International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-3, September 2019

Design of Infrared Radiation for Best Heat Source Performance In Paint Cure Oven

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***Abstract**: This project aims at altering the conveyor speed for maximum productivity and modifying the oven in order to increase the efficiency of powder coating process involved in painting the components of lifts. The primary thing to be considered while modifying the oven is the heat source provided. Most of the industries use forced convection for heating up the product in order to cure the powder coating process. This project aims at providing infrared radiation as the heat source to cure the powder over the metal surface. Forced convection is advantageous for more complex shapes. But the components of lifts are not of complex shapes. So, it would be efficient to use infrared. The forced convection system requires long heat up time, high energy consumption, large floor area and some additional setups for air circulation inside the oven. Infrared radiation heating would eliminate these drawbacks. The infrared radiation would be absorbed by the material in order to heat up. This is more efficient in case of curing the powder coated parts. Because, in case of forced convection first the paint in form of powder is heated and then the heat is transferred to the metal surface. Whereas in case of infrared heating, the metal would be heated first and then it would be transferred towards the powder paint. In other words, we could say that the infrared radiation heating provides backward heating which would increase the efficiency and life of the paint coated. Temperature control and instant heating are also the advantages of infrared heating. Hence designing the infrared source for the given metal and powder specifications is done in this project.*

Keywords: Powder coating; Infrared radiation; Conveyor speed; Convection; Curing oven; Heat source.

I. INTRODUCTION

Infrared is old and it is used in our daily aspects. The earth is receiving enormous quantity of heat which is transformed light in visible through infrared. [1]. since, we cannot use the infrared, the understanding becomes complicate. Several difficult formulas as well as constants have been involved on the heat transfer of computing radiant. Further, if we considered alone including the basics as well as involving terminology and the infrared method of heating could be easily being understood.

Infrared has minor portion and the spectrum of electromagnetic placed in between radar top end the radar visible light the portion of microwave. The main difference of visible light and infrared has temperature source [2]. The low temperature infrared power could not be visible by the eye of human. The infrared is same to light energy. It can travel at the light speed and also polarized, focused and reflected. Absorb infrared has varied Opaque objects depending of degrees on color; texture of the surface also its energy wavelength [5]. Wavelength is determined by the temperature of the source. As the temperature increases, the wavelength decreases. Light colored objects reflect the short wavelength radiation generated by the source of high temperature including long wavelength radiation which is generated through the sources of minimum temperature. The color is very tiny of bearing when comparing with radiation reflection. [3], the power of infrared including wavelengths 2.4 - 20 microns has freely getting through the general construction materials [3]. The actual visible light of Infrared power is including wavelengths less than 0.8 microns.

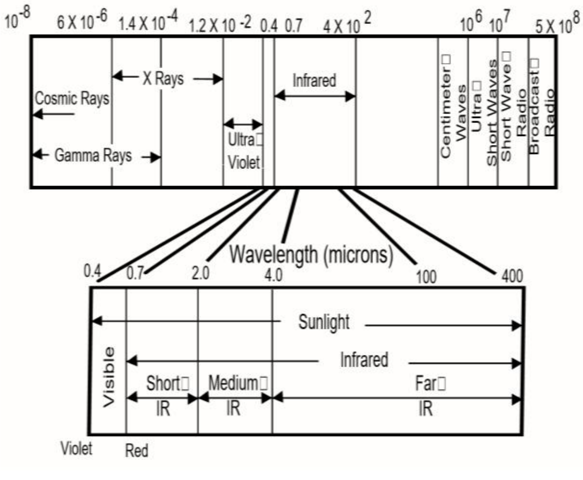

Figure 1: various wavelengths of electromagnetic waves

When infrared energy strikes an object, the molecules are excited and it also creates vibration motion of atoms. This excitation will make them to move which in turn generates heat. This heat is transferred through the body by means of conduction. All objects above zero absolute temperature produce infrared radiation by means of temperature as well as emissivity as formative factors.

Manuscript published on 30 September 2019
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Maximum industrial paint curing oven uses forced convection as the heat source [15]. It requires liquid petroleum gas to heat the air and separate blowers are used for forced convection of heat to the product for curing the powder paint in curing oven [8] [9]. The use of liquid petroleum gas makes it more dangerous and costly. Infrared heat source overcomes these disadvantages. Infrared increases the production rate by reducing the heating time [1]
[7].

Infrared heating helps in non-contact heating. This is very advantageous to heat the moving products or to heat products where physical contact will affect their surface finish [11] [12] [13]. The Little thermal inertia of the radiation by infrared removes the necessity of long preheats cycles [14]. Infrared heating is less than one-third of that of that of convectional ovens [10]. Since there is no medium required for transferring heat, infrared heating is much faster than others [6]. The infrared is actually absorbed by the product surface furthermore transferred through the thickness of the material. Infrared heating also gives high efficiency as they do not heat the surrounding air. It could be considered for achieving the efficiency with high. Certain amount of radiation which is not absorbed can also be reflected back to the product for heating by using reflectors which increases the efficiency. Infrared heating can be controlled easily and precisely. Uniform heating also becomes handy while using infrared radiation heating [4].

Atoms have electrically charged particles such as protons and electrons. Electric field will be present around these charged particles. When this charged particles move, magnetic field is generated. Atoms present in hot objects will vibrate violently. Due to this, the electric and magnetic fields are disturbed. This will be creating electromagnetic wave and hot substances radiate electromagnetic waves [3].

When this electromagnetic waves fall on cold body, the oscillating forces will cause the atoms of cold body to vibrate. As the vibration increases, the cold body is heated up. Hence, heat energy can be transmitted without any physical contact and also without a medium.

Our research work aims at providing infrared radiation as the heat source to cure the powder over the metal surface.

II. CALCULATION

The design of radiation heat source for the paint cuing oven with respect to the conveyor speed is calculated as:

A. Calculation of the Conveyor Speed

The Experimental data's tabulated in Table1, Table 2 and table 3.

Production per annum: 50000 elevators

Months: 12; Days per month: 21; Hours per shift: 9; Shift basis: 2; Mins per shift: 459.

Table- I: Types of components and its dimensions

Sl .no	conv. Speed	Surface Area		Weight		Max Thickness
	m/min	Per component	Per jig	Per component	Per jig	mm
1	1.4949	1.5	4.5	18.5	55.5	1-1.6
2	2.0477	1	3	15	45	1-1.6
3	0.1327	2.2	2.2	22	22	1-1.6
4	0.0442	0.21	0.2	75	75	3
5	0.0442	1.3	1.3	75	75	3
	2.05	2.2	4.5	75	75	3
	Max	Max	Max	Max	Max	Max

Table 2: Types of components and Jigs per shift

Sl .no	Types of comp Onents	Components	Component dimensions		
		Per annum	L (mm)	W (mm)	H (mm)
1	Car Panel	510000	400	200	3000
2	Door	700000	450	200	2100
3	Tiles	15000	1100	200	2000
4	Floor	5000	1100	200	2000
5	Roof	5000	1100	200	2000
			1100	200	3000
			Max	Max	Max

Table 3: Types of components and Jigs per shift

Sl .no	Components per shift	Components per jig	Jigs per shift	Pitch mtr	Mtr per shift
1	1011.9	3	338	2.03	686.14
2	1388.9	3	463	2.03	939.89
3	29.8	1	30	2.03	60.9
4	9.9	1	10	2.03	
5	9.9	1	10	2.03	
	2450.4 Total		**851** Total		

Sample calculation:

Components per shift = components per annum/shift per annum

$= 510000 / (12\times21\times2)$

$= 1011.9.$

Jigs per shift= components per shift / components per jig

$= 1011.9/3$

$= 337.30 \approx 338.$

Meter per shift = jigs per shift × pitch

$= 338 \times 2.03= 686.14.$

Conveyor speed = meter per shift / mins per shift

$= 686.14 / 459$

$= 1.4949.$

Calculation:-

Distance = Speed × time

$= 4\times6$

$= 24$ m.

Length of oven = Speed of conveyor × time

$24 = 2.0477 \times \text{time}$

$\text{Time} = 11.72 \approx 12 \text{ min}$

B. Determine required wattage

$$w/in^2 = \frac{weight\frac{lbs}{in^2}\times specific\ heat \times change\ in\ temp\ (°F)}{Time\ (hr)\times 3.412\frac{BTU}{watt hr}}$$

$$= \frac{\frac{520.25}{4650.25}\times 0.122\times 356}{0.2\times 3.412}$$

$$w/in^2 = \frac{0.119\times 0.122\times 356}{0.2\times 3.412}$$

$w/in^2 = 7.122\ w/in^2$

C. Effective emissivity

$$E = \frac{1}{\frac{1}{En}+\frac{1}{Ep}-1}$$

En = emissivity heater -0.85

Ep = emissivity of product- 0.12

$$E = E = \frac{1}{1.176+8.333-1}$$

$$E = \frac{1}{8.509}$$

$$E = 0.12$$

S = Constant of Stefan Boltzmann $=0.1714\times 10^{-8}$ BTU/hr $ft^2\,{}^0R^4$

D. Temperature of heat source

We know that,

$$w/in^2 = \frac{s(Tn^4-Tp^4)\times E\times F}{144\times 3.412}$$

$$7.122 = \frac{0.1714\times 10^{-8}\,(T_h^4-410^4)\times 0.12\times 0.9}{144\times 3.412}$$

$T_h = 2085.92^0F$

E. Peak energy wavelength (microns)

$$= \frac{5269\ microns°R}{Temp\ (°F)+460} \qquad = \frac{5269}{2085.92+460}$$

Peak energy wavelength (microns) = 2.07 microns

F. *View factor*

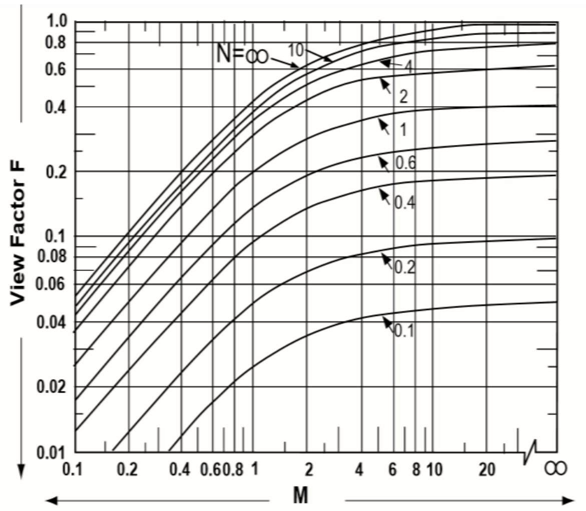

Figure 3: Graph for selecting view factor

$$\text{Where,}\quad M = \frac{heater\ width}{distance\ to\ product}$$

$$N = \frac{heater\ length}{distance\ to\ product}$$

$$M = \frac{4.5}{0.3} = 15$$

$$N = \frac{24}{0.3} = 80$$

∴ View factor =0.9

III. CONCLUSION

This paper shows the entire design of the radiation heat source with respect to the conveyor speed the usage of infrared heating instead of forced convection reduces the pollution and also increases the heating efficiency. It also occupies low floor area of the oven. In infrared, the heating is done backward. While in paint curing oven, the metal heat first and then heat will travel towards the front to cure the paint. This makes the process more efficient. Hence, infrared heating is the best source for paint curing oven

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