Continuous vertical galvanising for the hot-dip coating of steel strip

A continuous vertical galvanisng process has been developed and operated commercially. The pot size is only 10-15t which is electromagnetically sealed to prevent loss of molten zinc. Product quality and yield has improved compared with conventional galvanising lines.

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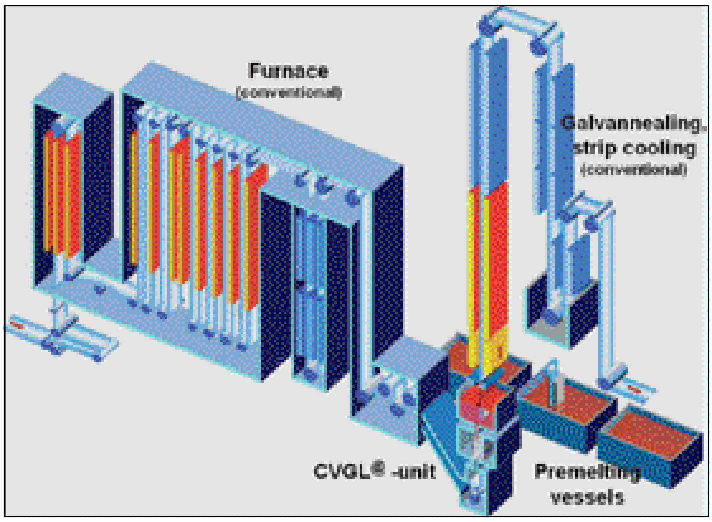


● **Figure 1** ***Basic design of a hot-dip galvanising line with CVGL***

The Strip Processing Lines Division of SMS Demag has exclusively developed an innovative vertical hot-dip coating process which offers significant advantages in terms of product quality, line capacity, investment cost and maintenance requirements. After a number of successful trials on pilot facilities, the continuous vertical galvanising line (CVGL®) technology was installed and successfully commissioned in the hot-strip galvanising line of Wuppermann in Judenburg, Austria in August 2002 and produced uniformly hot-dip galvanised strip over an extended period of time.

The concept

The special feature of the CVGL is that, after annealing, the steel strip is deflected into a vertical pass line already inside the furnace and then runs vertically up through a coating or working pot (see *Figure 1*). The pot contains 10–15t of liquid zinc or zinc/aluminium alloys and is sealed electromagnetically at its bottom. For product changes, unlike conventional hot-dip coating technology, which uses large melt volumes of up to 400t of zinc and shiftable pot systems, fresh melt with the desired chemical composition and temperature is pumped into the working pot out of one or more storage vessels (see *Figure 2*).

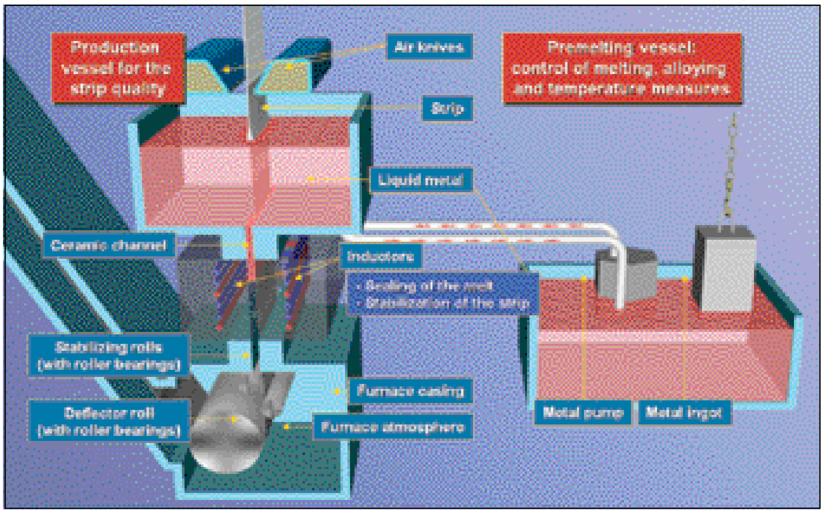
The process features are significantly different to conventional galvanising (see *Figure 3*). CVGL offers significant advantages in terms of product quality, line capacity, investment cost and required maintenance.

The main advantages of CVGL are:

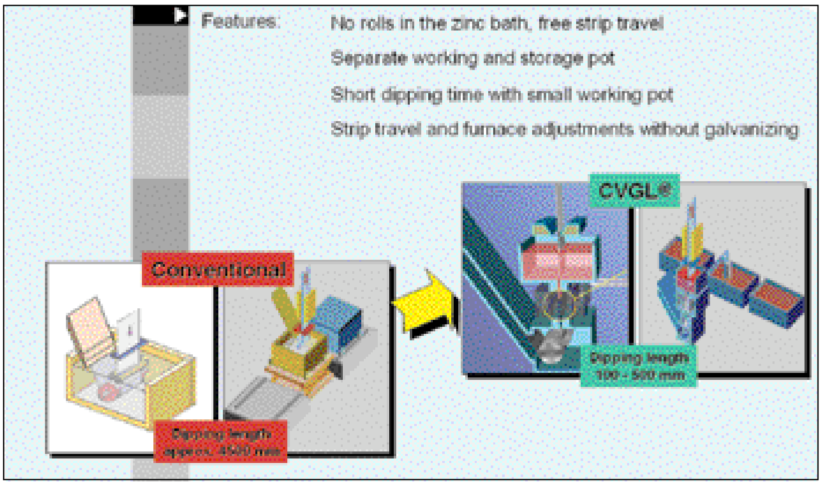
- Better strip quality and product properties
- Improved controllability of the zinc bath
- Quick and easy product change
- Good coating adhesion right from galvanising start
- No delamination of zinc during galvanising start
- High strip speed for thin strip and fewer line shutdowns
- Higher yield
- Quality impairments due to bottom dross or zinc dust in the furnace are precluded.

The process is such that the strip is not in contact with any rolls inside the melt, thus enabling higher line speeds than with conventional systems, and product changes can be made quickly and flexibly without lengthy line shutdowns. The dipping length is 100–500mm compared to 4,500mm conventionally and the dipping time is 0.2 seconds compared to 2.4 seconds. Furthermore, CVGL permits the significant galvanising parameters to be adjusted within a wider range so that thinner coatings can be achieved even at high strip speeds. In addition, because the dipping time in the zinc melt is much shorter than in the conventional process, a product improvement in terms of sheet weldability can be expected. Given the same Al-concentration in the zinc melt, CVGL will produce coatings with a markedly lower Al-content As a consequence the spot welding behaviour of hot-dip galvanised material can be improved.

As the working pot containing the liquid metal is open at the bottom for the strip to run through, to prevent the liquid metal flowing out through this channel-shaped opening, an electromagnetic force is applied from the outside to the channel in the area between the coating pot and furnace. This force counteracts the metallostatic pressure of the melt and thereby prevents leakage. Following an in-depth investigation of all potentially available sealing versions, a system involving one static magnetic field integrated into an electromagnetic moving field was devised. This is described below.



● **Figure 2** ***Schematic of the CVGL principle***



● **Figure 3** ***The features of CVGL technology***

Inductive sealing with integrated correction field for strip stabilisation

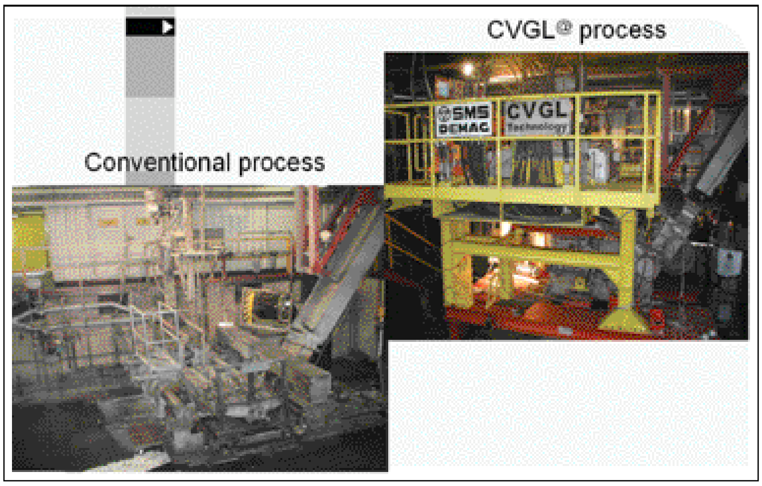
The coating vessel is sealed at its bottom by means of two moving-field inductors directly underneath and facing each other. They each consist of six coils which are energised with a frequency of 50Hz and 180° out-of-phase relative to each other. The coils of the moving-field inductor generate a magnetic field and the inductors lying opposite each other are wired up in such a way that a momentarily positive coil of one inductor faces a negative coil of the other. In this way, a magnetic field is generated which extends vertically in relation to the channel, because a north pole of one inductor always has a south pole of the other inductor opposite it (principle of quadrature-axis induction).

Eddy currents can be induced in all electrically conducting materials such as Al, Zn, Cu and steel. The buoyant force in the liquid zinc needed to seal the channel is produced by the eddy currents, which in turn result from the change of the magnetic flow over time. The buoyancy force results as the product of the induced eddy current and the magnetic field and counteracts the metallostatic pressure of the liquid zinc, thereby sealing off the galvanising channel of the CVGL unit.

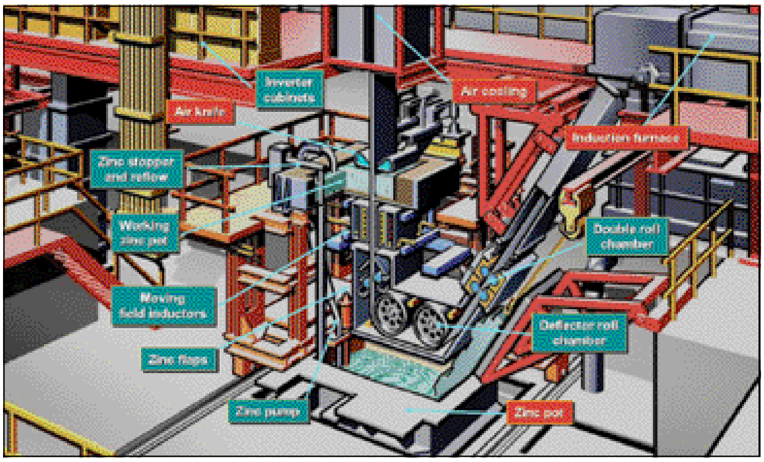
Unfortunately in the case of ferromagnetic materials such as steel strip the magnetic field directed vertically in relation to the strip produces additional attractive forces acting in the direction of the inductors. Consequently, the strip equilibrium is unstable in the channel centre, and the attractive forces acting on the strip are counterbalanced only when the strip is perfectly central. Therefore, adequate measures need to be taken to stabilise the strip within the moving-field inductors of the CVGL unit.

This is achieved by means of correcting coils which, based on the superposition principle, are superimposed on the sealing magnetic field in an in-phase manner relative to the main coil. The position of the strip is measured by means of air coils also integrated in the magnetic field. The local variations of the main field, as produced by the correcting coils impact the attractive forces between the inductors, are used in the form of a closed control loop for strip centring control.

This sealing of the coating vessel by means of an electromagnetic moving field is a unique solution requiring particular attention and development effort, including extensive finite element modelling simulations. The correcting coils, through sophisticated control, are able to ensure a stable and contactless passage of the steel strip through the ceramic sealing channel.



● Figure 4 *The project at Wuppermann in Austria*



● Figure 5 *The CVGL unit at Wuppermann*

The project

On October 2002, a cooperation agreement covering the development of the above-mentioned technology was signed between SMS Demag AG and Wuppermann, a producer of hot-dip galvanised sheets. To this end, Wuppermann made available a hot-dip galvanising line which had been operating since 1990 to produce hot strip up to 375mm wide with a maximum line speed of 130m/min. Into this line SMS Demag integrated a prototype CVGL. The project had a project cost of approximately €2 million (see *Figure 4*).

The project, comprising engineering, design and rating, preliminary trials, preassembly, installation and commissioning was completed in just over 10 months. Installation and commissioning of the CVGL, including all measures to adapt the existing mill, took two weeks. Within the periods of time agreed with Wuppermann for operating trials, the CVGL unit can be installed in about eight hours and operated in the hot-dip galvanising line then dismantled in about four hours (see *Figures 5* & *6*). While the facility was in operation, extensive test programmes were conducted.

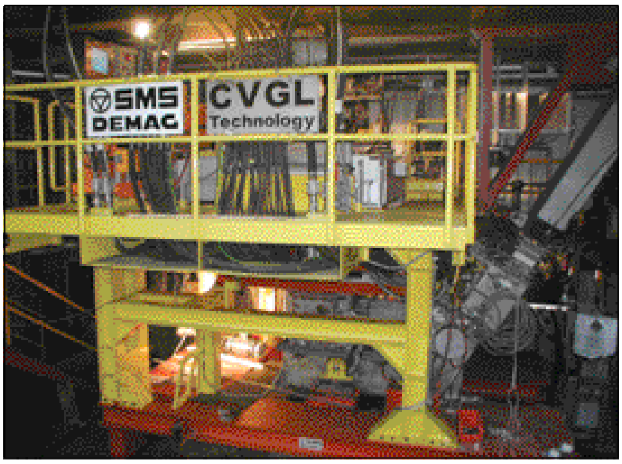
Commissioning and first operating results

On 14 August 2002, the facility was put on stream for the first operating tests which were successful (see *Figures 7* & *8*). All electrical functions and controls, the entire mechanical equipment and the process technology components of the line were tested and the inductive sealing system and the strip stabilising system were successfully commissioned. Line components and processes in need of optimisation were modified in the mill or after the initial operation.

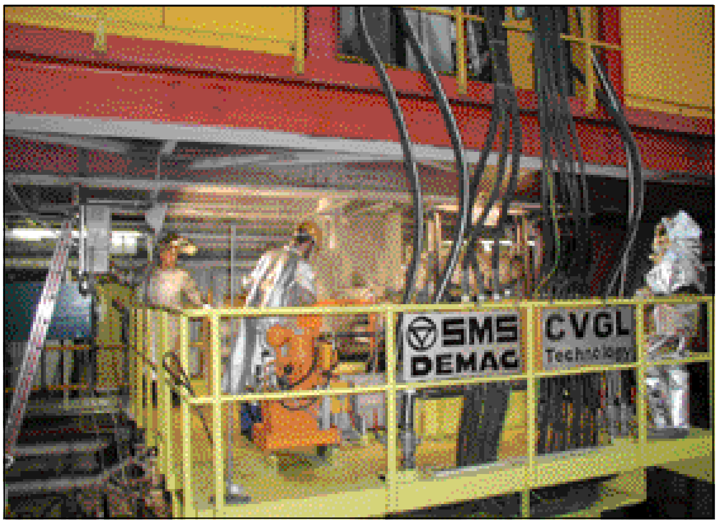
On 5 December 2002, another operating test was conducted during which a stable operating process was achieved and the hot-dip galvanised steel strip produced was then successfully further processed into special sections, one of Wuppermann's products. Further campaigns followed in April, May and July 2003, and in July a stable operation for one shift at maximum line speed and capacity was achieved. Significant operating experiences and user know-how was collected which will serve to implement CVGL technology in large-scale hot-dip galvanising lines for wide strip.

The most important results of the production tests are:

- The innovative CVGL technology was successfully commissioned
- A continuous and trouble free operating process at maximum line speed and capacity was achieved
- The movements of the zinc melt in the galvanising pot were minor and uncritical
- The moving-field inductor prevents liquid zinc from flowing through the ceramic channel



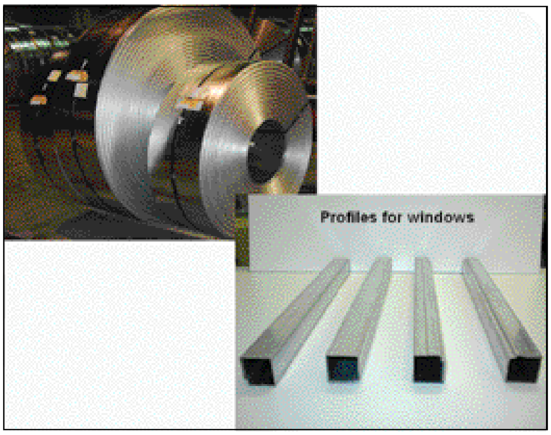
● Figure 6 *Components of the CVGL unit*



● Figure 7 ***Start of the galvanising process***

● Figure 8 ***H o t-dip galvanising with CVGL***

- Strip travel is stable and the strip can be positioned as desired
- There were no scratches or dents visible on the strip
- Strip could be coated with pure zinc immediately after commencement of the process and adhesion was good
- The structure of the zinc coating is comparable to that from a conventional hot-dip process
- Aluminium content in the zinc coating is lower than conventionally galvanised strip
- The amount and type of top dross were comparable to conventional processing using air to set the coating thickness
- The adhesion and the quality of the zinc coat on the hot strip were such that the material could be processed into special sections without any problems, (see *Figure 9*)



● Figure 9 ***Galvanised coils and processed material from CVGL***

Conclusions and future proceedings

The production tests with the CVGL technology on Wuppermann's narrow strip production facility were successful. The results show the potential that this innovative process has in terms of quality and cost efficiency. Thanks to the friendly assistance from Wuppermann, a reputed steelmaker was able to get a positive impression of CVGL technology locally, and this has resulted in a project for the installation of CVGL in an existing hot-dip galvanising facility.

It can hence be expected that the first large-scale implementation (1,350–2,050mm strip width) will set totally new standards in the field of hot-dip galvanising.

CVGL® is a registered trademark of SMS Demag

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