

Solar Thermal Coatings

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Abstract: Curved brass trough, roughened surface when exposed to sun light heat generated due to multiple scattering occurs and rough surface absorbs more light in comparison to plane & glassy surfaces. (by lessening specular reflection). Heat generation in trough type surface to UV rays path changing and more absorption of light. Brass tarnishing/oxidation filmy surface UV rays absorption more leads higher temperature above 120 degrees in normal sunshine and at winter part cloudy sky for cooking.

Black Body: "Black body concept is an idealization as perfect black body does not exist in nature. However graphite and lamp black with emission greater than 0.95 are good approximations to black material." A closed box with walls of graphite at constant temperature with small hole on one side produces a good approximation to ideal black body radiation emanating from opening.

All normal matter absorbs electromagnetic radiation to some degree. An object that absorbs all radiation falling on it at all wave lengths is called black body.

Solar radiation 0 to 0.38 microns wavelength 7% and 0.38 to 0.78 microns 47% and 0.78 to 4.0 microns 45% approximately. Absorbance and emittance of radiation for particular wave length not are equal for all surfaces. Sun rays maximum % wave lengths ranges of less than 2.5 microns. Highest absorption and highest emission for all wave lengths of light for ideal black body. Emission increase with temperature. The re-emitted light progressively shorter wave length and greater energy as temperature of black body increases. In general the coatings available are of limited to particular wave lengths

paraboloid is circle in cross section. By changing the circles into squares the formed shape is compound parabolic trough (two parabolas focal axis is perpendicular). The acceptance angle is more when trough designed (Considered parabolic curve coordinates bottom side $Y=2/3 a$ & $X=1/9a$; at top side co-ordinates $Y=2.2a$ & $X=1.21a$, a is focus of parabola)

The metals having shining surface and reflect sun light. As time passes the shining reduces and reflection from metal surface reduces. In general when metals are exposed to atmospheric conditions oxide film forms and light absorption is more due to this. Any metal surface the

surface finish for rolled sheet is less than polished surface (as per ASME14.36M standard) and in case rough surface it is still more. When oxide film forms this is still more

As per laws of reflection on glassy surface only specular reflection occurs. On rough surface diffusion /scattering reflection occurs. Light absorbed by metal surface through inter-band and intra-band absorption. Absorption increases due to surface roughness or resonating structure causing heating. The absorbed energy converted into heat through electron and photon interaction. Due to this part of light is absorbed in rough surface converts into heat.

Nanostructure like nano-voids or gratins can cause surface plasma resonance which dramatically increases light absorption at specific frequencies. In general specialized coatings work in this pattern.

Intra-band absorption increases with because free electrons have higher kinetic energy and probability of electron-photon collision grows.

In Inter-band absorption general decreases with temperature and certain wavelengths as the electron energy distribution broadens.

Polarization and wavelengths -the angle at which light hits the surface and the wavelength of light play role in determining the absorption efficiency

In general, specialized coatings work in the above pattern.

On curved surface the retro reflection and diffuse reflections, multiple scattering occurs due to diurnal/bi-direction movement of sun. When cylindrical vessel is placed in compound parabolic trough path changing of light occurs and light travel time increases. The above phenomenon increase light absorption is more and conversion into heat is more without specialized coatings

Vessel diameter is more compared to compound parabolic trough bottom square side length In general diameter of vessel is more than or equal trough bottom square side. In this selected trough the cooking vessel cylindrical shape is positioned. This trough shape gives support to cooking vessel. The contact between cooking vessel and trough is point /direct contact only.

Absorption of light and increase of heat (Q) or raise of temperature can be increased by virtue of profile/shape of trough and application of coatings solar thermal specialized coatings.

Above critical angle of light total internal reflections and scattered reflection of radiation occur and maximum light energy absorbed for conversion into thermal energy. For non-selective coating solar flux absorbed is equal to thermal flux generated. As trough surface is curved in nature thermal flux generated and reflected/diverted on to cooking vessel periphery/ surface from heated through. Heating starts radiation equilibrium balancing occurring between trough and periphery of cooking vessel. In this way vessel periphery heat transfer due to radiation emitted by trough occurs. Top of vessel lid absorbs light. sides and top of vessel heating is more. In spite due to convection heating is done due to inside air

circulation also. The trough bottom face (bottom square of trough) by virtue of thermal conductivity of trough material temperature raises at bottom but less in comparison to top. The radiation release from trough at bottom is less compared trough periphery. Due to gap between vessel bottom and trough bottom heat transfer through convection by air circulation occurs.

It can be concluded that heat generation and transfer through trough (curved) profile is more and coatings forms in brass trough due oxidation of copper in this situation. Higher light absorption increases more temperature raise in this experiment/design. All wavelength radiation absorption and utilization sun light is more in this experiment/design (The reflector designed specially with 13/14 segments mirrors as mentioned photographs for better distribution of light in trough.)

Brass is composite of copper and zinc. The UV spectrum absorption varies with Cu/Zn ratio. Surface roughness decreases specular reflection and increases the amount of diffuse & scattering radiation. The scattering effectively increases interaction path length of UV light with surface which can lead to overall absorption of light compared to smooth surface.

Brass quickly tarnishes when exposed to atmosphere forming oxide layer. The surface oxide films have optical properties distinct from pure brass and significantly alter UV absorption, often increasing it. In circular/curved surface will cause incident radiation to reflect at various angles. In concave configuration light undergoes multiple reflections within curve surface / structure. Each reflection will result absorption, meaning curved/rough and tarnished surface will absorb greater percentage of UV light due to light trapping effect wrt to flat surface of same material.

The energy distribution is different than flat surface wrt curved surface due varying absorbing levels across object profile. Areas where light hits perpendicularly will have different absorption characteristics compared to oblique angles.

Surface roughness should be more than the incident light wavelength then only higher absorption of light occurs.

Increased roughness leads to higher absorption and lower reflectivity of UV and visible range. Light scattering irregular micro cavities and texture cases incident UV to scatter multiple directions trapping more photons within surface structure increased path length likely of absorption. Surface roughness causes excited localized plasma resonance mode and further increases materials inherent UV absorption.

For higher light absorption using bionic/Micro/nanostructures or plasma nano particles the size of nanometer scale to interact reasonably with specific wave lengths of light ..Ex gold nano particles in 15 to 50 nanometer range absorbs enhancement in 600 to 800 range of visible light due to localized plasma resonance.

The thermal conductivity of brass is less with respect to aluminum and copper. The rate of copper and aluminum is more compared to brass. Due to this character by using brass as trough

in box cookers the heat retention time increases and temperature dropping is less in intermittent sky like clouds moving and it will act as cushion or reduction of temperature in box cookers can be controlled to some extent. This will avoid use of phase changing materials/thermal energy storing materials (using stones or metal balls) for controlling the temperature drops in box cooker.

For same temperature raise brass can store more heat than aluminum per 1 gram basis better heat retention in terms of storage. Aluminum has higher specific heat capacity 0.080J/Gr de centigrade whereas brass is 0.045J/gr Deg celcius

Brass has lower thermal conductivity (120to158 W/M-deg celcius) whereas aluminum has higher thermal conductivity (120-150W/M -deg celcius). Aluminum transfer heat away from its source to medium ambient environment faster than brass will less effective insulator. To retain heat when exposed to ambient conditions brass will stay warm for longer because it transfer heat to cooler surroundings more slowly than Aluminum does. Brass rougher& oxidized surface absorb and emit thermal radiation more effectively than polished surface.

Roughness height and amplitude play an important role in absorbing Sun light less than 0.0153 micrometer, has minimal trapping, very high roughness introduces defects or parasitic absorption losses. Surface roughness (width of V or correlation of length random roughness should be in order hundred nanometers to micrometers for visible and infrared solar spectrum.

If feature size is large approaching macroscopic scale the surface act as smooth one and light reflects specularly. If it is too smaller than the wavelength surface behave an effective medium layer and reduce reflection but not provide the desired wide angle scattering for light trapping. Light (for hundred nanometers to micrometers for visible and infrared solar spectrum)

It can be concluded that Morphology /shape geometry, texture matter, matter/surface roughness-V type groove and random surface with high aspect ratio (depth to width of roughness) are effective in promoting multiple reflections and light scattering. In spite the oxidation/ sulphide film layer increases light absorption

Brass naturally oxidizes aids heat absorption and retention more wrt fresh Aluminum. Moreover, in due course of operation the brass trough oxidation of copper occurs and cuprous /cupric oxides act as high absorption and low emissive coatings without any additional application of coatings on trough. This is of naturally occurring process. Aluminum oxidized the specific heat capacity is more in comparison to brass. Aluminum when exposed to sun rays its protective oxide layer breakdowns by U V radiation casing oxidize more rapidly. The effect of oxidation is less in comparison to aluminum. Aluminum is highly reactive but naturally formed oxide layer forms only protective coating. Aluminum generally polished and generally polished and absorption of sun rays is 30% and varies wrt surface finish. Polished aluminum absorbs less than 15% better reflection. Brass absorption rate is higher the above method was tested in box cookers. The observed time boiling remains same and unaltered wrt black coated

trough. Considering the above reasons brass was selected for trough to avoid coatings sage for some extent.

Even in brass trough using brass utensils without coating it was tested for boiling. The taken for boiling 500 grams rice boiling time 3 hrs and 3.5 to 3.75 hr minutes in clear sky in month September & October and in November month in clear sky condition .In December month 2 week though sky is part clear onwards brass utensils cooking is not possible But in 3 rd 4 week December and January 1st ,2 nd week the sky becomes too grim, and one time cooking with ss utensils with black coating one time cooking is achieved in 3.5 hrs to 3 hours as usual like in black coated aluminum trough(in continuous sun light without cloud coverage).As in residence testing with thermometer was not done ,but by physical observation- bubbles and steaming are the landmark is observed

With blackcoated SS utensils minimum 2 times boiling is possible in winter normal sky condition and one time slight/part cloudy sky boiling is possible without coating on brass trough.

As shown in Figs 1A&1: Fig -1A brass trough with brass utensil with brass lid& black coated utensil with lid black coated. In normal sunshine with clear sky brass utensil with brass lid takes 3.hrs + 30 minutes for 500 rams boiling and frying/drying 500 grams 3hr 30 minutes to 4 hrs in brass trough and in case black coated vessl and lid time of boiling 90 minutes And frying/drying 2 hrs 30 minutes brass trough. The above experiment carried in months September, October& November months. After 1st week of November inclination of sn rays increases and black coated vessels usage is essential.

The experiment was carried out Location Dowleswarum/Rajamundry city/East Godavari Dt/Andhra Pradesh/India

- Reference:
- 1) Sri Mahabharatum written by Indian sage Veda Vyasa
 - 2) New Design of box type Solar cooker (Book -978-6202513531)
 - 3) Indian Temple architecture & Gopurums

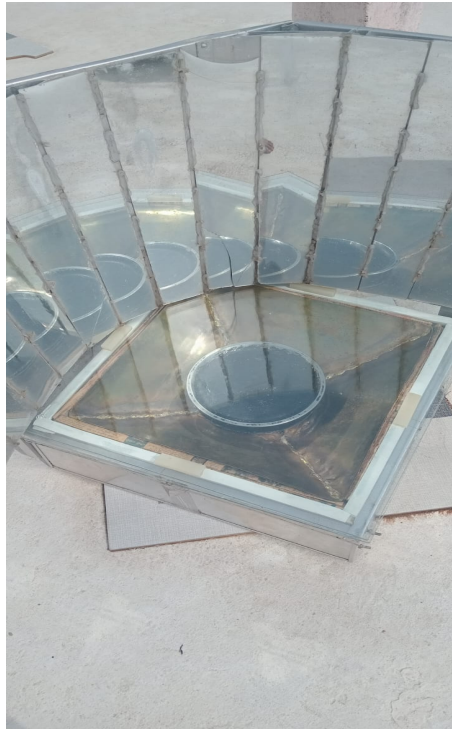


Fig 1: Brass trough instead black trough with reflector assembly



Fig-1A: Rice in brass utensil (without Coating) 500 grams without coating in brass trough



Fig-2: Brass utensil - Steam condensing on bottom cover glass kept in brass trough rice & Dal after boiling



Fig 2A



Fig-3: Dal & rice boiled condition above figure



Fried Ground Nuts 500 gms



Cooker assembly with ground nut utensil