LUNAR METHANE PRODUCTION PLANT: CH4/O2 VERSUS H2/O2 FUEL PRODUCTION

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Christiansen (1988) described a process for producing hydrogen and oxygen from the lunar regolith; however, the amount of regolith needed to be processed and the energy needed for processing were quite high. This paper discusses the possibility for production of methane from the lunar regolith, for use as rocket propellant. If the carbon constituents of the lunar regolith can be utilized, the amount of regolith and energy needed could be reduced. Methane, if it can be produced, has advantages with respect to the use of lunar H_2 in that it is more easily stored and should be less easy to lose from the production process. It is well known that the carbon concentration of the lunar regolith is low, but at 100 ppm, there is about as much useful carbon as there is hydrogen, which has an average abundance of 50 ppm.

We compared the performance of similar lunar launch vehicles, one utilizing CH_4/O_2 and the other, H_2/O_2, to determine their propellant requirements to launch identical payloads from the lunar surface, using the mass ratio from the rocket equation. The appropriate Isp's and oxidizer/fuel ratios are included in the comparative calculations. We then calculated the amount of regolith needed to produce the required amounts of CH_4 and H_2 needed to launch the same payload to orbit. Then, the production systems that would be needed to produce the required propellant were defined, based on the Eagle Engineering (1988) model. A basic premise of their approach is that hydrogen is extracted by simply heating iron-rich regolith to 900^{o}C in a reactor and oxygen is produced simultaneously by hydrogen reduction of a small proportion of the iron oxide in the regolith. The water produced is electrolyzed and the hydrogen either stored or recycled to the reactor. This means that the production of oxygen is "free" and the amount of regolith that must be processed is determined by the amount of hydrogen that is to be extracted. The same premise is applied to the production of CH_4. The results show that the amount of regolith processed for the CH_4 system is 65.7 % of that required for the H_2 system.

The characteristics of the two

systems are similar. Both architectures include mining and processing equipment, a thermal reactor to extract the propellant, a means of liquefying gaseous propellant, and the power supply for running the system. Each architecture is characterized in terms of input feedstock, output propellant, mass and power requirements, and necessary equipment for operations. For methane production, a Sabatier reactor and heat exchanger is added to the system required for hydrogen extraction. The Sabatier reactor reacts CO_2 and H_2 to produce CH_4. Their total contribution to the mass and power requirements of the plant is basically irrelevant compared to the total plant mass. In a real system, conditioning of the gases may require a small amount of additional hardware. The performance or economic value of these differences can be viewed in light of the amount of propellant produced as a function of the system mass. Whereas the hydrogen-oxygen plant can reproduce its own mass in over 5 months, the methane-oxygen plant can reproduce its own mass in about two and a half months, when considering a small plant of 1000 kg of oxygen production per month.

In our current models, conservative assumptions are made for the productivity of excavation equipment and reactors, which dominate the mass of the system. Development of new approaches to these systems could lead to systems that could be competitive with extraction of propellants from lunar polar ice, which currently is receiving increased attention. Improved extraction systems will increase productivity and reduce system mass requirements. Better reactor designs would be aimed at reducing the residence time for materials in the reactor, which would diminish reactor size. Finally, a better characterization of elemental abundances on the lunar surface may help determine whether the efficiencies of both systems can be improved in terms of regolith feedstock.

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References:

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