THERMITE REACTIONS IN THE MIXTURES OF MAGNESIUM WITH LUNAR AND MARTIAN REGOLITH SIMULANTS. A. Delgado, I. Lopez, and E. Shafirovich, Department of Mechanical Engineering, The University of Texas at El Paso, 500 W. University Ave., El Paso, TX 79968, eshafirovich2@utep.edu

Introduction: The use of lunar and Martian regolith for in-situ production of construction materials is of interest for future space exploration missions. Metals such as Al and Mg exhibit thermite reactions with lunar and Martian regolith simulants, the mineral compositions of which include oxides of Si, Fe, Al, Mg, Ca, Ti, and Na. It would be attractive to use these reactions for the production of ceramic materials that could be used as construction materials on the Moon and Mars. The required Al or Mg could be obtained by recycling the lander parts as well as from the regolith.

Previous research has revealed, however, that combustion of JSC-1A lunar regolith simulant with aluminum requires significant preheating [1]. The mixtures of this material with magnesium ignite much easier, leading to a steady or spinning propagation of the combustion wave over the pellet at relatively low concentrations of Mg [2-5]. Because of complex composition of lunar regolith, however, the combustion mechanisms of these mixtures are not fully understood.

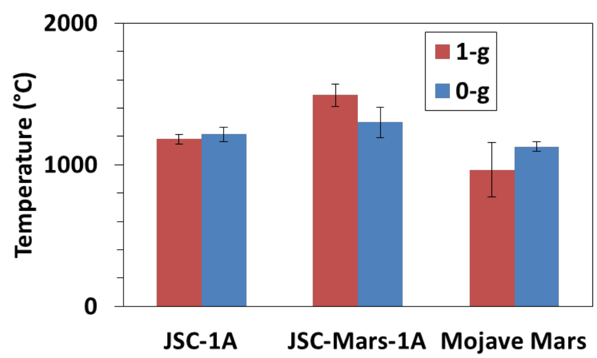
One objective of the present work is to ignite mixtures of Martian regolith simulants (JSC-Mars-1A and Mars Mojave) with magnesium and compare their combustion characteristics with those of JSC-1A/Mg mixtures. Another objective is to clarify, using thermal analysis, the mechanisms of reactions that are occurring during combustion of the regolith simulants with magnesium.

Experimental: The Martian regolith simulants (JSC-Mars-1A and Mars Mojave) and JSC-1A lunar regolith simulant were milled in a planetary ball mill as described elsewhere [3], and then mixed with magnesium powder (−325 mesh, 99.8% pure, Sigma-Aldrich) in a three-dimensional inversion kinematics tumbler mixer (Bioengineering Inversina 2L). The mixtures were then compacted into cylindrical pellets (diameter 13 mm) using a uniaxial hydraulic press.

To study the combustion process, the pellet was placed inside a windowed steel chamber, connected to a compressed argon cylinder and a vacuum pump. The pellet was ignited at the top by a tungsten wire heated using a DC power supply. The temperature in the middle of the pellet during combustion was measured by a thermocouple. Digital video recording was used for the determination of the combustion front velocity. All experiments were conducted in an argon environment at 1 atm. The combustion experiments were conducted at normal gravity and under reduced gravity conditions onboard research aircraft.

Mixtures of magnesium with JSC-1A, silica, and iron oxide were examined with a thermogravimetric analyzer (Netzsch TGA 209 F1 Iris). The mixture of 26 wt% Mg and 74 wt% JSC-1A was prepared as described above. The mixtures with silica (SiO_2, −400 mesh, 99.5%, Alpha Aesar) and iron oxide (Fe_2O_3, >2 μm, 99%, Sigma-Aldrich) were prepared according to the stoichiometry of the following reactions: (1) $SiO_2 + 2Mg \rightarrow Si + 2MgO$, (2) $Fe_2O_3 + 3\,Mg \rightarrow 2Fe + 3MgO$. The mixture samples placed in alumina crucibles were heated in an argon flow (20 mL/min). The heating process was terminated at different temperatures and the condensed products were cooled in argon. The product compositions were studied with X-ray diffraction analysis (Bruker D8 Discover XRD).

Results and Discussion: Figure 1 shows the maximum temperatures and front velocities, measured during combustion of three regolith simulants with magnesium (25 wt% Mg in all the mixtures). It is seen that JSC-Mars-1A simulants exhibits the highest temperatures and the fastest combustion.



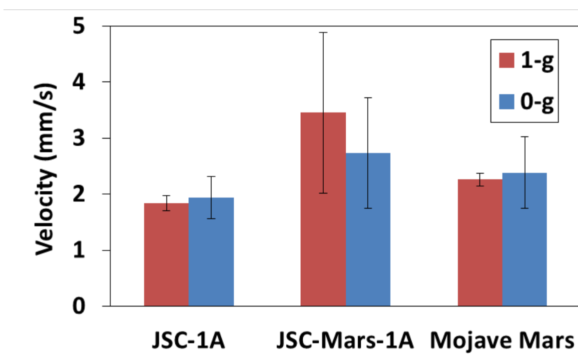


Fig.1. Maximum temperatures and combustion front velocities in mixtures of Mg with JSC-1A, JSC-Mars-1A, and Mars Mojave regolith simulants.

Analysis of the simulant compositions (Table 1) indicates that JSC-Mars-1A has the highest concentration of iron oxide. Note that among the oxides that are present in the compositions, only SiO_2 and Fe_2O_3 may exhibit thermite reactions with Mg. This implies that the reaction of Mg with iron oxide may play a very important role in the combustion process.

Table 1. Compositions of the studied regolith simulants.

Compound	Concentration, wt%		
	JSC-1A [6]	JSC-Mars-1A [7]	Mars Mojave [7]
SiO_2	**45.7**	**43.48**	**49.4**
Al_2O_3	16.2	22.09	17.1
Fe_2O_3	**12.4**	**16.08**	**10.87**
CaO	10.0	6.05	10.45
MgO	8.7	4.22	6.08
Na_2O	3.2	2.34	3.28
TiO_2	1.9	3.62	1.09

Figure 2 shows the thermogravimetric (TG) and calculated differential thermal analysis (c-DTA) curves obtained for JSC-1A/Mg mixture at a heating rate of 10°C/min. The c-DTA curve has a distinct exothermic peak at about 550°C, i.e., at temperatures below the melting point of magnesium (650°C).

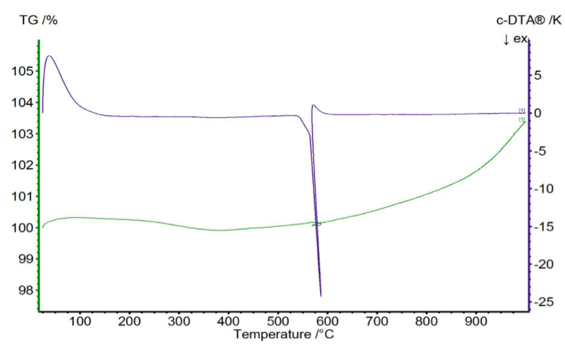


Fig.2. TG and c-DTA curves for JSC-1A/Mg mixture.

To investigate this reaction, the heating process, conducted at 5°C/min, was stopped at three different temperatures (500°C, 550°C, and 590°C). XRD of the obtained products (Fig. 3) revealed that there is no MgO at 500 °C, while all Mg is converted to MgO at 590°C. At 550 °C, there is a partial conversion of Mg to MgO. These results clearly indicate that the reaction between JSC-1A and Mg occurs at relatively low temperatures when Mg is still solid.

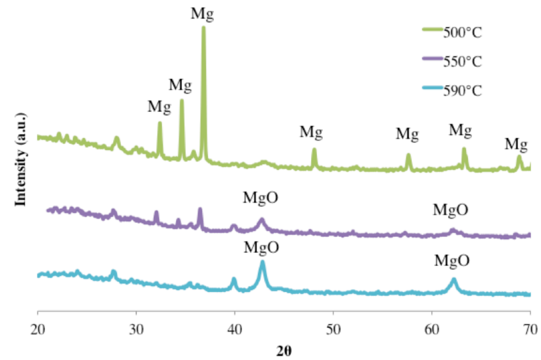


Fig.3. XRD patterns for JSC-1A/Mg mixture after heating up to 500°C, 550°C, and 590°C.

The thermal analysis of SiO_2/Mg and Fe_2O_3/Mg mixtures has revealed a much higher exothermic peak in the case of iron oxide. Also, XRD analysis of the products has shown full conversion for Fe_2O_3/Mg and only partial conversion for SiO_2/Mg. The higher exothermicity and better conversion for Fe_2O_3 correlate with the results of the combustion experiments.

Conclusions: Mars Mojave and JSC-Mars-1A regolith simulants form combustible mixtures with magnesium. Despite the lower content, iron oxide may play a more important role than silica in the combustion of lunar and Martian regolith simulants with magnesium. It is recommended that iron-reach regolith should be used for combustion with magnesium on the Moon and Mars.

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