CONTROLLED COOLING CONVEYOR - MODIFICATION IN CONVENTIONAL CONVEYOR SYSTEM

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ABSTRACT

Material handling is one of the most important tasks in any Industry. For the purpose of Material Handling many mechanical devices are used in current scenario such as Cranes, Robots, and Conveyors etc. Conveyor is a traditional way of material handling in which the required objects (metal jobs as in the given experiment) are loaded from one location and deposited at the desired location. This is the main function of a standard conveyor. But with a particular modification in the design, a standard conveyor can also be used for changing the base structure of a material which is being transported. The conveyor modified in the under taken experiment is a Controlled Cooling Conveyor. It is based on the principles of Metallurgy and Heat Transfer .The Conveyor conveys hot metal jobs at temperature 950^0 C and at the time of deposition the temperature is 600^0 C. The cooling process used is 'Normalizing' (cooling at ambient temperature) in which the base structure of the metal job exists to be less than 0.8% carbon, in the Pearlite region of Iron-Iron-Carbide diagram (Fe-Fe_3 diagram). The system is provided with compartment doors so as to maintain and control the cooling process. The doors are insulated with asbestos. Purpose behind such system is, obtaining a refined structure of metal with high machinability in controlled conditions and cost cutting by combing two processes and carrying them out simultaneously.

Keywords – Controlled Cooling, Normalizing, Iron-Iron-Carbide diagram, Cooling Compartments, Asbestos, Grain structure, Machinability

INTRODUCTION

With increasing luxury in human life, demand for variety of products is increasing. For an industry it is only possible to keep up to these demands with better production rate and efficient working of production systems which results into accuracy up to the supply level. Any industry whose sole purpose is production needs very effective and efficient material handling system. The system capable of cost cutting as well reduces "in process" time. Conveyor is one of the efficient way in which material can be transported from one location to the desired location in expected time. For time being conveyors are used only for the purpose of transportation of objects. But the paper presented here proposes the modification in conveyor system which combines transportation as well heat treatment so as to reduce the production cost and "in process" time.

For the proposed paper a standard conveyor of following dimensions is used:

1) Width – 1050 mm (Inside)
2) Length – 4050mm
3) Height – 1100mm (Top of Chain)

The metal job has following dimensions:

1) Diameter – 100 mm
2) Length – 70 mm

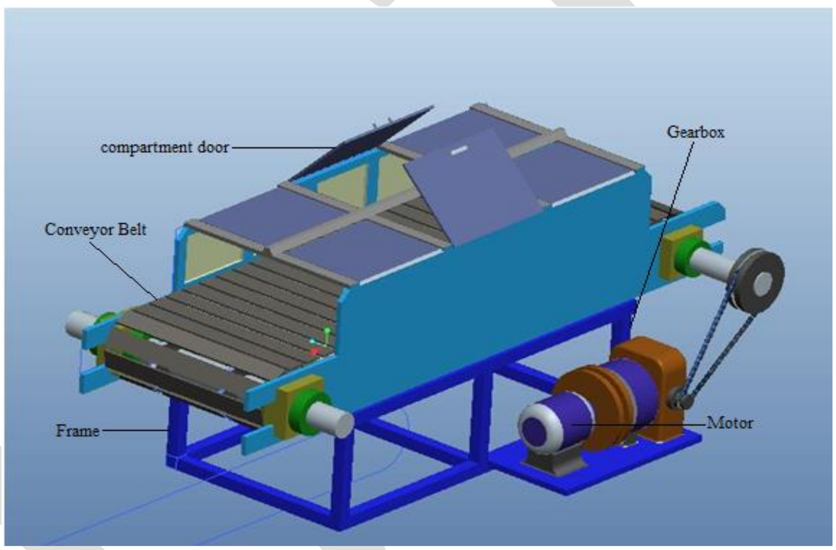

Figure 1: Modified Conveyor

OBJECTIVE

1) Determination of speed of the conveyor system for cooling of 161 metal jobs from 950^0 C to 650^0 so as to obtain a refined grain structure of the metal for better machinability.

2) Provide an arrangement to maintain the controlled cooling of the hot metal jobs.

CONCEPT

The entire concept of this modification is based on:

1. Principles of Metallurgy
2. Heat Transfer (Newton's Law of Cooling)

(1) PRINCIPLES OF METALLURGY

Typical Heat Treatment processes are listed below due to which change in the properties of a metal occurs:

1. Annealing
2. Normalizing
3. Quenching and Tempering

Above mentioned heat treatment processes are shown in the diagram with time taken by each process.

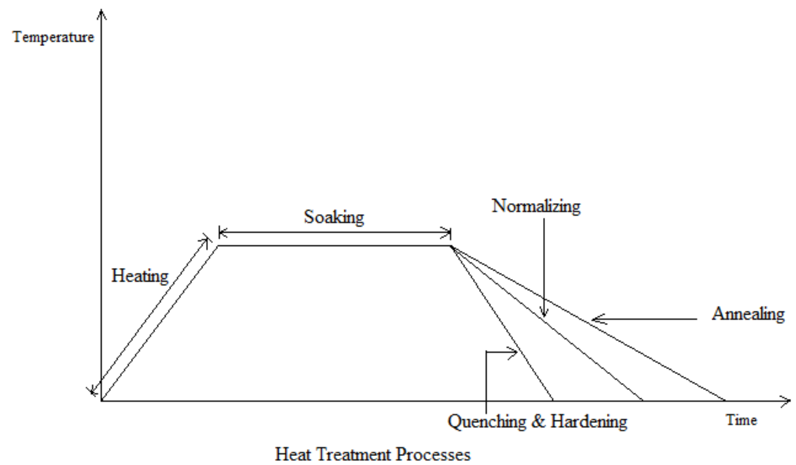

Figure 2: Heat Treatment Processes

From the graph above it can be observed:

1. The process of Annealing is a slow cooling process and hence the time taken by the process is the largest.
2. The process of Normalizing is cooling of a material at ambient temperature which results in refined structure of a material.
3. The process of Quenching and Hardening occurs at the temperature below its critical temperature.

(1.1) SELECTION OF HEAT TREATMENT PROCESS

When the metal is cooled from 950^0C to 650^0C the phase transformation takes place from the region of γ-austenite to Pearlite in Iron-Iron-Carbide diagram. As this metal job is forged before entry to the conveyor, the heat treatment process selected is 'Normalizing' so as to obtain better hardness, high strength and refined grain structure of steel job to 'Fine Pearlite'.

(1.2) NORMALIZING

Definition - Normalizing can be defined as heating steel to Austenizing temperature and cooling it in air. It is done to achieve any one of the following purpose:

1. To eliminate the coarse grain structure obtained in previous working operations such as rolling or forging.
2. To obtain desired micro-structure and mechanical properties.
3. To improve machinability of low carbon steel.

In normalizing steel is uniformly heated to a temperature which causes complete transformation to austenite. The steel is held at this temperature for sufficient time for formation of homogeneous structure throughout its mass. It is then allowed to cool in still air in a uniform manner. Air cooling is faster process than furnace cooling.

(1.3) PROPERTIES OF METAL AFTER NORMALZING

In normalizing due to higher cooling rate transformation of austenite takes place at much lower temperatures. Therefore, the transformation product Pearlite is finer.

Normalized steel will have higher strength and hardness due to following reasons:

1. The amount of Pearlite in normalized steel is more than that is in annealed steel having same carbon content.
2. The dispersion of Pearlite and ferrite phases is finer.

The effect of Normalizing on the grain structure of a metal is shown in the diagram below

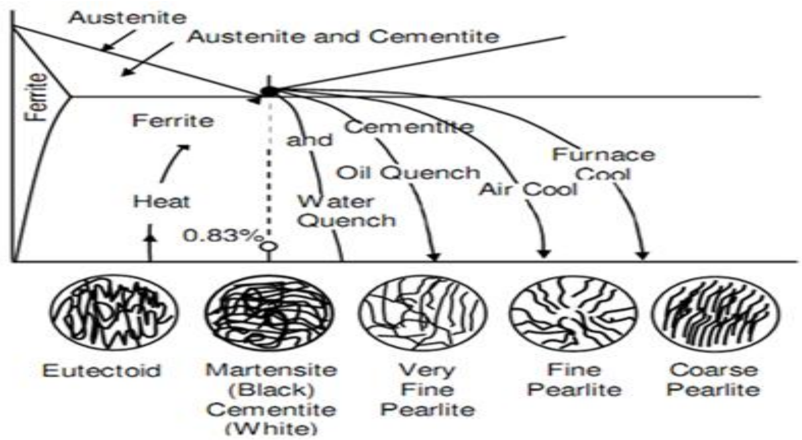

Figure 3: Grain structure of metal on application of Normalizing

Hence, so as to obtain the required grain structure of metal and required hardness and strength the heat treatment process selected is 'Normalizing' which will result in 'Fine Pearlite' with 0.8% of carbon.

With the help of Iron-Iron-Carbide diagram the point of expected metal condition after deposition of metal job in mentioned time span is shown in the figure below

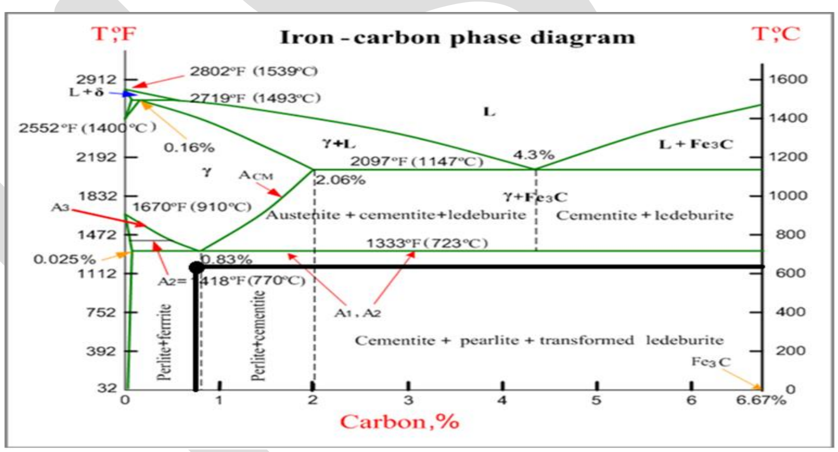

Figure 4: End condition of hot metal job

(2) PRINICPLE OF HEAT TRANSFER

To obtain the required structure the rate of cooling should be considered. Change in structure and properties of metal proportional to the change in temperature are observed. For this purpose Newton's Law of Cooling is taken into consideration to decide the rate of cooling which in turn decides the speed of conveyor.

When hot bodies are left in the open they are found to cool gradually. Newton found that the rate of cooling was proportional to the excess temperature of the body over that of the surroundings. This observation is what is called Newton's law of Cooling.

(2.1) NEWTON'S LAW

The rate of loss of heat by a body is directly proportional to the temperature difference between system and surroundings, provided the difference is small.

$$\frac{dT}{dt} \propto (T_t - T_s)$$

The Newton's law of cooling is given by

$$\frac{dT}{dt} = k(T_t - T_s)$$

Where,
T_t = the temperature at time t
T_s = the temperature of the surrounding,
k = constant of Thermal Conductivity.

(2.2) CALCULATION OF TIME REQUIRED BY PROCESS OF HEAT TRANSFER BY CONSIDERING OVERALL HEAT TREANSFER COEFFICIENT

This value of required time of process is experimental value. A hot metal job at 950^{0}C is kept in ambient condition. Time required for desired temperature reduction is noted down after specific intervals. The fall in temperature is observed for summer and winter conditions.

(2.2.1) OBSERVATION TABLE (FOR SUMMER)

Surrounding Temperature (T_s=35^{o}C)

Temperature (^{o}C)	Time (sec)	Overall Heat Transfer

		Coefficient (U)
950	0	0.75
900	45	
850	73	0.05
800	109	0.035
750	166	0.025
700	248	
650	380	0.0175

Total time required to reduce the temp from 950°C to 650°C = 1021 sec = 17 min

(2.2.2) OBSERVATION TABLE (FOR WINTER)

Surrounding Temperature (T_s=20°C)

Temperature (°C)	**Time (sec)**	**Overall Heat Transfer Coefficient (U)**
950	0	0.17
900	20	
850	30	0.11
800	49	0.076
750	75	0.052
700	116	
650	180	0.036

Total time required to reduce the temp from 950°C to 650°C = 470sec = 7 min

(2.3) DETERMINATION OF SPEED OF CONVEYOR

By considering all the factors and safety measures we have confirmed time range for speed of conveyor belt is between 4mins to 20mins.

Speed Calculation:

Length of the conveyor = 4050mm

Minimum time taken by the job for deposition = 4 minutes

Maximum time taken by the job for deposition = 20 minutes

As per formula,

Speed = $\frac{Distance}{Time}$

Therefore,

Maximum speed of conveyor = $\frac{4050\ (mm)}{240\ \text{sec}}$ = 1.00 m/min

Minimum speed of conveyor = $\frac{4050\ (mm)}{1200\ \text{sec}}$ = 0.2 m/min

(2.4) DETERMINATION OF HEAT FLOW RATE THROUGH COMPARTMENT DOOR

Assumptions:

1) All the doors facilitate equal amount of heat flow rate. Any variation in surrounding and operating condition is neglected.
2) It is mandatory for a customer to install a Pyro-meter while installation of this system so as to note the fall in temperature per interval of time.

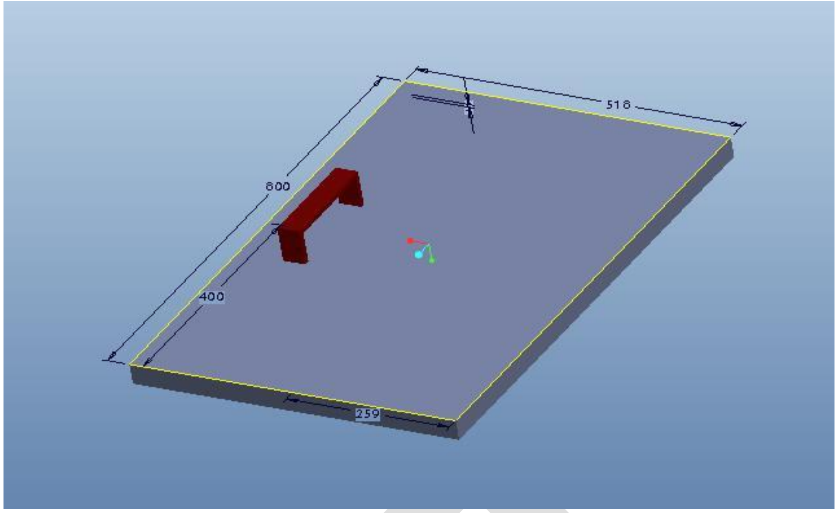

Figure 5: Compartment Door

The conveyor is provided with compartment doors so as to facilitate controlled cooling. The doors are insulated with asbestos material which prevents excessive heat flow.

Dimensions of compartment door

Length = 800 mm = 0.800m

Width = 518 mm = 0.518m

Heat Flow (Q) = $h_A \times A \times (\Delta T)$

Where, h_A – Convective heat transfer coefficient of asbestos material = 0.1 W/m2K

A – Area of compartment door = 0.4144 m^2

(ΔT) – Temperature gradient $(T_2\text{-}T_1)$ K

T_2 – Temperature of hot metal job = 1223K

T_1 – Ambient temperature = 303K

$Q = 0.1 \times 0.4144 \times (1223\text{-}303)$

Q = 38.12 W/S

Hence, 38.12 W/K is the heat flow rate through a single compartment door. The conveyor is provided with 6 such door therefore heat flow is proportional to the number of doors open at a time.

RESULTS

1. Deposited metal jobs at the temperature of 600^0C with grain structure of 'Fine Pearlite' and high machinability.

2. Reduced time required for the additional task of obtaining the required grain structure

3. Reduced cost expenditure which is required for the additional task of change in the grain structure.

4. Increased rate of production with reduced 'In process' time.

5. Though cost of installation of Pyro-meter is high it is negligible as compared to the profit incurred by this modification.

6. Job deposition occurs within prescribed range of time. Hence, system can be categorized as reliable.

CONCLUSION

1. In current scenario where fast and accurate production is required, material handling should contain multiple processes.

2. Modification suggested in this paper will reduce the time required for manufacturing, which in turn will result in better production rate and will cut production cost.

3. Labour cost reduction is exponential as two processes viz. Material handling and heat treatment are combined together.

4. The proposed system facilitates for both the major climatic conditions, i.e. summer and winter hence performance will be uniform.

5. Variation in speed can be achieved by installation of gearbox along with motor; therefore system can be used for different type of metals having different heat transfer rates.

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Tanmay Kale has recently completed his Bachelor’s of Engineering in Mechanical Engineering from TSSM'S BSCOER, Narhe and Pune (affiliated to Pune University) with distinction.