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Performance of Unconventional Propellants*

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This research involves the theoretical calculations of rocket performance of "exotic" propellants at various operating conditions, such as chamber pressure, pressure ratios, and oxidizer-to-fuel ratios. By "exotic" propellants, we mean using materials that may not normally be used as propellants here on Earth due to their low performance characteristics or other factors. The majority of the work was done using the Gordon and McBride CET 86 program in both a mainframe version and personal computer versions. In addition, the Lockheed/Air Force Solid Propellant Theoretical Performance program for the IBM PS/2, which handles condensed product species better, was also used.

Background

With the high cost of putting payloads into orbit, the ability to reduce the size and weight of the payload is highly beneficial. Since the largest part of any space vehicle consists of propellant, it is hoped that the overall size and weight of the vehicle can be reduced by finding near-Earth-orbit materials suitable for use as fuels.

To this end, this work seeks to find propellants that will give acceptable performance, yet be producible or readily available in near-Earth orbit. Another possibility for fuels is the use of materials, such as nylon and rubbers, that would be taken for other purposes. Also considered is the need for the propellant to be easily stored over long periods of time while, ideally, avoiding the use of heavy refrigeration systems.

Although extensive research has been done on Earth-transported propellants that give high performance characteristics, very little work is available on propellants that give less than ideal performance. In addition to studying such overlooked propellants, low chamber pressures need to be considered to help reduce weight and high-pressure ratios, which can be achieved in atmospheres such as that of Mars. Some propellants considered unacceptable for use on Earth could be ideal for use since tradeoffs of performance for availability, storability, and cost are acceptable within the scope of this research.

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Approach

We identified propellants that might be suitable for our purposes. These propellants have been divided into three areas: low-Earth orbit, the Moon, and Mars. The propellants were divided this way due to the availability of materials in these areas, such as CO_2 in the Martian atmosphere. A range of chamber pressures was also determined for each of the above areas, along with a range of expansion ratios.

The CET 86 program was first set up on a mainframe so that the two personal computer versions could be compared for accuracy. One version was obtained from the University of Minnesota, and the second was obtained from AVCO. Both proved to give results identical to those of the mainframe version.

Results to Date

Personal computer versions of the Gordon and McBride CET 86 program were obtained from the University of Minneosta and AVCO and set up on an IBM PS/2 Model 80. These two versions were compared to the mainframe version and were found to give identical results.

The Lockheed/Air Force Solid Propellant Theoretical Performance program was obtained and set up on an IBM PS/2. Since no mainframe version of this program was available for comparison, the CET 86 program was used to test the accuracy of the program. The Lockheed/Air Force program also proved to give accurate results.

Computer programs were written to help organize the data obtained from the CET 86 and Lockheed/Air Force programs into more useful forms. A commercially available plotting program, GRAPHER, was obtained for this purpose.

Twenty-one propellant combinations were analyzed using the CET 86 and Lockheed/Air Force programs. This generated over 1000 sets of data. Graphs were made of I_{sp} versus oxidizer-to-fuel ratio for various pressure ratios for each of the propellants. The data were organized into presentable formats. Some samples are shown in Appendix B.

Summary

This work involves analyzing propellants at various operating conditions and determining which give acceptable performance, yet can be easily stored for long periods of time and are readily available in near-Earth orbit. We have found that a number of the propellants studied would give acceptable performance for space missions. Another graduate student is using the data obtained in this work to develop a method for identifying the propellants and operating conditions that are best for a particular space mission. So far, conditions in excess of 30,000 separate sets have been calculated.

Participants

Jennifer Kares and Yamel Caquias, both undergraduate students, helped in analyzing the propellants. Jeff Kahl, also an undergraduate student, assisted in developing the various computer programs needed to process the data.