Enhancing the reflectivity and durability of reflector of solar parabolic dish collector

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Abstract: Concentrated solar Power (CSP) Technology promises solution to several problems in the present Energy Crises and Global Warming. Concentrating solar power plant made by several parabolic dish concentrator, And it consist of 40 to 50% manufacturing cost, For make this technology economical, it requires the development of advanced reflector which have low cost and high reflectivity for extended life times under the serve of outdoor atmospheric environment. Metalize the mirror of parabolic dish will make the technology economical, Parabolic dish system are typically designed for remote power need in rural area. This thesis consists of study of a solar reflectance of a stainless steel (SS-430) and various coating materials for improving the optical efficiency of reflecting surface. For determining the optical efficiency of Stainless steel, Reflectivity of surface were measured and Design parabolic dish to use this in rural area for reducing the burning of wood, charcoal and other domestic waste.

***IndexTerms* – Parabolic Dish collector, coating material, coating process, design parabolic dish, reflectivity measurement.**

I. INTRODUCTION

The solar parabolic dish concentrator has the highest efficiency in the conversion of solar energy to electricity as compared to other concentrator technology. This systems have high optical efficiencies and low start-up losses, and the performance of this technology is largely depends on optical properties of reflector. A reflector surface should have high optical efficiency, low cost and high durability.

The cost of reflector is important consideration in the overall cost of the solar power 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 would generate over the year.

Mirrors are used mostly as a reflector of parabolic through, parabolic dishes and heliostat type plants. Mostly glass and silver are used for their high reflectance, good specularity, durability and resistance to distortion from load, However heavy glasses, hard, abrasion resistant, corrosion resistant, transparent and resistant to UV light. The design specification of the "ideal" solar thermal reflector should include high optical performance (reflectance, transmittance), low maintenance cost, low initial cost and long life.

Metalize the reflector is the best option to achieve low cost and long life of this technology, like aluminium and stainless steel sheets are also used in solar reflector. A metal reflector reduces the structure requirement as they are lighter than glass, stronger and easy to be placed on the support structure.

Stainless steel is not commonly used as reflective metal for CST mirrors because it presents quite low reflectance. However, this material may represent an alternative solution for processes whose energy demand is low and implementation cost are more important than efficiency. Another advantage of this material is its high market availability.

II. SURFACE PROPERTIES AFFECTED BY ENVIRONMENT

A. Effect of Acid rain:

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

The acid rain does not affect all coating, the coating industries suggest to protect against coating or until acid deposition is adequately reduced, frequently washing and drying to minimize acid rain damage.

B. Effect of Corrosion on steel coating:

Atmospheric Corrosion:

Among the parameters determining corrosion rate are the presence of moisture film on the surface and pollutant content of this film. Some factors affect to the atmospheric corrosion such as Relative humidity, rain and temperature. In case of temperature climate zone, the levels of air pollutants influence the corrosion rate decisively. The major pollutants, in urban and industrial areas are SO_2 and NO_x, chlorides are usually the dominant pollutant in marine regions. Material like SS 430 (M) has the least chance to corrode but it has also some limitations with respect to some environmental pollutants or fluids. Some coating layer can prevent corrosion.

The zinc of hot dip galvanized is more corrosion resistance than bare 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 (UV) designates a band of the electromagnetic spectrum with wavelength from 10 nm to 400 nm, shorter than that of visible light but longer than X-rays. UV radiation is present in sunlight, and contributes about 10% of the total output of the Sun. Ultraviolet ray have shorter wavelength than visible light. A wavelength, the distance between the crest of two waves, is often measured in units called nano meter. 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% absorbed by the atmosphere, primarily UV-A mostly reached the surface.

A. Effect of UV radiation on materials:

The effect of ultraviolet light on the corrosion rates of different metals was studied in two separate investigations. Metal samples were immersed in a flowing fresh water discharge stream for either three or five months under both ultraviolet (UV) light and dark conditions. Weight-loss results demonstrated that pure zinc, carbon steel, aluminium 6061 (UNS A96061), pure copper, and pure silver all experienced photo-corrosion, that is, a greater weight loss under exposure to UV light us in the dark. Titanium, zirconium, Type 304 (UNS S30400) stainless steel, and pure nickel showed a weight gain during immersion, but the cause of the weight gain was uncertain. Pure nickel and Al 5052 (UNS A95052) did not show any reproducible trend. Zirconium, titanium, and brass showed a photo-effect in one investigation, but not in the other. The photo-corrosion is explained with models based on the photo-voltages measured on corroded metal samples.

Mostly metallic material have good UV resistance, in most cases, it is less UV resistance coating on metal surfaces that will be discoloured or brittle. The objective of the present research is to develop a low cost, small sized parabolic dish like mobile dish which can be used anywhere to cook food. The cost and life of reflector surface contributes largely to the unit cost of power generation from the device. It is proposed to use stainless steel grade SS 430(M) as a reflector for small size parabolic dish. Advantages of selecting this material are easy available in local market, atmospheric corrosion resistance and low cost $5/m^2.

However a protective hard coat on the surface can provide scratch resistance so that reflectance of the surface is maintained over a longer service life. Various method 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 reflector used in CST technology was glass mirrors that are made of low iron 4 mm float glass that had solar transmittance of 98 %. The mirrors are silvered polish at back and also polished with several protective coating, life of mirror more than 15 years. Alternatives have been tried out, even small improvement of 0.5 ppt in reflectance will have a high impact on the annual revenue of power plant.

Thin glass film transparent front coats have high reflectance with silver as the reflecting surface. The reduction of the glass thickness from 4mm to 1mm boosts the reflectance around 1ppt, but it is more fragile. Solar weighted reflectivity is 93 – 96 % and cost $ 15-40 /m^2.

Silvered polymer film achieves solar-weighted hemispherical reflectance values around 94% and cost $ 10-15/m^2, which is still below the state-of-art 4 mm silvered glass mirror reflectance (they achieve around 94.7%). Silver polymer film's have benefit of being flexible. Allowing one to construct any kind of reflector geometry, However in specularity durability and glass based mirror are superior.

Luz Industries Israel created a front surface mirror that consist of polymeric substrate with metal or dielectric adhesion layer, silver reflective layer proprietary dense, protective top hard coat. The reflector has excellent initial reflectance. Durability with solar weighted reflectance 95 % for more than five year of accelerated – exposure testing.

Mirroflex is a reflector material, whose composition of rigid high impact plastics, vacuum metalized and bonded together to create highly reflective, unbreakable mirror-like sheets.

Mirroflex is a impact resistant plastic with unusual surface treatments including silver, gold, brass, brushed metallic, wood grains and granites. This material is very easy to fabricate.

Industrial Solar Technology has been working with NREL (National renewable energy limited) to develop a silvered Teflon™ solar reflector material. The advantages of such a mirror include the fact that Teflon™ is an inherently weathered and non hygroscopic material, has good barrier properties, and exhibits a low surface energy which may reduce soil retention. The specular reflectance of weathered samples is generally low (typically 80% at 650 nm and 8-12 mrad full-acceptance angle, with >90% being the goal). Corrosion-resistant constructions have been fabricated that exhibit promising optical durability in accelerated exposure tests.

Alanod Aluminium is a German company that manufactures a variety of aluminium grades. The mero extra bright (Miro 27) is one of the material which reflect super intensive spectral areas. The spectral reflectance curve of this material follow the spectrum of the sun and it reduced diffusion together with high reflection value. And durability test have proved external protection in demanding conditions. They also state that the lacquer (color) does not reduce the optical properties of the material. The cost of this material is higher than other, it is around $ 2.15 per square feet.

V. ACRYLIC MIRROR

This material is half the weight of glass. It is shatter resistant and highly reflective. It is an optically perfect acrylic sheet that is vacuum metalized in a vacuum chamber. The sheets themselves are protected on the back by a durable scratch resistant coating and on the front surface be either a clear polyethylene film or a paper masking. The material can also be made with pressure sensitive backing. The manufacturing of this product is very complex. The cost of this material is also very high, which makes it unfeasible for this project. Close to $5 per square foot.

A. Selecting stainless steel (SS430 M) as a reflector material

Advantages:

- SS 430 M has a low carbon to minimize carbide precipitation.
- Ease of assembly due to low weight.
- Corrosion resistance under open atmosphere.
- High reflectivity of 90 % wavelength in the range of 500-650 nm.

Disadvantages:

- Reflectivity reduced due formation of surface scratches during cleaning.

Reduce brightness due to deposit formation.

VI. COMPARISON OF HARD COATING TECHNIQUES ON THE SS 430 (M)

A. Electroplating

Electroplating is a process in which electric current is used to reduce dissolved metal cation so that they form a thin coherent metal coating on an electrode, it is also known as electro chemical plating. 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 electric solution from the external power source. Electrolyte can be solution of acid, base or salt.

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

According to this law the mass of substance librated is proportional to the quantity of electricity passed through the cell, and the mass of the material is librated directly proportional to its electrochemical equivalent.

Mathematically can be stated as

$$V = KIt$$

Where V is the volume metal plated in m^3

I is the flowing current in ampere,

T is the time for which the current passes through and

K is constant

K is depending on electrochemical equivalent and density of electrolyte is m^2/A-S. E.

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

B. Zinc Plating

Zinc plating used on the steel product. Zinc plated steel products are fastener wire goods, electric switch box 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.

The cost of zinc plating is to Rs. 8 per kg for barrel plating method and Rs. 15 per Kg or $ 1.1 per square meter and life of zinc plating is 1-2 years.

C. Chrome Plating

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

Chrome plating basically includes some stages:

- Decrease to remove heavy soiling.
- Manual cleaning is done to remove all residual traces of dirt and surface impurities.
- Prepare a solution of chromium
- Application of plating current required to attend the desired thickness.
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There is variation of this process depending on type of thickness which is required for our purpose. Various finishing and buffering process are used in preparing component 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

Galvanization is an electrochemical process to reduce corrosion on the surface of another metal. It gives the anti-corrosive properties to the metal sheet. This technique is widely accepted due to effectiveness and economy. Galvanized sheet metals are available in market for their commercial use. Some important techniques are given below.

1. **Hot dip galvanizing:**

Hot dip galvanization is the process of coating iron and steel with zinc, in this process firstly we have to clean the work-piece that involves decreasing by acid rinsing followed by water cleaning then 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 840̊ F (449̊ C). The work-piece dipped into the bath then pure zinc (Zn) reacts with oxide and zinc oxide, 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 delicate and complex shaped parts. The cost of Hot dip galvanizing is to 38 Rs. Per kg or $ 1.5 per kg square meter and the life of coating is 20-30 years.

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 flow down the surface and is collected back for its recycling. This process is suitable 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. It also maintains a thin and uniform thickness layer of coating.

The cost of flow galvanizing is to 26 Rs. Per kg or $ 0.7-0.8 per square meter. And the life of coating is 10-15 year.

Table.1 Comparison of different coating process

S. No	Coating Process	Price (dollar per meter square)	Coating Life (Years)
1	**Zinc plating**	**$ 1.2**	**1-2**
2	**Chrome plating**	**$ 2**	**5-10**
3	**Hot dip galvanizing**	**$ 1.7**	**20-30**
4	**Flow galvanizing**	**$ 0.9**	**10-15**

VII. DESIGN PARAMETERS OF PARABOLIC DISH

The main parameters are used for describing the concentrating collectors are given below.

1. Aperture area (A): The area of the collector at which solar radiation is intercepted.

2. Absorber area (abs): It is the area of the absorber where the entire radiation is concentrated after reflection or refraction from the system the optical concentrator.

3. Concentration Ratio(C): It is the ratio of total aperture area to the surface area of the absorber.

It is also called as geometric concentration ratio. The value of concentration ratio is unity as in the case of at plate collector to few thousands for a parabolic dish collector.

7.1 Component characteristics

The concentrator dish is made up of 6 polished stainless Steel parts, reference 430 M.

Focus 1.5 ft

Cylinder 3cm in diameter, which is located perpendicular to the centre of the dish

Structure and solar monitoring mechanisms

The support has three support points each support point has a piece to level the structure to the surface.

Assume diameter of parabolic dish be $D_a = 5$ft and the depth of parabolic dish is assumed 1 ft, the absorber placed at the focal point and focus of dish can be calculated by formula:

$$f = \frac{(Da)2}{16d} \qquad (1)$$

$$f = \frac{(5)2}{(16\times1)} 1.5 \text{ ft}$$

The diameter of aperture and the maximum angle that defines it are related by equation (1)

$$\phi = \frac{2arctg\ Da}{4f} = 102.68° \qquad (2)$$

Another important parameter to adequately define the geometry of the solar collector parabolic dish is the edge radius (rr) or maximum distance value existing between the focal point and the paraboloid extreme. Equation (2) defines said value as the following:

$$\square\square = \frac{2f}{1 + \cos\phi} = 2.56 \text{ ft} \qquad (3)$$

Table.2 Geometric specification of solar parabolic dish

Parameter	Value	Unit
Reflectivity of dish	100% (450-700nm)	
Diameter of dish (D)	5 ft	Ft
Depth of the parabolic dish	1 ft	Ft
Reflective surface	Metallic mirror (SS 430)	-
Frame of the solar dish concentrator	Mild steel	
Calculation		
Aperture area of the dish (A_p)	19.625	Ft^2
Focal length of the dish (F)	1.5	Ft
Ratio(Focal length/diameter of the dish)	0.3	-
Rim angle of the dish	102.68	Radian
Geometric concentration ratio	13.440	-
Number of facets	6 facets	-
A_r	135648	mm^2

An indicator to bear in mind in solar collector systems is the concentration ratio; the higher the concentration ratio, the higher the temperature to be reached with the solar concentrator system. Parabolic dish collectors are known for having a higher concentration ratio than the rest of the solar collector systems. The concentration index is defined as the ratio between the aperture area (A_a) and the area of the receiver (A_r), as shown in equation.

$$\square = \frac{Aa}{Ar} \quad (4)$$

The aperture area can be calculated through the following ratio:

$$\square\square = \frac{\pi(Da)2}{4} = 19.625\ ft^2 = 1.8232\ m^2 \quad (5)$$

Area of receiver can be determined through equation:

$$A_r = 2\pi ah = 2\times3.14\times270\times80 = 135648\ mm^2 = 0.135648\ m^2 \quad (6)$$

$$C = \frac{1.8232}{0.135648} = 13.440$$

VIII. EXPERIMENTAL MEASUREMENT OF SURFACE REFLECTIVITY

For reflectance measurements, the spectrophotometer quantitatively compares the fraction of light that reflects from the reference and test samples. Light passed through monochromatic light source which diffract the light source into “rainbow” of wavelengths and output narrow bandwidths of this diffracted spectrum. Discrete frequencies are transmitted through the test sample. The reflectance value for each wavelength of the test sample is then compared with the transmission or reflectance value from the reference sample.

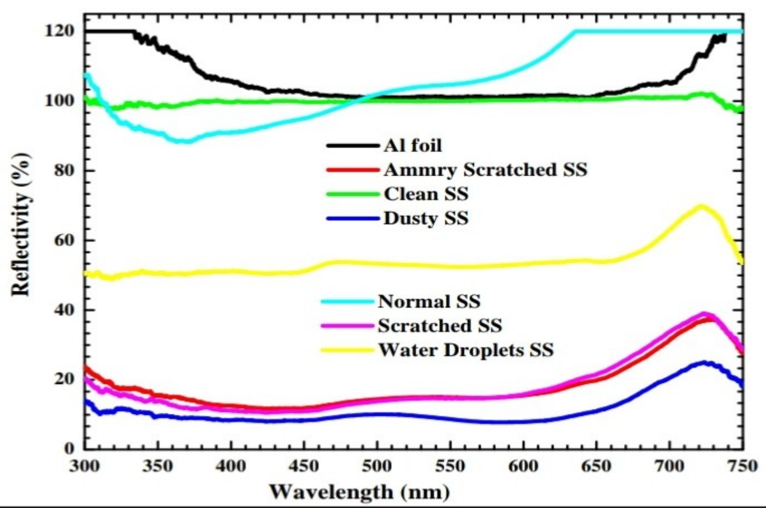

Figure.1

IX. CONCLUSION

In this report the reflectivity of SS 430 is excellent between 450-700nm wavelength and the concept of further enhancing the reflectivity of concentrator and development of highly reflective surface that contribute to the improvement of reflective efficiency. Due to scratching the reflectivity reduces up to 75% and effect of dirt it's reduce up to 85% Therefore hot dip galvanization is the best method for coating. Coating material will be zinc oxide. The reflective coating has a strong advantage to corrosion resistance with high reflectivity and economical. The cost of hot dip galvanizing is $1.5 per square meter and life of coating 20-30 year.

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