Selecting an Economic Technology/Material for Reflector Surface of a Solar Thermal Concentrator through Literature and Market Survey

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Abstract—Commercialization of concentrating solar power technology require the development of advance reflector that have low cost and high reflectivity for extended life times under the serve of outdoor atmospheric environment. In this paper consist of study and analysis market potential for a solar reflective material which has high reflectance and low material cost. The parabolic trough designed with a dimension of (210cm×60cm) and the thickness of 0.05cm of stainless steel (SS 304). We study the different types of coating material and applying method for improves the performance of reflecting surface.

Key words: Coating Material, Coating Process, Coating Life, Coating Price Alternative Reflector

I. INTRODUCTION

Performance of solar thermal concentrators is largely dependent on the optical properties of the reflector. A reflector surface should have high optical efficiency, low cost and high durability.

The cost of reflector is one of the primary constituent in the overall cost of the solar plant. Hence a lower cost of reflector and a higher durability and higher reflectance is going to provide a lower cost to per unit power that it would generate over the years.

A reflector surface comprises of a) Substrate b) Reflective layer c) Interference layer [1] Substrate provides the structural support to the reflector. Glass is the most commonly used reflector material in the available commercial parabolic trough type plants. It is hard, abrasion resistant, corrosion resistant, transparent, and resistant to UV light.

Metal substrates ("Metal Mirror Reflectors") like aluminium sheets are also used in solar reflectors. A Metal reflectors reduces the structural requirements as they are lighter than glass, stronger and easy to be placed on the support structure.

Reflective layer reflects the solar energy that is incident on it. It is comprised mostly of a thin metallic film of silver or aluminium that is applied to the substrate. Silver has higher reflectivity than aluminium and provides a higher efficiency. The top layer of reflector surface is protected by the (glass) substrate; the bottom may be covered with a protective coating, such as a copper layer and varnish.

Interference layer may be located on the first surface of the glass substrate to tailor the reflectance. It may also be designed for diffuse reflectance of near-ultraviolet radiation to prevent it from passing through the glass substrate. The interference layer may be made of several materials, depending on the desired refractive index, such as Titanium dioxide.

II. ENVIRONMENTAL EFFECTS ON SURFACE PROPERTIES

A. Effect of Acid Rains:

The term Acid rain refers to both wet and dry deposition of acidic pollutants that may damage material surfaces, including finishing and shining of the coating surface. These pollutants, which are released when coal and other fossil fuels are burned that react with water vapour and oxidants in the atmosphere and are chemically transformed into sulphuric and nitric acids. The acidic compounds that may fall to earth as rain, snow, fog, or may join dry particles and fall as dry deposition. All forms of acid rain, including dry deposition, especially when dry acidic deposition is mixed with dew or rain, may damage automotive coating [2].

The acid rain does not affect all coating. The coating industries suggest to protect coating or until acid deposition is adequately reduced, frequently washing and drying to minimise acid rain damage. [3]

B. Effect of Corrosion on Steel Coating:

1) Atmospheric Corrosion:

Among the parameters determining corrosion rate are the presence of a moisture film on the surface and the pollutant content of this film. Some factor affect to the atmospheric corrosion such as Relative humidity, rain and temperature. In case of temperate climate zone, the levels of air pollutants influence the corrosion rate decisively. [4] The major pollutants, in urban and industrial areas are SO₂ and NOx, chlorides are usually the dominant pollutant in marine regions. Material like SS304 has the least chance to corrode but it has also some limitations with respect to some environmental pollutants or fluids. Some coating layers can prevent corrosion. [5]

The zinc of hot dip galvanized is more corrosion resistance than bore iron and steel. Similar to steel, zinc corrodes when exposed to the atmosphere however zinc corrodes at a rate approximately 1/30 of steel. Also like steel, zinc corrosion is dependent on its environment.

III. UV RADIATION

Ultraviolet rays have shorter wavelength than visible light. A wavelength, the distance between the crests of two waves, is often measured in units called nano meter.[6] Invisible short wave radiation beyond the violet end of the visible spectrum is called UV radiation. On the basis of wavelength UV radiation is subdivided into UV-A (315-400nm), UV-B (280-315nm) and UV-C (<280nm). The shorter wavelengths of UV radiation have higher frequency and energy. UV-C is completely absorbed by oxygen and ozone in the atmosphere. UV-B is approximately 90% is absorbed by the atmosphere, primarily UV-A mostly reached the surface.
A. Effect of UV radiation on materials:
UV radiation is responsible for aging of materials. When discussing outdoor exposure, we are only concerned with UV-A and UV-B radiation. Since UV radiation of shorter wavelength is responsible for building the ozone layer, which does not penetrate the atmosphere. Only UV-A penetrate the atmosphere. UV-A radiation at the earth surface is normally 15-20 times greater in intensity than UV-B. [6] The high energy UV light causes the bonds between atoms to oscillate until they break apart. Mostly metallic materials have a good UV resistance. In most cases, it is the less UV resistance coating on metal surfaces that will be discoloured or embrittled. The objective of the present research is to develop a low cost, small sized parabolic trough type solar thermal reflector that can be placed at the roof tops or for isolated farm locations. The cost and the life of the reflector surface contributes largely to the per unit cost of power generation from the device. It is proposed to use stainless steel grade SS 304 as a reflector for a small sized parabolic trough. The advantages offered are easy availability in local market, atmospheric corrosion resistance, Low cost $ 5 /m².

However a protective hard coat on the surface can provide scratch resistance so that the reflectance of the surface is maintained over a longer service life. Various methods that can provide a hard coating on the surface have been compared and also a comparison is made for the alternative reflective surfaces that have been proposed by various researchers.

IV. ALTERNATIVE AVAILABLE REFLECTORS
Earlier reflectors used in LS-3 trough were glass mirrors that are made of low iron 4 mm float glass that had solar transmittance of 98%. The mirror are silvered at back and polished with several protective coating. Life of the mirrors is more than 15 years. [7] Alternatives to glass reflectors have been tried out to reduce the cost and the maintenance issues.

Thin glass mirrors are as durable as glass reflectors but are however more fragile. The solar weighted reflectivity is 93-96 % and costs $15-40 /m².

Polymeric reflectors have been developed that are based on multilayer radiant film technology. The technology is being developed by 3M. The polymeric sheet is being developed to provide a high reflectivity over a broader range of wavelength. A Silver polymer non metallic reflector that has a lamination of UV screen film over it is developed by NREL. The reflectance of the mirror is of the order of 93 % and costs $10-15, M²

FSM (front mirror surface) is another technology that uses polymer substrate with a metallic adhesive layer, silver reflective layer and a protective top layer. The average solar reflectance is greater than 95 % and the life is estimated to be more than 20 years as determined from accelerated exposure testing.

Super thin glass is being developed by SAIC (Science Application International Corporation) of Mc lean and NREL (National Renewable Energy Laboratory) that has a mirror surface at front and a hard coat protective layer. Ion beam deposition is used to produce the alumina hard coat and the substrate can be alumina or steel. Front surface aluminised reflectors uses polished aluminium substrate that has a protective alumina top coat. Average reflectance is 90% and costs $20 / m².

Alanod Aluminium is a German company that manufactures a variety of aluminum grade material. The mero extra brite (Miro 27) is one of the material which reflects super intensive spectral areas. The spectral reflectance curve of this material follows the spectrum of the sun and it reduced diffusion together with high reflection values. The lacquer (colour) used to provide external protection from weather in demanding condition. The cost of this material is higher than others, but the material would be indestructible. The cost of this material is $2.15 per square foot. [8]

Miro flex is another material which is a composition of rigid high impact plastics, vacuum metalized and bonded together to create highly reflective, unbreakable mirror-like sheets. [8]

Miro flex is a impact resistance and high reflective plastic with unusual surface treatments on silver, brass, and granites. This material is very easy to fabricate and its available in sheets or rolls depending on the thickness. Miroflex materials are primarily manufactured for interior decorative purposes. According to use of solar project the cost of this material is too high.

[8]Aluminiized polyester is also a reflective material but this material discolored and faded after one or two year.(According to comments of Solar Cooked International archives ). Therefore this material does contain ultra violet ray inhibiting coatings or properties.

V. 3M VM2000 RADIANT MIRROR FILM
This material is a multi layered polymeric film which has outside layer is polyethylene. This material is metal free so this is non-corrosive and non-conducting. The manufacturer claims that this material has low shrinkage and the material is not ultra-violet ray resistance. [9] Its thermally stable up to temperature of 125°C. The material can be coated with 3M adhesive. The reflective optical luminosity is more than 98. That mean it reflects more than 98% of visible light. It is film like product that is highly reflective, flexible and lightweight. Price of this product is $1.25per square foot.

A. Selecting Stainless steel (SS304) as reflector material
1) Advantage:
   - 304 stainless steel has lower carbon to minimize carbide precipitation.
   - Ease of assembly due to low weight.
   - Corrosion resistant under open atmosphere.
   - High Reflectivity of 93%.
   - Low cost @ $5/m².
2) Disadvantage:
   - Surface Scratches during cleaning reduces the reflectivity.
   - Reduce brightness due to deposit formation

VI. COMPARISON OF HARD COATING TECHNIQUES ON THE SS 304
A. Electroplating [10]
Electroplating is also known as electro chemical plating. it is an electrolytic process and in this process electrolyte solution are deposited onto a cathode. In this process, metal
which is being plated is used as an anode and work-piece where coating is applied is used as a cathode. Direct current passed through the electric solution from an external power source. The electrolyte can be solution of acids, bases or salts.

Working principle of this process is based on the Faraday’s law.

According to this law the mass of substance liberated is proportional to the quantity of electricity passed through the cell, and the mass of the material liberated is proportional to its electro chemical equivalent.

Mathematically effect can be stated as

\[ V = K I t \]

Where \( V \) is the volume metal plated in \( m^3 \)
\( I \) is the flowing current in ampere,
\( t \) is the time for which current passes through and
\( K \) is a constant

Electroplating may have platting of different metals. Some important metals are described here.

**B. Zinc Plating \[11\]**

Zinc plating is used on the steel product. Zinc plated steel products are fasteners wire goods, electric switch boxes and sheet metal parts. Zinc coating provided high resistance to corrosion. If zinc deposited at 0.8V it gives fairly bright reflection on deposition time 20 minute and it gives bright reflection, deposition at 1.0V on same deposition time. \[6\]

The cost of Zinc plating is to 15 Rs. Per kg Or $1.1 per square meter. And the life of zinc plating is 1-2 years.

**C. Chrome Plating \[12\]**

Chrome plating is a technique of electroplating a thin layer of chromium onto steel sheet. The chrome layer used to increase the properties and performance of the surface layer. The chrome layer can be decorative, provide corrosion resistance, increase shining of the steel sheet and increase surface hardness.

Chrome plating basically includes some stages:
- Degreasing to remove heavy soiling
- Manual cleaning to remove all residual traces of dirt and surface impurities.
- Prepare a solution of chromium
- Application of plating current for required to attend the desired thickness.

There are variation of this process depending on the type of thickness which is required for our purpose. Various finishing and buffing process are used in preparing components for decorative chrome plating.

The chrome plating chemicals are very toxic. The cost of Chrome Plating is to 25 Rs. Per kg or $1.95 per Square meter. And life of chrome plating is 5-10 year.

**D. Galvanizing\[13\]**

Galvanizing is an electrochemical plating for reduce corrosion on the surface of another metal. This technique is widely used to coat zinc over the iron and steel. This technique is widely accepted due to its effectiveness and economy. Galvanized sheet metal are available in the market for their commercial use. Some important techniques are described below.

1) **Hot Dip Galvanizing:**

In this process firstly cleaning the work piece that involves degreasing by acid rinsing followed by water cleaning. Than annealing and cooling in an oxide free atmosphere. At the time of cooling when temperature of work piece reaches near to the temperature of molten zinc bath temperature approximately 460°C. \[10\]The workpiece dipped in to the bath. Very thin and uniform coating layer can be maintained by passing the sheets through rollers just after the coating.

This method is not recommended for galvanizing of very delicate and complex shaped parts. The cost of Hot dip galvanizing is to 20 Rs. Per kg Or $1.5 per square meter. And the life of coating is 20-30 year.

2) **Flow Galvanizing:**

In this process hot zinc bath is made to flow over the surface of the sheet metal to be galvanized. Molten zinc is spread over the whole surface of the sheet. Excess zinc flowing down the surface is collected back for its recycling. \[10\]This process is suitable for galvanization of flat sheet. This modified process uses a metal spray gun. The gun is equipped with a device to produce flame, through which a zinc wire is fed and melted. Air pressure is used to spray this molten zinc on the surface of sheet metal. Its also maintains a thin and uniform thickness layer of coating.

The cost of flow galvanizing is to 10-12 Rs. Per kg Or $0.7-0.8 per square meter. And the life of coating is 10-15 year.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Coating Process</th>
<th>Price (Dollar per meter square)</th>
<th>Coating Life (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Zinc Plating</td>
<td>1.1</td>
<td>1-2</td>
</tr>
<tr>
<td>2</td>
<td>Chrome Plating</td>
<td>1.95</td>
<td>5-10</td>
</tr>
<tr>
<td>3</td>
<td>Hot Dip Galvanizing</td>
<td>1.5</td>
<td>20-30</td>
</tr>
<tr>
<td>4</td>
<td>Flow Galvanizing</td>
<td>0.8</td>
<td>10-15</td>
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Table 2: Comparison of Different Coating Process

VIII. **CONCLUSION**

In this report the concept of further enhancing reflectivity in the development of highly reflective surface that contribute to the improvement of reflective efficiency. Therefore hot dip galvanizing is the best method for coating. Coating material will be Aluminium oxide. The reflective coating has a strong advantage to corrosive resistance with high reflectivity and economical. The cost of hot dip galvanizing is 1.5 Dollar per square meter and life of coating 20-30 years.

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