Synthesis and Characterization of Manganese Sponge doped with TiO$_2$

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Abstract. The aviation and mechanical industry has seen tremendous growth in recent years. While these trends only continue, the materials on development of better fabrication technologies. Spongy materials are projected as favourable materials for the future as porous in nature. The current paper devotes to enhance mechanical properties by the use of Manganese sponge doped with TiO$_2$ possess an outstanding array of properties not readily achievable with other materials. Samples were synthesized by Kroll process and solid-state reaction. The specified materials compares well with the presently used aeromechanical materials in all terms. The scope for further research work in this area will be outlined.

1. Introduction

Now a days, the term “sponge material” is often used for any kind of metallic material contains voids, but generally sponge materials are produced in the partial solid state. According to fabrication process, sponges are basically materials who boundaries are made up of solid lattice, the interior are voids and individual cells are separated from each other by the metal. It is usually closely embedded by uneven pores in it, and for a sponge material porosity level generally be less than 70-75%. Sponge material have continuous network of metal pieces and followed by the co-existence network of the empty space. The certain properties of “material sponge”, generally they exhibit like having a versatile potential in many industrial fields because of capability of producing light weight structures, high energy absorption and emission phenomenon, having low density and stiffness. As they are spongy in nature must exhibit the wide range of porosity and volume fraction in microstructure scale. According to the application requirement, the term porosity plays a very high command role in deciding the optimum shape and also mechanical properties of the structure. Manganese sponge is one of the best contender material to be used in manufacturing turbine blades because of having high strength to weight ratio, propellants tanks for various space vehicles as non-corrosive in nature etc.

Figure.1. Macro picture of (TiO$_2$ doped Manganese sponge)
2. Synthesis of Manganese sponge doped with TiO₂

Metallurgy for synthesizing sponge with TiO₂ is an advantageous task of increasing the possibility of obtaining the simplex geometry of the material. Initially, manganese chloride sintered at low temperature effectively with cobalt metal and ethanol as a binder at 473 K gives “manganese sponge” by Kroll process as the desired product followed by bi-products are hydrochloric acid and carbon dioxide. It has shown a good control over porous structures as follows:

\[
\begin{align*}
473 \, \text{K} \\
3 \text{MnC} + \text{CO} + 6\text{C}_2\text{H}_5\text{OH} & \rightarrow 3\text{Mn} + 2\text{Co}_2 + 6\text{HCl} + \text{CO}_2
\end{align*}
\]

Getting manganese sponge is followed by doping TiO₂ at 1260 k (sintered)

\[
\begin{align*}
1200 \, \text{K} \\
3\text{Mn} + \text{TiO}_2 & \rightarrow + \text{TiO}_4
\end{align*}
\]

The product reveals in equation (2) is the titanium dioxide [2] dopant in manganese sponge.

3. Characteristics of manganese sponge doped with TiO₂

The core product after doping the desired sponge with TiO₂ is 99.64%. Dopant is just about 0.24% in the overall stoichiometry. It is phenomenal that after doping with titanium oxide for the flexibility in the bit amount leads the manganese output closer to the currently glowing titanium sponge following basic properties compares well with the current titanium product.

The following table gives the some experimental results:

| Properties | Manganese sponge Doped with TiO₂ | Titanium sponge |
|------------|---------------------------------|----------------|
|            |                                 |                |

Figure 2. Sintered graph (TiO₂ doped Manganese sponge)
3.1. SEM analysis of TiO₂ doped manganese sponge

- At 200 nm, it is clear as per the characterization of the material has been described about the granule size also the van der wall forces also helps in binding overall structure from the molecular level.
- At 1µm level although at per the magnification it is showing the certain trailer of the porosity originates from that point. As the magnification varies is being showing clearly about the binding force strengthens the material from micro level.
- At 200µm, the surface look smooth with some bit of holes, but the overall characteristics compares well with the current scenario of the light-weight materials.
- At the certain level of 10µm, the surface is showing high density, though it is affording healthy amount of porosity ratio in it.

### Table 1

| Phase        | Partially-solid | Semi-solid |
|--------------|-----------------|------------|
| Granule size (nm) | 0.49            | 0.70       |
| Boiling point (K)   | 2334            | 3533       |
| Melting point (K)   | 1579            | 1941       |
| Hardness (BHN)      | 122-153         | 141-160    |
| Porosity (per mole)| 4.40%           | 4.13%      |
| Thermal conductivity (W/m.K) | 7.81           | 29.7       |
| Density (gm/cm³)    | 7.21            | 4.48       |
| Strength to weight ratio (kN,m/kg) | 277.58         | 287.7      |
| Tensile strength (MPa) | 1154.24        | 1300.23    |

**Figure 3.** SEM micro pictures of (TiO₂ doped Manganese sponge)

4. Conclusion

The paper visits the synthesis and the various properties of Titanium dioxide doped manganese sponge. The vital intension to consider porous material for the manufacturing applications has been discussed, giving solid evidence. The paper intended to show the fabrication of manganese sponge at the initial stage and then pursued by doping it with titanium dioxide. The analysis shown above tries to provide quite a few reasons for replacing titanium products by the doped manganese compound. The properties and overall picture resembles with each other and therefore the new products can be seen comparing well soon with it in the aviation manufacturing field.

5. Uses

The research so far shows, manufacturing of airplane’s wing, flap and compressor blade by using manganese sponge doped titanium dioxide results the overall specific fuel consumption by any twin-aisle engine would get better in keeping the idea implemented which shows a remarkable journey in the field of Aviation.
As per the survey, generally the entire cost of an airplane is somewhere around $400 million. As mentioned earlier as well, reduction in few percent can lead aviation industry to a cost effective manufacturing by implementing these ideas in certain prospects and could get a compensation of a few thousand dollars by implementing the above proposal with high overall efficiency. So, the research and development work on these couple of proposals are worthwhile and investment would be highly rewarding.

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7. References
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