of the oil increases suddenly when the engine is started, the pressure keeps on increasing until the speed is made constant. At the steady state when speed is constant, temperature is still increasing because of which viscosity of the oil decreases and this in turn will reduce the pressure of oil. As the speed of the engine is again increased the same process will repeat again.

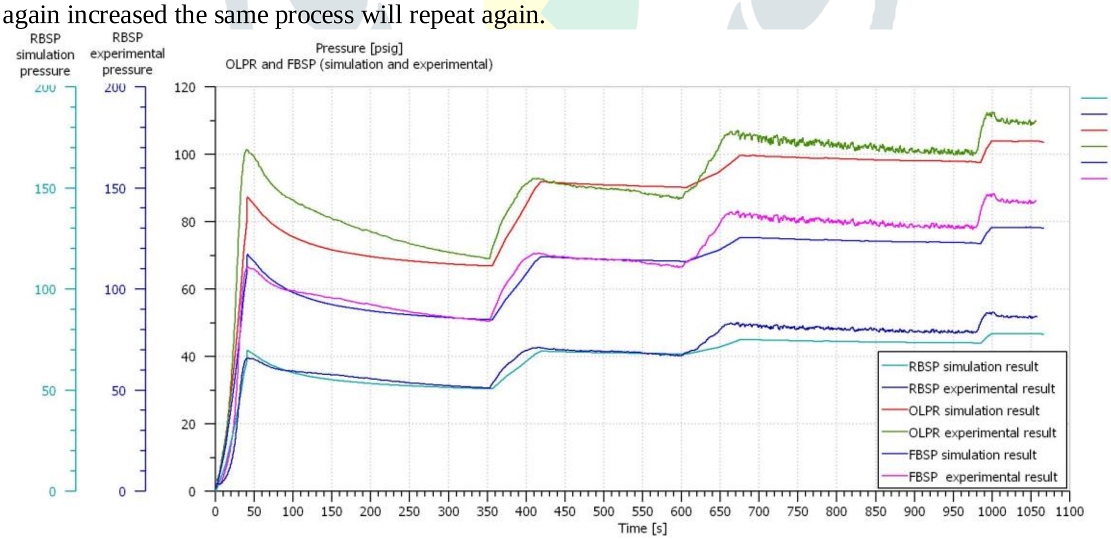


Fig 8.1 Time v/s Pressure Output of a Supply Line of Gas Turbine Engine

8.2 TIME V/S TEMPERATURE GRAPH

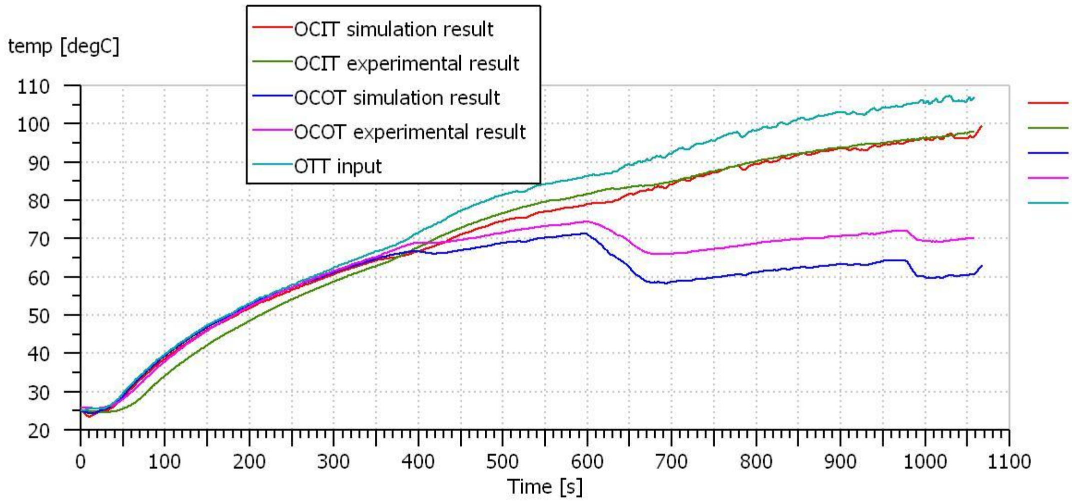


Fig 8.2 Time v/s Temperature Output of a Supply Line of Gas Turbine Engine

The figure above shows the temperature variation during the course of the engine run where OTT is given as the input. When the oil passes through the pipes, pumps and other oil system parts, it's temperature changes due to heat loss to the surrounding which is evident from the temperature difference between OTT and OCIT (oil cooler inlet temperature) which is measured at the entrance of the heat exchanger. Since, this oil system model does not have the actual pump model & thermal effect of the filter and other fittings, a heat exchanger pipe is modelled in the model to simulate the thermal effect of the actual engine hardware.

The OCOT (oil cooler outlet temperature) is measured when the oil comes out of the heat exchanger, it exchanges the heat with the fuel used in the engine, the oil after passing through the heat exchanger will undergo a decrease in temperature and the temperature of the oil which is obtained from the simulation results is in the desired range with the OCOT experimental data.

8.3 MASS FLOW RATE OF THE OIL

Table 8.1 Mass flow rate at different speed

Engine Oil Wetted Component	Injector Nomenclature	Injector Diameter (mm)	Simulation Flow Rate In [LPM]		Design Flow Rate In [LPM]
			Individual Hole	Total	
number 1 bearing	number 1 bearing (1)	0.87	0.815	1.63	1.68 - 1.84
	number 1 bearing (2)	0.87	0.815		
number 2 bearing	number 2 bearing (1)	0.95	0.92	2.62	1.66 – 2.43
	number 2 bearing (2)	0.95	0.95		
number 2 bearing seal runner	number 2 bearing seal runner	0.85	0.75		
number 3 bearing	number 3 bearing (1)	1.55	2.52	3.57	3.7
	number 3 bearing (2)	1	1.05		
Bevel	Bevel	1.3	1.77	1.77	0.66 - 0.88
Pinion	Pinion	0.85	0.73	0.73	0.47
number 4 & 5 bearing	number 4 bearing	1.626	3.67	3.67	3.84
	number 5 bearing	1.796	2.82	2.82	1.5
By Pass	By Pass Restrictor	2.7	7.54	7.54	8

IX. SUMMARY

The principle aim of this project was to study the various parameters change during the course of running of a gas turbine engine. This analysis shows the variation of pressure, temperature with respect to time and flow of the fluid through the different components of the system. As the fluid flows through the different components, there is a pressure drop within the components and friction factor which restricts the flow of oil. This restriction in the components create a back pressure on the pump (outlet) which in turn increases the pressure throughout the supply line. As the engine generates more heat, the viscosity of the fluid

decreases due to heat absorption by the fluid which is generated from the engine and the pressure drop continuous till the viscosity attains a constant value.
To test the flow of fluid, we have created the supply line using AMESim software and used the required lubrication oil and checked the variation in the fluid parameters, if the parameters of the flow of fluid through the supply line matches with experimental results the system can be used in future for incorporation of new components and it will help in reducing the testing cost of the engine.

X. SCOPE OF FUTURE WORK

The supply line which is designed, comprises of eleven main injectors in it. If in future a need arises for adding a new component in the engine system which requires better lubrication system, then modifications could be done in the previously made supply line model. Designing new injectors and testing in the engine will be very difficult in terms of time and cost, so by developing a virtual model in AMESim software, it helps us in modification and improving the system by introducing some new components. These result can be used for further studies. This in turn will help in reducing the overall cost of the project.

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