THERMAL- AND FLUID-DYNAMICAL PROBLEMS FOR SPACE FLIGHT

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1. Introduction

The space exploration program of the Institute of Space and Aeronautical Science, University of Tokyo, has been started around 1964 when the Institute was organized to the present form, as a natural extension of the sounding rocket program which had been carried out within the University. As an integral part of the program, planning and construction of the space simulation facilities for satellite check-out test have begun about that time. In 1970, the first Japanese satellite was launched by the Institute using the solid propellant rocket developed in the Institute. Since then, it has successfully launched various scientific satellites for space observation. On the other hand, National Space Development Agency of Japan -NASDA- was established around 1969, succeeding the former governmental space research and development agencies, with the purpose to develop, launch and operate the commercial satellites for Japan. NASDA launched its first test satellite at 1975, and now has been operating the communication, weather and broadcasting satellites, which had been launched using Japanese liquid propellant rockets or by the US launch vehicles. Both of these activities are controlled by the National Space Development Committee which is one of the advisory comittees to the Premier and approves the National Space Exploration Program to the Government. Now it has ambitious plans to promote the space exploration, which include the planetary exploration, the advanced observation satellite and the use of the Shuttle Payload.

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Independently but with close relationship to those developmental efforts, the basic research in all the aspects of the space science and technology have been taking place in the research Institutes and Universities of Japan, and various thermal- and fluid-dynamical problems have been brought into the basic research scientist's attention, which, in turn, have caused strong impetus to the progress of the basic science. Some of those related to launch vehicles and spacecaft will be discussed in this report, with the emphasis to the spin-out effects to the basic science. The astrophysical and geophysical problems will not be treated here.

2. THERMAL DESIGN OF SPACECRAFT

The environmental control of spcecraft during sustained space flight or during manouvers of launch operation has been the most urgent task asked to the scientists from the beginning of the space exploration, since there was no such previous experience at all. The complete vacuum, the absolute radiation sink of the outer space and the solar irradiation are the environment the satellite must endure. In order to analyse the temperature distribution and variation during space flight, we have to construct a mathematical model which usually expressed as a network system of the thermal nodal points assigned to various places on the satellite. Computer codes to analyse the design of spacecraft have been developed and used in many institutions in more or less heuristic way. In order to give more rigorous mathematical foundation to these phenomenological analysis, a systematic thermal design method for spacecraft has been developed using the finite element method combined thermal and structural analysis of spacecraft system (1).

Since the accuracy of the temperature predictions of the satellite depends upon this network accuracy, it must be corrected through space simulation data on ground and also flight data (2). In essence, this is a technique to extract the best mathematical model of the satellite thermal character from the observation data using the statistical regression (3). The design optimization is achieved through this process (4).

3.THERMAL PROTECTION DURING PLANETARY ENTRY

When the probe recovery or the planetary soft landing is the mission, the thermal protection system for the aerodynamic heating is the most critical problem we must solve. Due to the excess speed of the probes during the entry to the atmos phere, the air in front of it is heated and dissociation and ionization of it take place. And radiation heat transfer from the heated gas becomes dominant or comparable to the convective heat transfer. The heat protection materials commonly used are abrating cooling material, which means the body surface is receding during the flight. The theoretical and experimental study of this problems has been done in the Institute (5). Various computer codes to calculate this problem are now available in major institutions, at least for the one-dimensional case, which include all those effect.

The fundmental understandings of the heat transfer problems through radiative and emitting gas layer and abrating surface is needed here. This problem is reduced to mathematical anlysis of the integro-differential equations under changing boundaries. The physical characteristics of the various heat protecting materials have to be precisely provided. The Monte-Carlo simulation is again one of the most useful method and used widely (5).

4. SURFACE CONTAMINATION OF SPACECAFT

The spacecraft surface tends to be contaminated due to the deposition of contaminants emitted from the various rocket plumes and from the volatile surfaces. This phenomenon is classified into three stages: The emission of the outgas or the ejection of the rocket plumes; the migration of the emitted molecules and the interaction with the ambient molecules; and the deposition of the contaminants onto the surfaces and their effects to the spacecraft, including the synergic and accumulated effects.

The rocket plumes fired in the complete vacuum in space expand almost spherically and reaches almost everywhere of the spacecraft surfaces. Various organic compounds used in spacecraft, such as electric insulator and surface coatings are volatile and emit the volatile mass to the outer space in vacuum condition. The emitted molecules propagate according to the law of rarefied gasdynamics and reach the opposit surfaces and sometimes deposit on it. This effect is particularly serious for optical experiments onboard the spacecraft, and the decoloration due to this effect suffers the thermal balance of the spacecraft. Indeed, we have had some failures due to this effect causing excess temperature rise of the critical components onboard.

In order to study this phenomenon, various types of space simulation chambers have been constructed and extensive testing has been carried out. One of the examples of this kinds of study appeared in the reference (6).

5. MICROGRAVITY EFFECTS

During the sustained space flight, the spacecraft environment is under quite reduced gravity -microgravity-, which is caused by the centripedal force, the gravity gradient, the fluid venting and the atmospheric drag, and usually is less than 10^{-5} of the earth surface gravity, quite small but finite and changeable. Thus the behavier of the fluid aboard the spacecraft is strongly influenced by this absence of gravitational force. The other forces which are minor at the terrestrial environment become to be influential. Among of them are the surface tension, thermoacoustic, electric and magnetic forces. The influenced phenomena by this effect are the convective motion of the continuum fluid, the interfacial instability between the different fluids and the behavier of the free surface of the fluid. For the practical aspects, this phenomenon is quite successfully

utilized for the space processing of various materials, the attitude control system of spacecraft using liquid containing wheel are also subject of this effect, and the coolant circulation system and the heat pipes have to be carefully designed to overcome this effect.

In this Institute, the analysis of the liquid behavier in the wheel stabilizer, which include the surface tension and the microgravity field and some free fall experiments were carried out (7). The rocket-borne flight test of the heat pipe was carried out. The effect of the gravity was identified and the successful operation under the space environment was confirmed.

6. CONCLUSIONS

The basic research activities taking place in the Institute of Space and Aeronauticl Science, University of Tokyo and other institutions have been introduced; concerning four problems for space flight, which are, Thermal Design of Spacecraft, Thermal Protection During Planetary Entry, Surface Contamination of Spacecraft and Microgravity Effect.

Because of the wide variety of the problems concerned, the author regretts, all the aspects of the problems were not properly covered.

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HYDRODYNAMIC STUDY ON VASCULAR LESION

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1.0 INTRODUCTION

It is well known that vascular lesion appears usually downstream of a constricted portion (stenosis), in the neighbourhood of a branch, in the region where the curvature of an artery is very large as in the aortic arch, and so on. But, its origin has not been conclusively elucidated, in spite of many theoretical and experimental works/1/-/3/.

The present series of numerical study is aimed at searching for the origin of vascular lesion from the hydrodynamic point of view. In §2, numerical study on the viscous flow in a constricted channel is given as a two-dimensional model of blood flow in a constricted vessel. Steady and pulsatile flows of a viscous fluid in a channel with a branch are numerically studied in §3.

2.0 VISCOUS FLOW IN A CONSTRICTED CHANNEL

2.1 When there appears a constriction in artery for some reason or other, the region downstream of constriction often starts to swell, and it is called "post-stenotic dilatation" (PSD) and one of main disease in artery. Concerning the origin of PSD, there have been many theories:

(1) stasis in standing vortex downstream of constriction (Fox and Hugh/4/, Caro/5/),
(2) pressure variation (Holman/6/),
(3) turbulence(Roach/7/),
(4) cavitation(Rodbard et al/8/),
(5) shearing stress(Roach/7/, Fry/9/),