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POWDER METALLURGICAL COMPONENTS FROM LUNAR METAL

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INTRODUCTION

Assuming the eventual establishment of high technology colonies on the moon, one may wonder what possible industrial goods can be produced at these colonies using lunar resources. It is proposed that in such a colony, with adequate but limited energy resources already developed, industrial powder metallurgy components can be fabricated from native iron alloys.

Free iron is readily available on the lunar surface, making up approximately 0.045 st% of the regolith [2] (Fe, <.02-23 wt% Ni, <0.02-3.1 wt% Co, < 0.02-11.5 wt%P, < 0.02-1.6 wt% S, and < 0.02-0.1 wt% Cr) [3]. Using a regolith density of 0.9-1.1 g/cc [4], one can calculate that 3.9×10^{10} metric tons of Fe alloy are available in the top five cm. of the regolith. The quantity would be even larger if one considers greater depth and the possibility of crushing larger rocks.

With the raw material available the appropriate manufacturing techniques must be selected. Traditional processes such as casting, rolling, forging, etc. are rejected because they are all very energy intensive procedures. One viable alternative is powder metallurgical fabrication. It is a well suited option since its energy requirements are not extravagant, iron metal is readily available and a natural vacuum (2.7×10^{14} atm) [4] is already present.

The components considered for fabrication will be smaller than 100 kg., probably less than 10 kg. It is not suggested that large structural components can be fabricated in this manner. Proposed components cover a broad spectrum of uses. Machine parts such as gears and cams are distinct possibilities and are currently two powder metallurgy parts widely produced on earth. Other possibilities include nuts, bolts, screws, connecting rods, bearings, and electrical contacts. One distinct advantage of a powder process is that the final product can be essentially fabricated in one step. For example, a gear can be directly fabricated without subsequent machining.

Despite the cost required to develop a powder metallurgy facility, it is thought that it is a better alternative than transporting all these components from earth. The first technological problem is the collection of the "ore." It may easily be collected by lunar roving vehicles with magnetic skimming devices, and then transported to a central production facility. By controlling the magnetic field strength of the skimming magnet and the skimmer distance from the surface, one can restrict the gathered material to highly magnetic metal and avoid collection of weakly magnetic minerals.

Metal Preparation and Part Fabrication - (see Figure 1 for a flow sheet.)

Initially the material will be mechanically sieved into various size distributions. Following, it will be sent to a vibratory device to separate the metal particles from any adjoining silicate. It is hoped that the low temperature in the lunar shadows (-173° C) will somewhat embrittle the material and assist in metal/gangue separation. The precise configuration of such a separating device has yet to be determined. The retained gangue must be kept at a minimum, since it will adversely influence the properties of the finished component. A magnetic separator will then serve to differentiate the metals from the gangue.

With powdered metal stock available, production may begin. One earth proven powder process is hot compacting, where compacting and sintering are done simultaneously. Dies of air or oil hardened tool steel will be used, and suitable production parameters would be T-800°C (>0.5 mp) (electrical resistance heating), P-6.89 x 10^7 Pa (10,000 psi), and time-20 min.[5,6]. Another possibility, yet to be thoroughly investigated in the laboratory, is to compact the powder in the ultrahigh lunar vacuum (ion-pump range). It is possible that under these conditions, and with no oxide present on the surface of the metal, the green compact will auto-sinter. The 100°C lunar daytime temperature may assist this reaction. Various subsequent heat treatments could be used to vary the components mechanical properties with design requirements. For reference, Table 1 summarizes the mechanical properties of pure Fe and a possible lunar alloy (both annealed) [7]. Realize that the remaining traces of silicate will somewhat deteriorate the mechanical properties of the lunar component, especially impact resistance. Fortunately, Ni is a toughener when added to Fe, and one may still expect a suitable finished product.

Following the basic production of the part, many subsequent procedures are possible, including machining and welding.

Conclusions -

Once a high level colony has been established on the lunar surface, lunar resources of free iron could be used to produce industrial components. The raw material is plentiful and the quality of the finished goods should be excellent. Proposed components would find uses in lunar machine manufacture and maintenance. The production of large structural components (>100 kg.) is not feasible with a lunar powder metallurgical process. If one wishes to allow his mind to wonder, even the production of components for orbital assembly of interplanetary spacecraft and orbital stations is technically feasible.

Figure 1

Production Flow Sheet

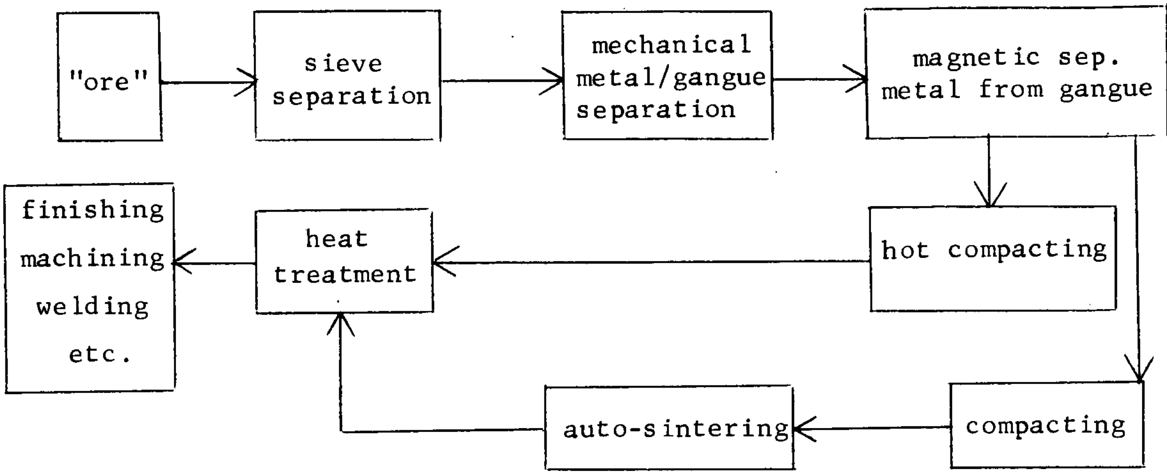

Table 1

Mechanical Properties of Lunar Alloys (annealed) [9]

Property	Pure Fe	Fe-5.Ni-0.5 C
theoretical density	> 95%	> 95%
tensile strength	90×10^6 Pa (13,000 psi)	420×10^6 Pa (61,000 psi)
elongation	1.7%	5%
hardness	-	Rb 50

Note: The other elements present, especially Ni, will significantly increase the properties listed above.

References

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