EFFECT OF STEEL COMPOSITION ON ZINC COATING AND POT FAILURE

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Zinc Coating on Steel Tubes

The main topics of this paper are the study of major factors affecting the growth of the zinc coating on steel tubes in a semi-automatic galvanising plant. By knowing & controlling these factors it is possible to maintain the zinc coating well under control as far as possible. Before discussing he factors affecting zinc coating in details I would like to discuss the structure of zinc coating in short.

When the steel is immersed in molten zinc bath the following activities take place :

i) Dissolution of solid iron into molten zinc
ii) Reaction between zinc and iron to form alloy
iii) Subsequent development of alloy layers by diffusion of iron & zinc.
iv) Formation of a coating of pure zinc on the top of the various alloy layers.
v) Cooling down and crystallization of the pure zinc layer.

Therefore, the combination of various alloy layers and the pure zinc layer forms zinc coating. The typical structure of Fe-Zn alloy layers are given below :

Phase		% Fe	
Eta layer	( ) Zn	0.02	Termed as pure zinc layer
Zeta layer	( ) $FeZn_{13}$	5.8 to 6.2	
Delta layer	(S) $FeZn_7$	7.0 to 8.0	Alloy layers
Gama layer	( ) $FeZn_{21}$	21 to 28	

Basically galvanising coating can be termed as (a) Grey coating (b) normal coating & (c) spangled coating. Grey coatings are composed of almost entirely alloy layers i.e. with nominal eta layer. Spangled coatings on the other hand have prominent eta layer and spangles are infect crystals of zinc. Layer spangles are obtainable with slower coating rate, high content of zinc and some other additives. Spangle coating however, do not give any more or less corrosion resistance.

Flaking of zinc coating is caused by prominence of zeta and delta layers because these are brittle in nature. To suppress these layers, galvanising operational parameters should be controlled. Suppression of these layers will also reduce the total zinc coating. The major factors which determine the thickness and structure of the zinc-iron alloy layer and the speed with which iron is attacked by zinc during the reaction in hot dip galvanising are :

- i) Temperature of molten zinc bath
- ii) Immersion time or dipping time
- iii) Withdrawal speed
- iv) Angle of withdrawal
- v) Air die pressure
- vi) Steam pressure and duration of steam blowing
- vii) Surface condition of the steel
- viii) Cooling rate (quenching)
- ix) Type of pre-treatment
- x) Quality of zinc
- xi) Chemical composition of steel

Almost all the parameters can be adjusted as per the requirement except the last two i.e. quality of zinc and chemical composition of steel where normally a galvaniser does not have much control. But yet in some cases if the galvanisers have prior information regarding chemical composition of steel, they can adjust their operation parameters accordingly.

Temperature of zinc bath at which reaction occurs play an important role in deciding the growth of iron zinc alloy. But with the present developments and widespread use of electronics in temperature controlling devices for galvanising furnaces, it is reasonably easy to set the zinc bath temperature as per the requirement and maintain it within a close tolerance.

When the dipping time is prolonged the monoclinic crystals of the zeta layer form and grow rapidly. This constantly allow molten zinc to penetrate into the interstices between the crystals and react further with the iron forming new crystal which again grow very rapidly. Iron diffusion into the zinc is also dramatically increased as a consequence.

In the semiautomatic galvanising plant there is no way to control the sequence of the pipes through the zinc bath. In most of the cases it is left to the ability of the man on job. But if it is feasible in principle with large diameter pipes, it becomes almost impossible with the small sizes.

The time, during which the pipe is dipped in the molten zinc, is directly influenced by the withdrawal speed which is limited by the drainage capability of the molten zinc on the withdrawing tube. Thus the difference in the dipping time from the two opposite ends of the pipe affects the zinc coating and its quality. The semi-automatic or batch type system relies on natural drainage of zinc depending on temperature, withdrawal angle and speed. However, the withdrawal speed is normally much higher than with natural drainage of zinc. Although all the pipes are made to pass through 'air dies' and where by means of compressed air the excess zinc on the pipes is removed. By controlling the air pressure it is possible to achieve a good result at this stage.

The inside removal of excess zinc carried out by using steam (saturated or super heated) or compressed air. Keeping in mind the structure of the zinc coating and its physical characteristics, it must be noted that, at the normal galvanising temperature, all the intermetallic iron-zinc alloys are solid. Thus the mechanical cleaning effect of compressed air or steam is limited to the outer part of the coating i.e. the eta layer (pure zinc layer, still liquid at that temperature). We observe that there is no difference in coating on the outside surface of the pipe while on the inside surface we have some difference caused by time elapsing from the moment the head of the pipe is lifted from the zinc to the moment when pipe reaches to the steam blowing station and steam blown. The time difference and the difference in temperature are thus the reasons for different coating structure from head to tail of the pipe which results in a difference in thickness of the inside coating.

Knowing the physical parameters involved and having the flexibility to adjust them as per the requirement it is possible to comply with values stated by various specifications, limiting unnecessary zinc consumption and ensuring more efficient quality control of the final product.

This, of course, is not an easy task but it becomes possible to a great extent when one knows the reaction occurring between iron and zinc inside the galvanising bath. The effect played by alloying elements present in the iron as well as in the zinc bath determines the control of actual galvanising parameters governing the reaction and the coating growth such as temperature and dipping time.

The influence of elements present in the steel such as silicon and phosphorus is very well known and rate of its reaction with dipping time and bath temperature are widely investigated. It appears from most of the specific literature and from our direct plant experience that he slight increase in silicon content of steel can cause problems in galvanising due to the formation of heavy, grey and brittle coatings. There has been some concern expressed by general galvanisers on the effects of steel covering the typical range of silicon contents.

Generally, the results of the galvanising trials confirm that no problems are encountered with steels containing silicon levels of less than 0.03%. But even with very low levels of silicon in the range from 0.05 to 0.12% approximately, which is considered the most critical, at the ordinary galvanising temperature around 450°C causes problems in controlling the zinc coating.

Silicon contents at levels 0.05% to 0.12% and above 0.25% can cause problems in galvanising due to very heavy coating if bath temperature is around 450°C and the dipping time is more. For example, the experiment shows :

Silicon content of steel	Bath Temperature	Dipping Time	Coating Thickness
0.05%	455°C	5 minutes	100 m 675 gms/m^2
		10 minutes	120 m 809 gms/m^2
0.08%	"	5 minutes	200 m 1348 gms/m^2
		10 minutes	300 m 2022 gms/m^2
0.22%	"	5 minutes	150 m 1011gms/m^2 (but has more of alloy layer compared with 0.05% Si steel)

Therefore, for galvanising steel with silicon content less than 0.04% should be specified. However, in case where steel compositions are known and galvanises are forewarned, measures can be taken to minimise the effects of unfavourable silicon levels.

Introduction :

It is well known that a galvanising pot is the most important production unit in any galvanising plant. Premature failure of a pot is actually a nightmare for the industry, as it calls for unscheduled change and adversely affect the cost of production. It is therefore, all the more necessary to find out the root cause for such failures.

Possible Reasons :

Given below are some important factors that contribute towards poor pot life :

a) Improper selection of steel
b) Improper selection of welding rods
c) Method of heating
d) Failure of the instrumentation system
e) Design aspects with respect to output
f) Stress relieving
g) Poor dossing operation
a) Improper Selection of Steel :

<u>a) Improper selection of steel</u>

Much literature has been published on the effect of metal composition on the pot life. Low carbon steel below 0.10% is conducive to long life. A carbon level of 0.20% brings down the pot life to half.

Armco steel is the most widely worthwhile choice in construction of a galvanising pot. The typical composition f Armco steel is

C	:	0.03% (max.)
Mn	:	0.30% (max.)
S	:	0.03% (max.)
P	:	0.01% (max.)
Si	:	traces

Since availability of Armco steel in India is little difficult, there are other grades of similar composition are manufactured for pot construction such as Tata 'A' Grade with steel composition of

C	:	0.050% (max.)
Mn	:	0.200% (max.)
S	:	0.015% (max.)
P	:	0.025% (max.)
Si	:	traces

or Fire box quality steel the composition of steel is

C	:	0.08% (max.)
Mn	:	0.30% (max.)
S	:	0.03% (max.)
P	:	0.01% (max.)
Si	:	0.01% (max.)

Under normal course it is common to use 50 mm or 40 mm thick plates, however, the thickness of plates can be calculated from the heat balance.

Summarising it can be said that lower the impurities in steel, the longer will be the pot life. It is this aspect that renders the steel not only difficult to make but also expensive. For this consideration, many have drawn a safe material specification.

b) Improper Selection of Welding Rods :

A pot may fail from the weld joint if improper welding rods are used. Like parent steel the composition of weld rods is equally important from zinc melt steel dissolution point of view. The most common brands are Cetofine electrodes, D&H Sechron A5-S and vorbic electrodes.

The typical chemical composition of the steel used for manufacture of these electrodes is

C	:	0.07%
Mn	:	0.16 to 0.33%
S	:	-
P	:	-

Si : 0.025 to 0.049%

In addition, it is necessary that welding be carried out paying close attention to welding technique keeping in mind basic preparation and root penetration. The weld joints may be finally examined through non destructive testing techniques such as ultrasonics or X-ray examinations. It is customary to ask for test certificate and radiographs of weld, chemical compositions, stress relieving and mechanical tests etc. from the manufacturers.

c) Method of Heating

There are various methods discussed in literature such as induction method, top firing and normal gas/oil firing etc. In India firing with either gas or oil or both, is more common depending upon the availability of gas or oil. Gas is preferred if available. What is more important is method of heating. It is desired to have a uniform heating so that furnace temperature is uniformly distributed. It will not be out of place to mention here that we at Tata Steel are struggling to augment the pot life. It may be mentioned here that root cause is faulty design in heating the pot which is illustrated in Fig.1. Out of three galvanising baths, at bath No.-1, the heating system has been modernised using flat flame burners. Today, as a result the pot life has been enhanced and there is reduction in heat rate.

Today, pulse firing system with high velocity gas burners is becoming more common in foreign countries where the pot life is about four years or two lakh tonnes of galvanising output.

d) Failure of Instrumentation System :

Failure of instrumentation might lead to disaster. Inaccurate temperature particularly at high temperature in the region 480 - 515°C can play havoc. It is always advisable to have at least two thermocouples for the bath melt temperature measurement so that if one thermocouple by any chance goes out of order, the second can be used.

e) Design Aspects with Respect to Output :

The pot dimension should be carefully chosen. As a thumb rule the quantity of molten zinc should be about twenty times the desired output per hour. In addition depth/width ratio is important more so far manufacturing pot for tubes galvanising with minimum number of weld joints. At times, stiffeners are provided to prevent pot bulging.

f) Stress Relieving :

It is important to avoid the residual stress in the material by stress relieving and the most common temperature for stress relieving is 630 - 650°C.

g) Drossing Operation :

It is essential to ensure thorough dossing (removal of dross) from the bath particularly such that its accumulation does not take place. Since dross is a poor conductor of heat, it causes over heating/localised heating of the pot which must be avoided to have considerably a good pot life.

Conclusions :

Pot life is very closely related to the chemistry of the plates used for fabrication. Best results are obtained with very low carbon steels, containing very low silicon. The quality of weld and weld metal play an important role in dictating pot life. Operating conditions influence the pot life significantly, over heating, localised heating and severely fluctuating temperatures lead to poor life of pot.

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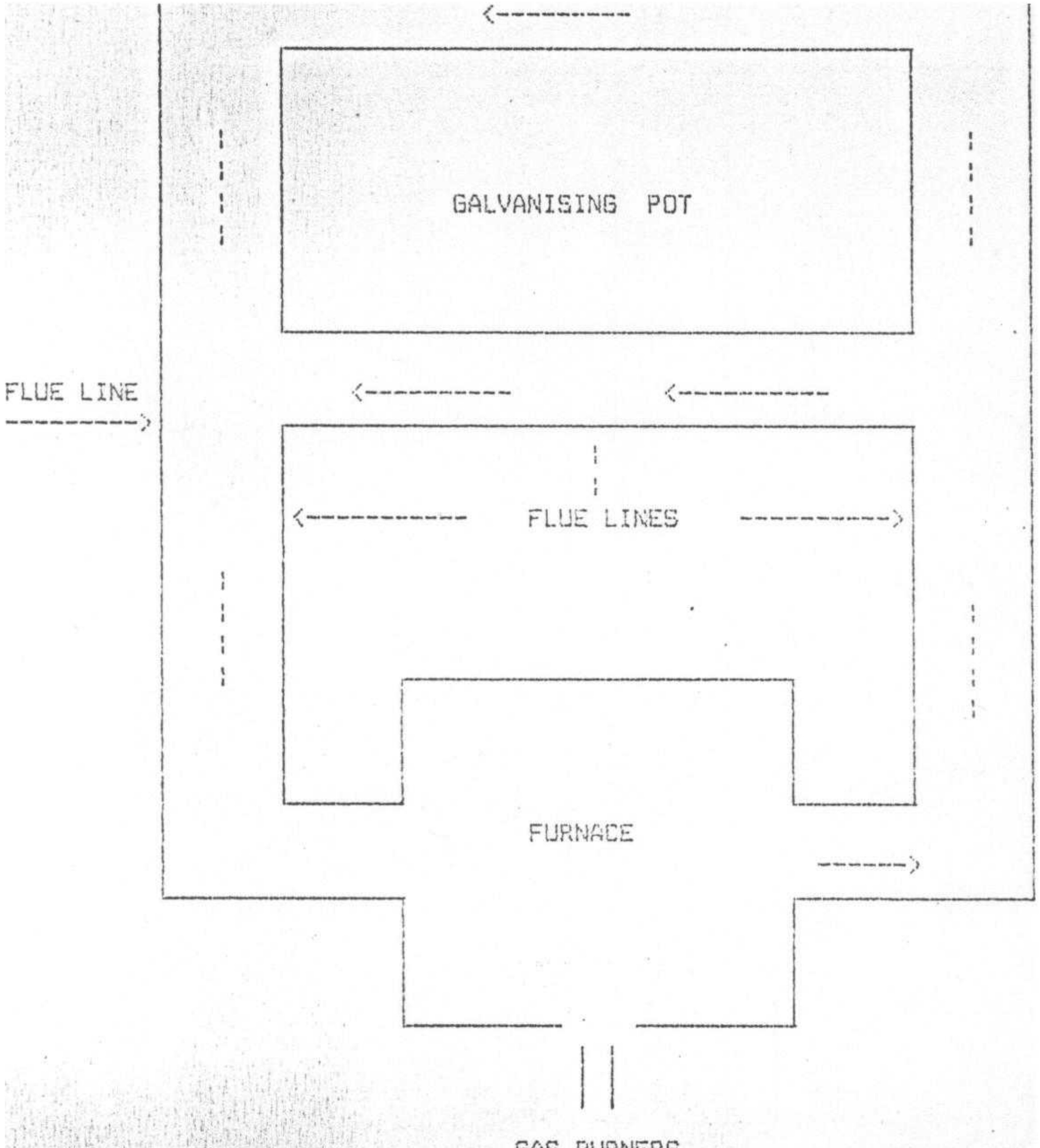

LINE DIAGRAM OF HEATING SYSTEM FOR BATH NO.- 2 & 3

(FIG.- 1)