Abstract: Fe-Al₂O₃ composite coating was deposited by self-propagating high-temperature synthesis assisted flame spray coating process. The green composite paste were prepared using ferric oxide agent powders, aluminum powders and polyvinyl alcohol. The paste on the substrate was ignited by oxy-acetylene. The resulted Fe-Al₂O₃ composite coating was characterized by X-ray diffraction (XRD) and scanning electron microscope (SEM), respectively. The successful of this process can be create a novel thermal coating process.

Key Words: Fe-Al₂O₃ composite coating/SHS/Self-propagating high-temperature synthesis/Flame spray coating

1. INTRODUCTION

Thermal spraying is a generic term for a group of processes that utilize a heat source to melt material in powder, wire or rod form. The molten or semi-molten material is propelled toward a prepared surface by expanding process gases. The particles quench rapidly, upon impact with the surface, and bond with the part. Flame spraying is the thermal spraying that uses combustion of gases to melt powder, wire or rod material. It can create coatings out of a wide range of materials. But they have to be low melting point materials because the heat that get from flame spray is not very high (~2000 °C) compared with HVOF (~3,000 °C) and plasma spraying (~12,000 °C) [1].

Self-propagating high-temperature synthesis (SHS), a variant of combustion synthesis, is a method for producing substances, materials and items via exothermic autoclave reaction. This combustion process is ignited by point heating of a small part of the prepared sample. The heat should be enough for initial burning of surrounding material, which in turn, generates heat that burns the following part of the material, and in this way a wave of exothermic reaction is generated that covers the rest of material. With this method it is possible to obtain various products both inorganic and organic nature with unusual properties, for example TiB₂ powder [2], Si-SiC composite material [3], and TiB₂-Al₂O₃-FexAl₃ composite material [4].

By combining SHS method with flame spray process, it is possible to coating higher melting temperature material on the substrate with the heat to ignite the SHS reaction from oxy-acetylene of flame spray process. This novel coating process will require less energy and less expensive instrument cost than tradition process.

2. EXPERIMENTAL

2.1 Preparation of green composite paste

The raw powders used in making green composite paste were commercially available Fe₂O₃ (Riedel de Haen Nr. 12344) and Al (HIMEDIA RM 740-500G) powders according to Fe₂O₃ + 2Al = 2Fe + Al₂O₃ + 836 kJ. The polyvinyl used as binder to bind Fe₂O₃ and Al powders together. The preparing process of composite solution was as follows: firstly, Fe₂O₃ and Al powders were thoroughly mixed for 24 h in a grinding machine. Then, the compounded powders were mixed again with polyvinyl alcohol solution, to form green composite paste.

2.2 Fabrication of composite coating

The mild steel thickness 1.2, 2 and 3 mm were use as the substrates. Prior to follow the composite coating process all the substrates were polished to get rough surfaces, cleaned by acetone, painted by composite paste and dried in an oven under 100 °C. The green composite paint were ignited by oxy-acetylene flame and reacted, to form Fe-Al₂O₃ composite coating.

2.3 Characterization

The samples were characterized in terms of chemical composition and surface morphology by X-ray diffraction (XRD) and scanning electron microscope (SEM), respectively.
diffraction (PHILIPS X’Pert MPD) and scanning electron microscope (JSM-5800LV, JEOL) respectively.

3. RESULTS AND DISCUSSION

3.1 Thermodynamic analysis

The overall chemical reaction can be expressed as:

\[
\text{Fe}_2\text{O}_3(s) + 2\text{Al}(s) = 2\text{Fe}(s) + \text{Al}_2\text{O}_3(s) \quad (1)
\]

The equilibrium compositions of the Fe$_2$O$_3$-Al system at different temperatures were calculated using Gibbs energy minimization method [3] and the results are shown in Figure 1.

The adiabatic temperature of the SHS process can be calculated from the enthalpy of reaction. This is the maximum theoretical temperature that the reactants reach, and determined from Equation (2). This equation applies to a phase change occurring between initial temperature and $T_{ad}$. The calculated result of overall reaction from Equation (1) is 3266.1 °C.

\[
\Delta H = \int \left[ \frac{C_p}{T} \right]_{\text{solid}} dT + \int \left[ \frac{C_p}{T} \right]_{\text{liquid}} dT
\]

\[
\Delta H_f + \int \frac{\Delta H_f}{T_m} dT
\]

Where, $\Delta H$ is the enthalpy of reaction, $\Delta H_f$ is the enthalpy of transformation, $C_p$ is specific heat capacity, $T_m$ is the melting temperature and $T_{ad}$ is adiabatic temperature. It has been accepted that the reaction can be a self-sustained combustion when the adiabatic temperature of the reaction is higher than 1800°C [3].

Then, it can be seen that it is thermodynamically feasible to fabricate an iron matrix composite reinforced with alumina using SHS method.

3.2 Characterization

The morphology of composite coatings obtained from SEM method in Figure 2 show detaching of composite coatings (b) from the substrate (a). This may be due to heat loss to the metal substrate that result to insufficient heat to complete the reaction of the green composite.

The components of composite coatings were identified by EDS-SEM and XRD patterns as presented in Figure 3 and 4. It shows that the system compose of the elements of Fe, O and Al in which Al and O are located at the coating area but Fe located in both coating area and substrate.

The composite coatings consist of Fe, Fe + 2Al$_2$O$_4$ and Al$_2$O$_3$. Phase Fe + 2Al$_2$O$_4$ are metastable phase that were produced during reaction because the heat of reaction is not sufficient for green composite to complete the reaction.

4. CONCLUSIONS

The Fe-Al$_2$O$_3$ composite was successfully coating on mild steel substrate by combining of SHS and flame spray coating process. Although the detachment of the
coating from the substrate is evident but this novel coating process shows its promising. In the future, the process need further study to solve the problem.

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6. REFERENCES

[1] V. Sitthichai, Thermal Spray Technology, Department of chemistry science, Faculty of science, Chiang Mai University, 2004.


