# Numerical Prediction of Flow and Heat Transfer on Lubricant Supplying and Scavenging Flow Path of An Aero-engine Lubrication System

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**Abstract**

This paper presents a numerical model of internal flows in a lubricant supplying and scavenging flow path of an aero-engine lubrication system. The numerical model was built in the General Analysis Software of Aero-engine Lubrication System, GASLS, developed by Northwestern Polytechnical University. The lubricant flow flux, pressure and temperature distribution at steady state were calculated. GASLS is a general purpose computer program employed a 1-D steady state network algorithm for analyzing flowrates, pressures and temperatures in a complex flow network. All kinds of aero-engine lubrication systems can be divided into finite correlative typical elements and nodes from which the calculation network be developed in GASLS. Special emphasis is on how to use combined elements which is a type of typical elements to replace some complex components like bearing bores , accessory gearboxes or heat exchangers. This method can reduce network complexity and improve calculation efficiency. Final computational results show good agreement with experimental data.

## 1 Introduction

The key role of aero-engine lubrication system is to effectively lubricate and cool bearing bores, shroud ds, gear wheels, and so on at total flight envelope to e nsure safety and life demands of engine. While design ing or analyzing a lubrication system, detailed temper atures, pressures and flowrates distribution at various flight states are needed. But measuring these parame ters are extreme difficult on high temperature, pressu re and rotational speed conditions while aero-engine working, so numerical simulation technology come to play a important role in lubrication system design and analysis. Some famaous aero-engine research instituts or companies have developed their own softwares , such as SSME [1], GFSSP [2][3] and FLOMODL [4], all of them being proved very useful.

Air and oil flow paths in aero-engine lubrication system are typically a type of flow network, which consists of a group of flow branches, such as pipes and ducts, that are joined together with a number of nodes. But the lubrication system flow networks of aero-engine are very complex networks containing many flow branches such as orifices, bends, pumps, heat exchangers, gear cases and turbines. In the analysis of existing or proposed lubrication system networks, only few nodes pressures or temperatures are specified or knowning. So the key problem is how to get all unknown nodal pressures, temperatures and branch flow rates.

The General Analysis Software of aero-engine Lubrication System(GASLS) developed by Northwe stern Polytechnical University is a general-purpose computer program for analyzing steady state flow rat es, pressures and temperatures in a complex flow net work. GASLS emploies 1-D steady state network alg orithm [5] and automatic network modeling platform for rapid building and analyzing lubrication system. F low branches are classified as various typical element s including pipes, ducts, orifices, bends, pumps, heat e xchangers .ect. So all kinds of aero-engine lubrication systems can be divided into finite correlative typical e lements and nodes from which the calculation network be developed in GASLS.

## 2 Simulation

A lubricant supplying and scavenging flow path of a specific aero-engine lubrication system are numer ical simulated in GASLS. The system consists of thre e bearing bores, two heat exchan gers, one accessory gearbox, some pumps, pipes and bends, showings in figure.1, which makes th e flow network very complic ated. Especially the bearing bores, heat exchangers an d accessory gea rbox, anyone of these should be simu lated as sub -network respectively to get accurate ana lysis re sult, then the whole flow network becomes too complicated to calculate.

To solve this problem, a combined elements was introduced. Combined element is a type of general-purpose element which represents only correlations between two nodes'(in and out nodes') parameters. The correlations are specific equations or data tables or schemes, usually the equations are welcoming for they can be used directly while calculating but they are not easy to be given actually. Often used corelations are data tables, for which can be experimental or numerical simulation data. When GASLS network algorithm processing to the combined elements which have data tables, then interpolation subroutine launchs to find the proper exit datas in the datatables based on the entry data. So the key problem transfers to how to get the right correlations of the combined elements.

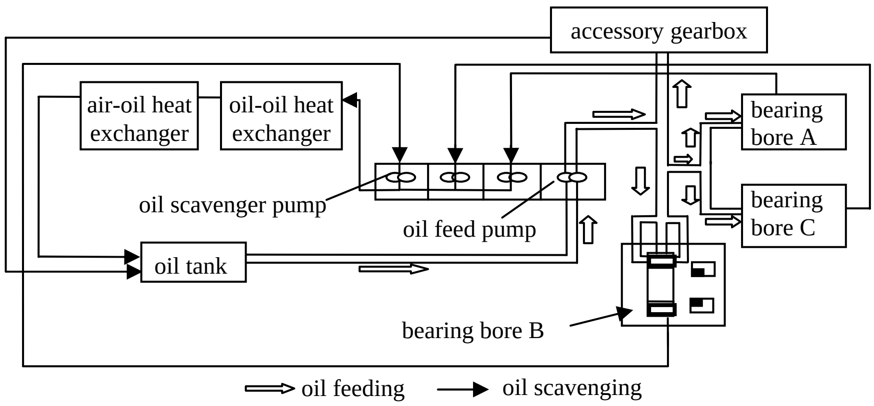


Figure.1 Scheme of lubricant supplying and scavenging system

A convenient method is given to get the correlations. Firstly,bearing bores and accessory gearboxes are analyzed respectively by GASLS, for example, a flow network of bearing bore B showing in figure 2 and analyse result showing in table.1, and the other bearing bores and gear boxes following the same way. The heat exchangers' datas are given through experiments, an table of oil-oil heat exchanger showing in table.2.

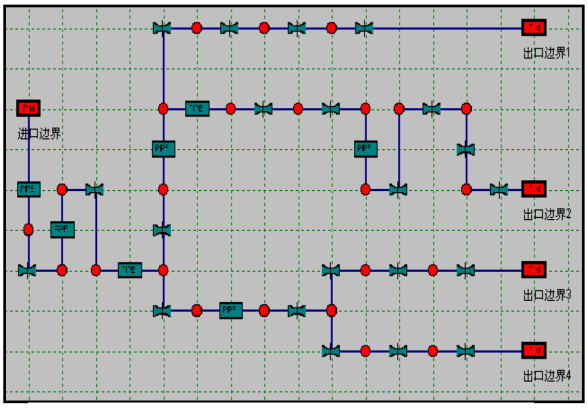


Figure 2: network of bearing bore B

Table.1 calculation results of bearing bore B

| Pout /Pa | Pin /Pa | Ploss /Pa | Flowrate /L·Min$^{-1}$ |
|---|---|---|---|
| | 432587 | 319262 | 3.35 |
| | 442589 | 329264 | 3.40 |
| | 452685 | 339360 | 3.45 |
| 113325 | 465882 | 352557 | 3.52 |
| | 479792 | 366467 | 3.60 |
| | 488124 | 374799 | 3.64 |
| | 496458 | 383133 | 3.68 |

Secondly, the whole calculation network of the lubricant supplying and scavenging system is set up and uses the combined elements instead of sub networks of bearing bores, accessory gearbox, heat exchangers, showing in figure.3. The whole network looks simple and the number of nodes and elements is small which bring great advantages to solve the matrix of the flow network become only a few group of equations are need to calculate.

## 3 RESULTS

This simulation aims at detailed oil flow rates and temperatures distribution with known inlet and outlet boundary conditions. Cared simulation results are given below. Mass flow comparion between calculation results in GASLS and experimental data is given in table.3, and lubricant temperatures distribution of main nodes is given in table.4.

Analyzing the result, the flow rates agree well with experimental data looking from table3, and the lubricant temperatures distribution also reflect the actual temperatures distribution whether from the trend or from the magnitude looking form table 4. All of these prove that the GASLS numerical simulation can meet the needs of engineering.

## 4 Conclusions

1. This paper describes a numerical simulation network model of internal flows of the lubricant supplying and scavenging system of an aero-engine.The model was developed with the General Analysis Software of aero-engine Lubrication System,GASLS.

2. The flow network model includes typical elements and combined elements. The combined elements are used to instead of complex components like bearing bores, heat exchangers, and accessory gearboxes.

3. Using proper combined elements can reduce network complexity and improve calculation efficiency.

4. The numerical predictions are compared with measured flowrates and temperature data.Generally, a good agreement was observed between measurements and predictions.

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Table.2 experimental data of oil-oil heat exchanger

| Oil(lubricant) | | | Oil(fuel) | | |
|---|---|---|---|---|---|
| Flow rate /L·min$^{-1}$ | Inlet T /℃ | Otlet T /℃ | Flow rate /L·min$^{-1}$ | Inlet T /℃ | Outlet T /℃ |
| 13.7 | 90.0 | 81.4 | 6.5 | 34.8 | 57.3 |
| 13.7 | 110.0 | 91.6 | 6.5 | 34.7 | 61.1 |
| 13.8 | 120.0 | 100.5 | 6.5 | 34.6 | 65.5 |
| 13.8 | 140.0 | 118.7 | 6.5 | 34.6 | 74.8 |
| 13.8 | 150.0 | 126.0 | 6.5 | 36.7 | 79.6 |

Table 3 Mass flow comparison between calculation results in GASLS and experimental data

| Mass flow(L/min) | Experiment | Numerical simulation |
|---|---|---|
| Accessory gearbox | 1.5～1.8 | 1.5665 |
| Bearing bore A | 6.5～7.5 | 6.3290 |
| Bearing bore B | 3.5～4 | 3.6238 |
| Bearing bore C | 3.8 | 3.6993 |

Figure.3 the whole flow network in GASLS

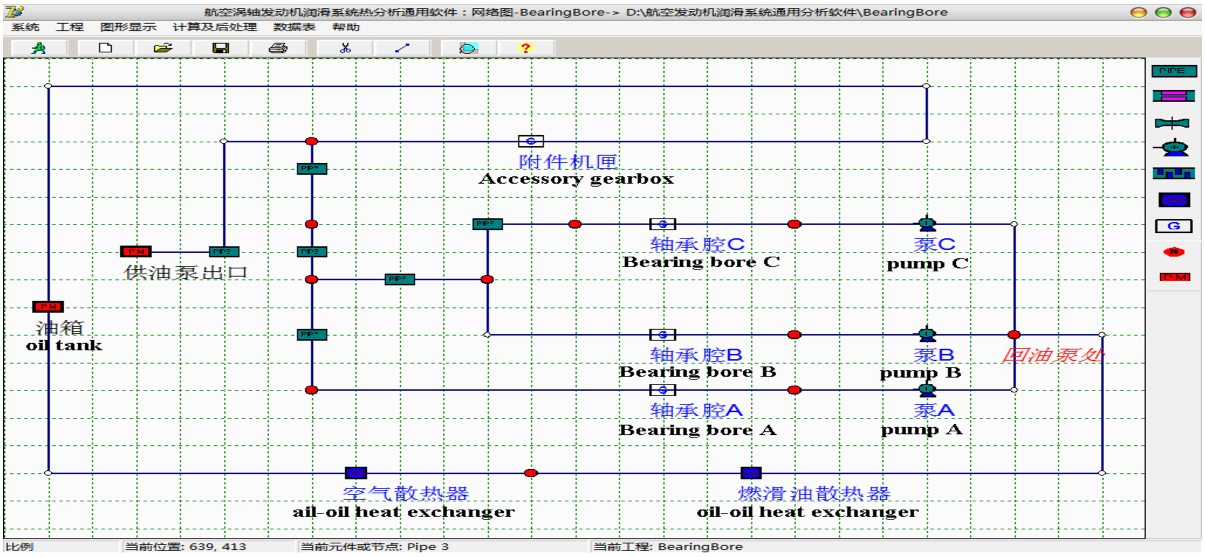


Table 4 Distribution of Lubricant temperatures

| Main node | Numerical simulation T (℃) |
|---|---|
| Oil(lubricant) tank | 67.59 |
| Outlet of bearing bore A | 73.24 |
| Outlet of bearing bore B | 124.74 |
| Outlet of bearing bore C | 71.2 |
| Inlet of oil-oil heat exchanger | 86.36 |
| Inlet of oil-ail heat exchanger | 78.98 |

## REFERENCES

1) Cheng AK. SSME Alternate Turbopumps Axial Thrust Balance and Secondary Flow Models. Sverdrup Technology MSFC Group, Report No. 322-002-91-153-R01,1992.
2) Majumdar, AK. VanHooser, K. P., A General Fluid System Simulation Program to Model Secondary Flows in Turbomachinery. AIAA 95-2969.
3) Majumda AK. A Generalized Fluid System Simulation Program to Model Flow Distribution in Fluid Networks. AIAA 98-3682.
4) McAmis,R.W.,Miller,J.T., Modeling Fluid Flow Networks, 32rd AIAA/ASME/SAE/ASEE Joint Propulsion Conference,July 1-3,1996. AIAA 96-3120.
5) WU Ding-yi. Network Algorithm of Internal Flow System. *Journal of Aerospace Power,* 1996;**17**:653-657.