The Delot Process –
A New Technology for Steel Wire Galvanizing
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Introduction
The Delot Process developed by the French firm Delot Process S.A. is a revolutionary high-performance wire, rod and bar galvanising system. At the heart of the process, magnetohydrodynamics (MHD) forces are use to pump, contain and control thickness of molten zinc or zinc alloys. MHD is the science which combines fluid mechanic and electromagnetic field behaviours to control an electrically conductive metal such as molten zinc.

This article will reveal how MHD devices are combined with effective steel cleaning, efficient steel heating, inert gas shielding and rapid quenching to produce superior zinc and Galfan® coatings on steel wire, rod and bar. The five main stages of the process:

- Surface preparation;
- Steel heating;
- Zinc or alloy application;
- Steel and coating cooling;
- Steel transport

are discussed in detail.

The superior quality of the zinc or alloy coatings produced by the Delot Process will be demonstrated with physical tests results.

The technical advantages of the Delot Process are enumerated including:

- Controlled thickness;
- Small quantity of molten zinc or alloy;
- No acid required for surface preparation;
- Elimination of dross;
- Entire process is computer controlled and documented;
- It is suitable for Galfan® alloy and many more.

The data presented and claims made for the Delot Process are based on five years of development work on long product galvanising by Delot Process S.A. and on specific production and trial runs at the Delot plant in France, during 1993, 1994 and 1995.

The Process
The Delot Process for wire, rod and bar is a continuous process and consists of five primary steps as illustrated in Figure 1.

A) Raw Material
The Delot wire, rod and bar coating system can receive the long products on spools, in coils, or in the case of bars, in straight lengths. Accumulation may be desired for joining lengths by welding, but the Delot system can be easily stopped and restarted without waste if that method of coil exchange is preferred.

The process should receive wire or rod which is free of contaminants such as oil, carbonaceous smut, residual drawing lubricant and moisture. Mill scale and other oxides are acceptable. Residual drawing lubricants may be removed with popular hot water cleaning systems, provided the steel is dry when it enters the steel preparation stage.

The input product temperature should not exceed 150°C and, in higher than room temperature cases, an additional radiation thermometer may be added to the heat control circuit.

Processing speeds may be controlled from 15 to 150m/min for product diameters from 2 to 12mm, and coating thickness from 8 to 10 microns.

B) Steel Preparation and Heating
The Delot Process employs the widely used rotoblast wheel method of shot blasting to clean and profile the wire surface. The shot blaster consists of three rotoblast wheels arranged at 120° angles around the horizontal wire centerline. Concentrator plates are used to focus the blast pattern on the wire surface for greater efficiency. An abrasive cleaning, recycling and replenishing network maintain uniform shot characteristics and provide machine ventilation and dust control.

The blast cleaned wire exits the 3M long cabinet through an air ring which blows any residual metal fines back into the vestibule.

The wire now enters a low pressure inert gas shield (nitrogen) which is maintained through the rest of the process up to quenching. Also, the wire passes through laser micrometer No. 1 and the diameter is transmitted to the process controller.

At this point in the process, the large or small wires may continue on a horizontal path, or the small wires and rod may be directed to a vertical – up path. The choice will be discussed further in the coating section. In either case, the wire will enter induction heating coils of 1 to 2 M in length. Here the power from a 60 KW power supply will efficiently raise the wire to zinc application temperature (450°C) or higher.

C) The Zinc Coating Unit
Upon leaving the induction heating coils the hot wire, still shielded in nitrogen, passes a radiation thermometer for non-contact verification of correct temperature. The hot wire now enters the Zinc Coating Unit. See Figure 2.

This coating unit consists of a crucible and a reactor.

![Figure 1: Process diagram](image-url)
Molten zinc is supplied to the reactor via a recirculating loop from and back to the crucible. The crucible is housed in a nitrogen blanketed electric furnace and contains only one metric ton of zinc. Melting of ingots occurs in the crucible and is controlled to achieve a constant melt level and temperature. The entire network of crucible, recirculation loop and reactor is externally temperature operating. Melting of ingots occurs in the crucible and is controlled to achieve requirements. The pump cannot leak and has no moving pump whose internal geometry minimises fluid disturbances yet controlled to assure uniform temperature, even if the system is not operating.

In addition, all molten zinc or zinc alloy wetted surfaces are constructed of specially engineered ceramic materials, to prevent corrosion. This feature also allows the use of Galfan® the Zinc-Al. alloy.

Zinc is pumped from the crucible to the reactor by a sealed MHD pump whose internal geometry minimises fluid disturbances yet consumes less power than previous electromagnetic pumps. Precise adjustment of the pump field current controls the zinc flow rate to match wire size, desired coating weight, line speed and return flow requirements. The pump cannot leak and has no moving parts to wear out.

The reactor is a cylindrical containment of about one liter in volume and sealed at both ends by MHD pumps which permit entry and exit of the passing wire, but contain the molten zinc.

The entry pump exerts force in the direction of wire travel to prevent any zinc leakage.

Within the reactor, the iron zinc alloy forms on the wire surface and pure zinc wets the alloy layer.

Wire exposure time in the reactor is adjustable from 0.1 to 0.4 seconds, depending on line speed and MHD pump separation selected.

Further the exit pump force, opposite the direction of wire travel, is regulated to control the coating thickness on the exiting wire. Thickness of coating can be controlled from 8 to 100 microns by precise regulation of the exit pump field current.

D) Rapid Quench

The exit of the Delot reactor is nitrogen covered to prevent oxidation as the wire passes into the rapid quench stage. In the case of the horizontal reactor, a classic water flooded trough of controlled temperature is used to freeze the coating.

In the case of the vertical reactor, a specially engineered water quench system:
- quickly freezes the coating in only 1.3 seconds;
- does not distort the molten zinc or
- allow coolant leakage into the reactor below and
- reacts to emergency stops without damaging the product or equipment.

E) Thickness Control

Immediately following quench, the wire passes through laser micrometer No. 2 which sends the two plane coated wire diameter measurements to the process controller. With diameter measurements before and after coating, zinc thickness is compared and computed to the desired value. A PID function control then makes adjustments, if required, to the exit pump on the Delot reactor.

F) Horizontal or Vertical Reactor

When considering the orientation of a Delot reactor, several factors will influence the decision:
- the ratio of coating thickness to product diameter;
- the allowable tolerance for coating eccentricity;
- and the combination of product diameter and tensile strength as they influence difficulty in redirecting the wire around transport sheaves.

In general, large diameters (7.0 to 12mm) with coatings of 8 to 25 microns are best for the horizontal reactor and small diameters (2.0 to 6.0mm) with coatings of 25 to 50 microns are best for the vertical reactor. The vertical reactor is not sensitive to the effects of gravity in so far as eccentric coating is concerned.

G) Final Quench, Wire Transport and Take-Up

At this stage, the vertical wire is redirected to a horizontal plane, receives a final quench and passes on to a take-up.

H) Process Control

The entire Delot Process is managed by a Supervisory Control and Data Acquisition (SCADA) system adapted to a hot zinc process. The SCADA system facilitates ISO certification, insures optimum product quality and best utilisation of process energy and materials.

Superior Coatings

Tests conducted on wire and rod zinc coated by the Delot Process reveal superiority to classical hot dip galvanising in several aspects:

- In the Delot zinc coating unit, the molten zinc is in contact with the hot steel for only 0.1 to 0.4 seconds before it is quenched. This compares to 6 to 10 seconds, time at molten zinc temperature, for wires galvanised in a classical hot dip kettle system.

- One result of the significantly shorter exposure time is a very thin Fe-Zn intermetallic layer (3 to 6 microns) compared to classic hot dip methods (12 to 18 microns) for an equivalent coating thickness of 35 microns. Because Fe-Zn alloy is brittle and prone to crack when the product is bent, a thin Fe-Zn layer is preferred. Unlike classical methods, the Delot Process produces a thin Fe-Zn layer even with thick coatings.

- In the case of the classical hot dip galvanising, cracks and embrittlement of the coating frequently appear after bending of the products. The existence of a much too thick proportion of
Numerous tests have been conducted on Delot Process coated rod same as electroplated zinc, even at class C levels exceeding 500g/m².

In terms of coating homogeneity, the capability (Cp) of a process is defined as:

\[
C_p = \frac{c_{\text{max}} - c_{\text{min}}}{6 \sigma}
\]

where:
- \(c_{\text{max}}\) = maximum thickness
- \(c_{\text{min}}\) = minimum thickness
- \(\sigma\) = standard deviation of the measured thickness distribution.

For the Delot Process, the homogeneity is very good. It varies slightly with the thickness.

\[C_p = 1\] for thickness up to 25 microns (180g/m²)
\[C_p = 0.9\] for thickness of the order of 50 microns (360g/m²)

**Drawability**

Numerous tests have been conducted on Delot Process coated rod and process wire to determine the behaviour of zinc coatings when drawn after galvanising. The results have been uniformly satisfactory and can be illustrated by the following example:

A 7 mm (0.275 inch) diameter high carbon steel rod, tensile strength of 1,200N/mm² (174,000psi), was Delot galvanised with 205g/m² (0.67oz/in²) weight of coating. The coated rod was then drawn six drafts to 2.74mm (0.108 inch), for a total reduction of 85%. The finished wire tested 1824N/mm² (265,000psi), produced 39 revolutions on a 100D torsion test, and passed 12 bends on a 10mm mandrel. This performance surpasses extra improved plow requirements (Level 4) for rope wire and is equivalent to properties measured when the same rod is drawn uncoated.

The theoretical coating weight on a finished wire, given 205g/m² on the rod, is computed to be 80g/m². Actual weigh-strip-weigh results averaged 91g/m², indicating no loss of zinc during wire drawing. What’s more a IX Dia. wrap test on the finished wire exhibited no cracking or peeling of zinc.

**Corrosion Protection**

Of the several tests which have been performed to evaluate the corrosion resistance of Delot coated wire, the anodic dissolution test typifies the positive results. In this test, wire samples zinc coated by the classic hot dip method with 70 microns (500g/m²), and samples Delot processed with only 40 microns (280g/m²) are submerged in a 30 per cent aqueous solution of NaCl. Some samples were tested straight and others bent. All samples had 10cm² of surface submerged. At regular intervals, the voltage across each test cell was measured with a milli Volt meter and plotted. The Delot coated specimens, both bent and straight, maintain a low - 1.05mV/ECS corrosion potential. This is the known potential for pure zinc and it is maintained for forty hours. The classic hot dip samples, on the other hand, exhibit higher corrosion potential after only ten hours. Corrosion on the bent hot dip specimen proceeds even faster. This in spite of 75 per cent thicker zinc coating than the Delot specimens. The classic coatings present a strong danger of corrosion by local pitting.

**Summary of Advantages**

Superior quality and lower production costs, the Delot Process offers these improvements in many ways.

- Controlled thickness and uniformity of the zinc coating. Application is computer controlled.
- Continuous and fully automated production (stop, back-up and production start-up again within a short time).
- Process close to electroplating quality because of accurate thickness control and high coated product ductility.
- Metal coating under controlled atmosphere.
- Very little zinc or alloy required in melting furnace.
- Surface preparation by acids is eliminated.
- Elimination of chemical vapours and dissolved metals bath.
- Efficient induction heating of steel.
- No toxic waste to be treated.
- Higher coating quality (adhesion, forming, handling).
- Horizontal or vertical product orientation in the Delot applicator.

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