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Modification of Passivation Unit in Galvanizing Line

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Abstract : *Mild steel sheets along with zinc coating have gain popularity in diversified applications due to its availability and cost effectiveness. However, storage of this sheet is subjected to formation of white rust (zinc oxide) which reduces its storage life and consequently its durability hampered. The formation of zinc oxide can be reduced by taking care at production stage by increasing the time required for the passivation process. Hence, in current work effort has been made to develop the effective and efficient passivation unit for galvanizing of the mild steel sheet. Various parameters associated with passivation have been optimized such as number runner, nozzle diameter, number of nozzle and nozzle height. It is observed that these parameters have great influence on the time required for the passivation that ultimately affects the storage life of the mild steel sheet. Moreover, numerical simulation has been carried out for optimization of these variables. From the experimentation and numerical analysis it is concluded that optimized parameter are 8 runners, 4 mm nozzle diameter, 30 numbers of nozzle and 200 mm height for new solution- thin organic coat. Current study would be helpful in further advancement of the passivation process specifically pertinent to mild steel sheet.*

Keywords - *Experimental Analysis, Numerical Simulation, Pareto Analysis*

I. Introduction

It is important for steel in protecting life and utility in atmosphere. Economical technology has developed the process of continuous hot dip Galvanizing. In this molten zinc react with steel to form a metallurgical protective bond/coating that had more durability to any other coatings for atmospheric exposure. The hot dip galvanized coating is the result of a metallurgical reaction between the steel and the molten zinc, and for this coating, surface of steel should be clean otherwise coating peel offs[1]. In process industry passivation, refers to a material becoming passive that is, less affected or corroded by the environment or by moisture. Passivation is developing of an outer layer or shield by applying passivated material which is created by chemical reaction with the base material, or allowed to build from spontaneous oxidation in the air. As a process, passivation is the use of a light coat of a protective material, such as metal oxide, to create a shield against corrosion. As zinc is unstable material in water/moisture. When zinc is come in contact with moisture it forms zinc oxides hence to protect zinc passivation is done. In this chemical of chromium solution reacts with zinc and produces corrosion protecting layer that prevents oxidation of zinc. The protective layer is containing a complex mix of chromium compound and zinc which is self-healing effect. [2]

There are three different types of solutions applied on galvanized steel strip as per customer demand[3].

i) Chromic acid hexavalent
ii) Chromic acid trivalent
iii) Thin organic coating

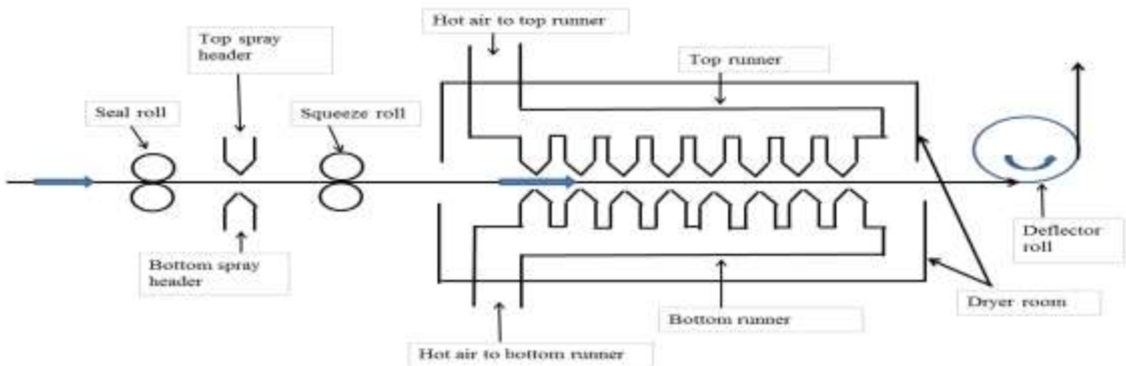
II. Literature Review

Wei-Biao Ye [1] showed the unbalance rate of air flow distribution was controlled less than 10% for single nozzle and 5% for single level. Therefore, it was confirmed that the design method was validated for uniform air flow distribution. Is adding vertical baffles were proposed to improve the uniform of air flow. Adding vertical baffles between fixtures can not only improve air flow distribution greatly but also the uniformities of mass flow rates on every level are also under acceptable.**Galoppi et al. [2]** worked on the influence of the drying air path and the air working conditions was assessed by performing tests with different configurations, temperatures and pressures. The results were analyzed in terms of drying time and energy consumption as the optimum drying condition is a trade-off between these parameters. The mechanical process consists on creating a pressure difference between the external and internal parts of the bobbins.

Wang [3] worked on the blackish green passivation solution had good compatibility with the potassium chloride zinc plating handicraft one of the green environmental protection electroplating produces handicraft. The appearance of galvanized sample treated by this passivation craft was blackish green, color was uniform and luster was gentle. The passivation film can endure neutral salt spray test for 400 hours. **Klaus Czaputa and Günter Brenn [4]** studied the passivation coating on metal wires for electrical insulation was based on the convective drying of liquid polymer solution films applied on cylindrical substrates. The evaporation rate of the solvent was by considering thermodynamic state of the ambient medium and the convective flow situation.**Narayanan [5]** used passivation process after chromic acid rinsing the parts must be dried before finishing, the common methods used being simple evaporation, forced drying by blowing air or by heating. Where evaporation conditions are good, warm air circulating fans and compressed air blow offs are the most economical methods.drying is the last part of passivation process after drying the materials are ready for application of further finishes such as color coating.

Fig.1 shows experimental set up of passivation unit. Passivation is post galvanizing procedure. In the working principle of passivation three main functions are as follows:
i) Rinsing of Passivation solution/spraying: In this passivation solution is sprayed on both surface of galvanized steel with header .header is pipe on which multiple nozzles are fitted through it solution is sprayed on both sides.
ii) Squeezing: In this section solution is squeezed by rubber coated squeeze roll which are placed on both sides

Fig.1 Experimental Set Up



which are touching to the running strip with squeezing roll pressure 4-5 bars. In this section proper coating of solution is done.
iii) Drying: In this section applied solution is dried in dryer. In dryer hot air is blowed on the running surface with pressure 3-4 bars through nozzles which are fitted on pipe which is called as header. Hot air is generated in hot air generator and this air carried through insulated duct and delivered to hot air dryer.
In existing passivation unit we are applying only one solution which is chromic acid hexavalent. To dry this solution hot air is blowed on running strip with temperature 135°C through headers on which nozzles are fixed. Hot air is generated in hot air with RLNG fuel burner having maximum capacity to produce 400°C temperature. In existing passivation unit only one solution was applied on galvanized steel strip[6]**.**
In exiting passivation unit only one solution was applied but customer demands two different solution to applied on galvanized steel strip as per there end use purpose of galvanized steel. These solutions are i) chromic acid trivalent and ii) thin organic coat (TOC). But we have only one passivation unit so have decided to process all three solution in existing unit instead of making separate units to avoid excess cost, time and space. But while processing these two solution following are the problems occurred even keeping hot air temperature as per suggestion of solution supplier are Deposition solution on deflector rolls which after drying unit of Passivation, Powder formation due to non-uniform circulation of hot air in drying unit [7].

The dryer room that was to be designed contained the pipe assembly to supply the hot air. This hot air was to be supplied through the nozzles of circular cross section in order to generate the high speed jets in to the drying room. So, the dryer room assembly must be designed such that the metal strip surface to be maintained with a temperature of 210 °C and above. This would ensure the complete drying of the chemicals from the Mild Steel metal strip. In order to achieve this objective, the hot air must be supplied uniformly along the length of the metal strip. Hence, the design of this unit must ensure the criteria Uniform mass flow distribution through each runner pipes, every nozzle and Homogeneous surface temperature of metal strip[8].
With these design considerations and requirements, the following methods were employed in this paper work.

- Stage 1: Identifying the optimal number of runner tubes
- Stage 2: Identifying the optimal nozzle diameter
- Stage 3: Identifying the optimal number of nozzle
- Stage 4: Identifying the Drying room height

III. Experimental Analysis

To identify the parameter to overcome the problems occurred during processing TOC. Firstly, experimental analysis is done by Pareto analysis then the results of Pareto analysis are compared with CFD Analysis.For identifying the number or runners, nozzle diameter, number of nozzles and height following are the boundary conditions taken Hot air flow 2000cu.m/hr, Hot air temperature 210°C Hot air pressure 2bar, Process speed 90m/min, Input strip thickness 0.40 mm, Width of strip1250mm Length of dryer 8m, Width of dryer 2m, Height of dryer 500mm, Input strip temperature 40°C and Passivation solution is Thin organic coat (TOC). Selection of number of runner and nozzle diameter and number of nozzle are based of intensity of drying in drying room. To avoid deposition of solution drying intensity should be more so number of runner increased every time and respective time noted same logic for all remaining parameters. Table 1 shows the cumulative time for different number of runners. Table 2 shows the cumulative time for different diameter of nozzles. Table 3 shows the cumulative time for different number of nozzles. Table 4 shows the cumulative time for different height of runners.

3.1First Pareto analysis for number of runner:

Table no 1- Cumulative Table for Number of Runner

Number of Runner	Time in Minutes	Cumulative time	Cumulative %	80% marker
6	510	510	18%	80
7	570	1080	50%	80
8	700	1780	82%	80
9	540	2320	107%	80
10	480	2800	129%	80
	2800			

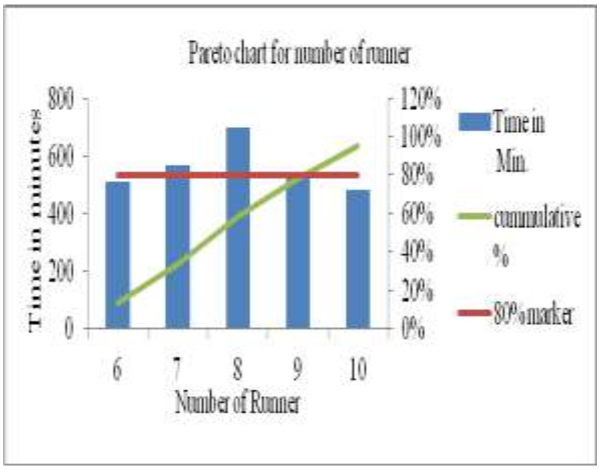


Chart 1-Pareto Chart for Number for Runner

3.2Second Pareto analysis for nozzle diameter:

Table no 2-Cumulative Table for Nozzle Diameter

Diameter in mm	Time in Minutes	Cumulative time	Cumulative %	80% marker
3	500	500	22%	80
4	720	1220	54%	80
5	560	1780	79%	80
6	480	2260	100%	80
	2260			

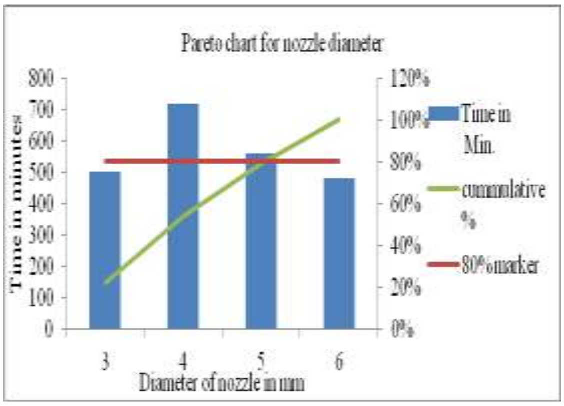


Chart 2-Pareto Chart for Nozzle Diameter

3.3Third Pareto analysis for number nozzles on each runner:

Table no 3-Cumulative for Number of Nozzle on Each Runner

No of Nozzles	Time in Min.	Cumulative Time	Cumulative %	80% marker
20	380	740	16%	80
22	480	1220	27%	80
24	520	1740	39%	80
26	550	2290	51%	80
28	600	2890	64%	80
30	740	3630	81%	80
32	420	4050	90%	80
34	420	4470	99%	80
36	390	4860	108%	80
	4500			

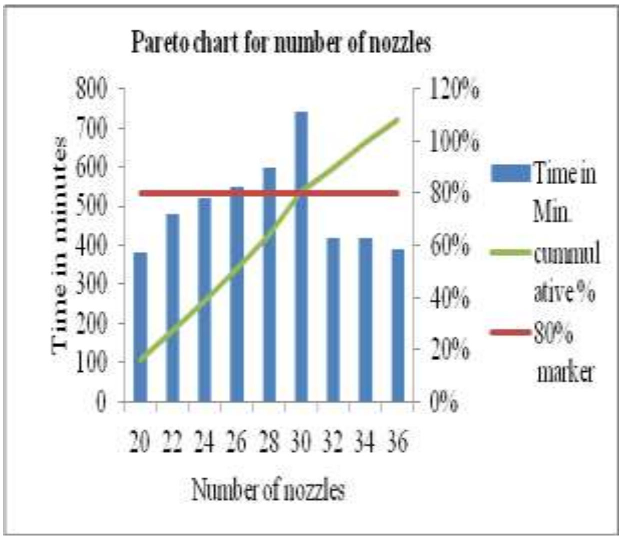


Chart 3-Pareto chart for number of nozzles

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Analysis from Pareto chart: From above chart 1 number runner only runner 7 and 8 crosses the 80% marker line. So from chart optimal number of runner should be in range of 7-8. From chart 2 is optimal nozzle diameters should be 4-5mm because only this diameter range crosses the 80% marker line so the optimal range of nozzle diameter is 4-5 mm for drying. Analysis from Pareto chart 3 is optimal numbers of nozzles on each should be 28-30 because only this number of nozzles range crosses the 80% marker line so the optimal range of number of nozzles is 28-30 mm for drying and from chart 4 optimal heights of nozzles from running strip on each side should be 190-210 mm because only this height of nozzles range crosses the 80% marker line so the optimal range height of nozzles is 190-210 mm for drying from each side of running strip. From above four Pareto analysis following are the outcomes for better drying of thin organic coat solution.

i) Optimal Number of runners in dryer is in range of 7-8 each side
ii) Optimal Nozzle diameter ranges from 4-5 mm on each runner
iii) Optimal Number of nozzles on each runner ranges 28-30
iv) Optimal Height of runner /distance between runner and running strip from each side =190-210 mm.

3.4 Fourth Pareto analysis for height of runner /distance between runner and running strip each side.

Table no 4 –Cumulative Table for Height

Height in mm	Time in Min.	cumulative Time	cumulative %	80% marker
160	400	400	7%	80%
170	530	930	17%	80%
180	580	1510	28%	80%
190	680	2190	41%	80%
200	820	3010	56%	80%
210	700	3710	69%	80%
220	590	4300	80%	80%
230	580	4880	91%	80%
240	480	5360	100%	80%
	5360			

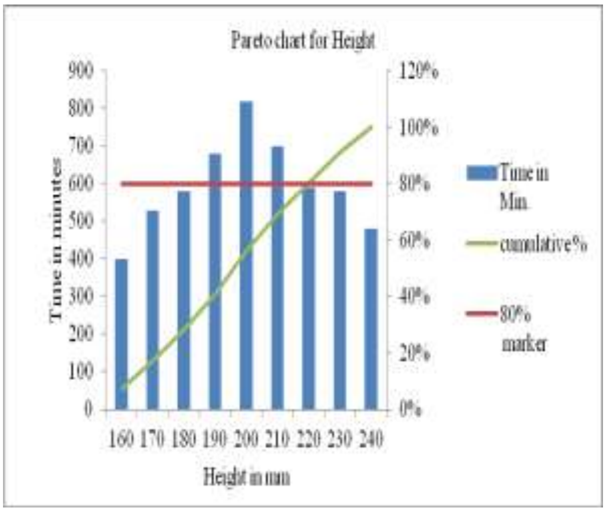


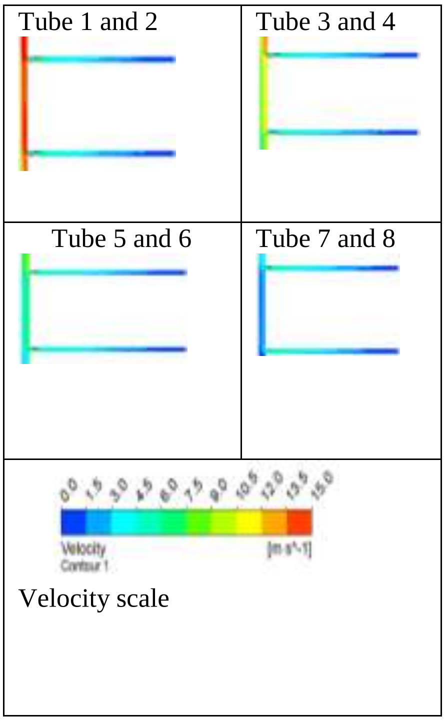
Chart 4-Pareto Chart for Height

v) Optimal Number of runners in dryer is in range of 7-8 each side
vi) Optimal Nozzle diameter ranges from 4-5 mm on each runner
vii) Optimal Number of nozzles on each runner ranges 28-30
viii) Optimal Height of runner /distance between runner and running strip from each side =190-210 mm.

IV. Numerical Simulation

1. Computational Fluid Dynamics (CFD) Simulation Approach: ANSYS Workbench v 17.1 was used for the simulations in the paper work. It contains multiple software modules such as Design Modeler, Mesher, FLUENT, CFX, CFD-Post etc. For geometry preparation Design modular is used, for meshing Mesher, for simulation Fluent and for post processing CFD-Post is used. The optimized pipe network had a total of 240 nozzles and for each of these nozzles the values were exported from the pipe simulation

2. Results and Discussions: The first phase of the work involved in identifying the optimal number of runner tubes to distribute the hot air to the drying room. In order to have homogeneous drying process across the metal strip surfaces, the hot air must be supplied uniformly. This was verified using the CFD simulations for three different runner tube configurations. When there were 6 runner tubes, the hot air flow distribution was highly non-uniform with the initial tubes received major hot air flow. Such a design would result non-homogenous drying process. However, a near uniform distribution of hot air was observed for the 8 Runner Tube configurations. For the different Configuration, Runner tube 9 and 10 received 6.5% and 6.0% of hot air flow while the Runner tube-1 had a flow rate of 13%. So, the difference in hot air flow rate between these runners tubes were nearly 200%. As discussed earlier, such a design would lead to un-even drying process for the Mild Steel (MS) metal strip in the Passivation Galvanizing process; it is observed that the Runner Tube 1 and 2 for the Configuration A received 57.6% of total hot air flow rate. This was highly non-homogeneous.Based on these data that were obtained from the CFD simulations, Configurations was chosen as the optimal design as the hot air distribution was found to be nearly uniform and would lead to homogeneous drying process of the metal strips. In order to further understand the fluid flow mechanism inside the runner tubes, the velocity contour plots at the mid-section of the runner tube were plotted. While analyzing the data for the configuration Nozzle diameter of 4,5,6 mm, the initial runner tubes (runner tubes 1 and 2 received 36.6% of total mass flow rate) had high hot air distribution as compared to the last stages of the runner tubes.When the numbers of nozzle were kept as 30, a uniform distribution of hot air across the runner tubes was observed. Nearly 34% of mass flow rate on Configuration (25 Nozzles) were distributed from the Tubes 1 and 2 whereas Tubes 7 and 8 had received 7.6% and 7.8% of the total hot air mass flow. This would, expectedly, result in better drying process near the Tubes 1 and 2 while incomplete drying process for the zones corresponding to Tubes 7 and 8. When the drying room was 200 mm in height, the fluid flow velocity near the metal strip was in the range of 0.3 to 0.5 m/s for most of regions. However, low velocities were observed in some parts of the metal strips also. However, as the drying room height was increased further (220 mm and 240 mm), the flow velocity in almost every part of the metal strip was less 0.01 m/s (near stagnant velocity).



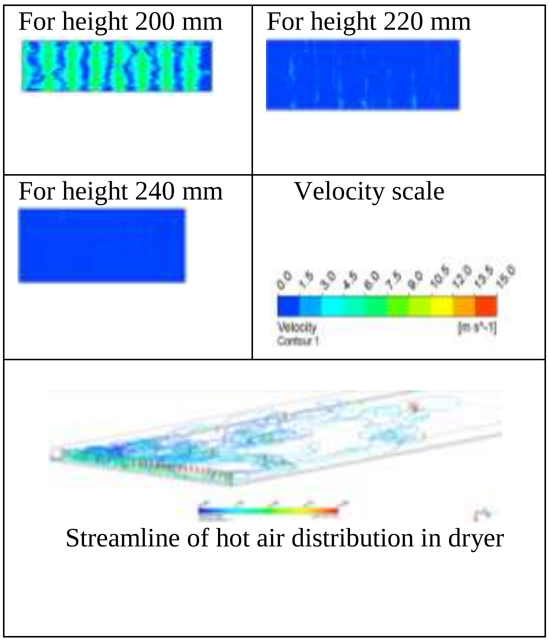


Fig.2 (a)-velocity counter plot for tube

Fig.2 (b)-velocity counter plot for dryer

From fig.2 (a) hot air velocity at tube 1and 2 is higher from this velocity of hot air is goes on decreasing up to 8.From velocity scale we can easily understand the high velocity region and low velocity region just by matching color. From fig.2 (b) when distance is 200 mm the temperature distribution on surface is uniform and as height goes on increasing non uniform distribution on hot air on surface. Also streamline of hot air in dryer.

V. Conclusion

From experimental and CFD Analysis following conclusions have been drawn,Optimal numbers of runner are 8, Optimal nozzle diameter is 4 mm, Optimal numbers of nozzles are 30,Optimal distance between runner and running strip each side is 200 mm.

i) Results show that, hot air distribution through each runner is varies from 14-10.8 % of total hot air, when numbers of runner are 8 distributions of decreases from runner 1 to runner 8 respectively. Flow in runner 1 is 32% of total and for runner 6 is 7.2%. When numbers of runner are 10 distributions of decreases from runner 1 to runner 8 respectively.

ii) When the drying room was 200 mm in height, the fluid flow velocity near the metal strip was in the range of 0.3 to 0.5 m/s for most of regions However, low velocities were observed in some parts of the metal strips also. However, as the drying room height was increased further (220 mm and 240 mm), the flow velocity in almost every part of the metal strip was less 0.01 m/s.

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