THE DEMCO SYSTEM
Non-contact electromagnetic strip stabilisation for strip galvanising lines
Figure 1. The DEMCO system in operation at the Wuppermann-CGL.
A large quantity of zinc is used in conventional strip galvanising lines. Since the coating process is subject to fluctuation, for example strip movements, additional zinc has to be applied so as to ensure the minimum required coating at all points. Once the strip has been stabilised, the quantity of zinc to be applied can be adjusted more precisely. The quantity of zinc thus saved enables a more economical production of high-quality galvanised steel strip. In addition, the line speed can be increased because of the stable strip travel. Surface defects are also reduced as a result of the contact between strip and air knife.

Together with Fontaine Engineering (FOEN) and SMS Elotherm, SMS Siemag has developed the DEMCO system of electromagnetic strip stabilisation for strip galvanising lines with FOEN air knives (DEMCO – Dynamic Electro Magnetic Coating Optimizer). By means of inductive measurement, the system controls several magnetic forces in such a way that undesired movements or forms of the strip can be levelled simultaneously. This occurs in a non-contact manner in the area above the FOEN air knives which adjust the zinc coating. Since April 2007, the first strip stabilisation system has been successfully in operation in the annealing and galvanising line at HYSCO in Korea. A second system has meanwhile been tested during production at Wuppermann in the Netherlands, Figure 1. Orders have already been placed by MMK and TKS for further plants.

The following first shows the conventional procedure used for hot-dip galvanising with special consideration of the air-knife system. This will be followed by a detailed description of the functioning of the DEMCO system, including that of its individual components as well as the process-related and economical effects. The report will also provide a summary of the operating experience so far of Hysco and Wuppermann and present a final conclusion.
STRIP GALVANISING LINES

Galvanised steel strip
Galvanised steel is a composite material which combines the excellent properties of zinc, such as resistance to oxidation and its high-quality appearance, with the strength of steel. Owing to these properties, galvanised steels are used in many applications in order to meet the high material requirements, for example, in the automotive industry, the building industry, plant construction and the household goods industry.

Of the 220 million tons of cold strip produced worldwide in 2008, 113 million tons were hot-dip galvanised (Source CRU). Even in future it can be assumed that more than half of the total cold strip produced is hot-dip galvanised. A big advantage of galvanised steel is its extremely lasting resistance to corrosion, as a result of which there is frequently no need for maintenance.

Conventional strip galvanising lines
In conventional hot-dip galvanising lines, the annealed steel strip is dipped into a zinc bath (bath temperature approx. 460°C). When coming out of the zinc bath, the strip entrains some metal depending on its speed and surface structure. Since this quantity of metal considerably exceeds the required coating thickness, knives at the front and rear end wipe off a part of the excessive zinc by means of a fine but strong air or nitrogen jet. In addition to the coating thickness, the knives also ensure that the zinc is evenly applied on the strip. The steel strip coated on both sides by liquid zinc is then conducted upwards vertically after the wipe-off process, Figure 2.

However, due to the strip movements and deviations from the ideal strip form, more zinc than necessary has to be left on the strip so that the required coating can be attained on an average along the entire cross-section and length. The examination of the coating thickness is regulated by a standard (e.g. DIN EN 10327). At certain positions, three areas are taken from the strip and the coating thickness is determined by chemically dissolving the coat. Every individual surface must have a specific minimum coating thickness and the arithmetic mean of the three test results must at least correspond to the coating characteristic value.

For a desired strip coating of 100 g/m², for example, approx. 103 to 110 g/m² must be left on the strip so that the required minimum coatings are met at all points in case of turbulent strip travel. For continuous checks at the manufacturer’s, non-destructive testing methods are normally used. In case of arbitration, the procedure which describes the standard applicable to the relevant material should be used.

Air knives
The air-knife system controls the coating thickness after the strip has left the molten-metal bath. Knives arranged on both sides with an extremely fine opening blow air or nitrogen at a certain pressure onto the strip and thus systematically wipe off the superfluous zinc. The coating thickness is obtained in this manner.
depending on the pressure and distance from the strip. The FOEN air-knife system is outfitted with control systems which are directed centrally onto the strip travel in order to guarantee uniform wiping as far as possible. The system is also equipped with a "skewed position" movement function by means of which it can be adapted perfectly to the skewed movement of a strip, Figure 3.

GI and GA steels
It is possible to manufacture two different types of hot-dip galvanised steels:

- On the one hand, GI steel plates are manufactured, with GI standing for "galvanised". For the production of these steels, the steel strip coated with liquid zinc is cooled, and a high-grade zinc coating with a metallic shine emerges, Figure 4.

- On the other hand, GA steel strips are manufactured, with GA standing for "galvannealed". In the case of GA plates, the zinc-coated strip after having left the zinc bath is reheated by means of an induction furnace to more than 500 °C. This annealing diffuses iron into the zinc coating, thus producing an alloy coating of zinc and iron. The otherwise shiny metallic surface now becomes a matt grey coat. Compared with the pure zinc coat of the GI steels, the GA steels are characterised by weldability and paintability.

Strip Movements
Strip movements are unavoidable in this process: The strip has to travel contactless between zinc pot and upper deflection roll (approx. 35 - 70 m) because of the still liquid zinc. Thus, it cannot be stabilized by any roll. In addition slight turbulences arise in the zinc bath and the cooling tower, which influence together with the bath rolls the strip travel. Every reduction of the strip movement in the knives reduces overcoating. In order to save zinc in this way, the electromagnetic strip stabilization system DEMCO has been developed.
THE DEMCO SYSTEM

The principle behind the DEMCO system
Strip stabilisation takes place via several electromagnets and inductive sensors which are arranged in pairs at the front and rear side of the strip above the air-knife system. In this way, non-contact measurement and control of the strip position is performed, and undesired strip movements are reduced to a minimum. This applies to movements orthogonal to the longitudinal axis of the strip, i.e. the vibrations, as well as to horizontal deviations from the strip form, for example the so-called cross-bow, Figure 5 and Figure 6.

Positioning and number of magnets
The electromagnets are arranged above the air knives on both sides of the strip and at the same level. The outer pairs of magnets parallel to the strip width are movable. The middle pair of magnets cannot be moved. With the help of quick-clamping devices, the magnets can be easily installed on the FOEN air knives. The movement functions of the air knife system are taken over by the strip stabilisation by means of a mechanical connection. Hence the middle pair of magnets always remains in a central position in the centre of the strip.
The effect of strip stabilisation decreases with the growing distance between the magnets and the air knives. If the distance between the air knife gap and magnet centre is more than 1.5 times to twice the strip width, a considerably lower effect on the strip vibration and form in the knife is attained.

Depending on the setting, the distance between magnet and strip is between 20 and 50 mm. This distance is to be selected in each case in such a way that an as efficient force impact as possible is ensured between the strip and the magnet.

Since the DEMCO system is of modular design, three or five pairs of magnets can be used depending on the strip widths to be galvanised and the customer requirements. At least three pairs of coils are required for cushioning the strip vibrations and for eliminating a cross-bow in the strip which may arise. The two outer pairs of magnets are then positioned precisely at the strip edges. Due to the movement functions of the FOEN air-knife system, the centre pair of magnets is always positioned at the strip centre. This enables the largest possible cross-bow correction.
Figure 7. Arrangement for max. 2,110 mm strip width.

Figure 8. Arrangement for > 1,300 mm strip width.

Figure 9. Arrangement for < 1,300 mm strip width.
For an extended solution with five pairs of magnets, the outer magnets are likewise always arranged at the strip edges. The next pairs of magnets are then positioned in such a way that the strip can be uniformly controlled along the entire width and travels in a stable manner, Figure 7 and Figure 8.

For strip widths less than 1,300 mm, only three pairs of magnets are used even if five are available. The outer magnets are not active, and the system automatically switches over to the three-pair arrangement, Figure 9.

Owing to the movable magnet pairs, the strip stabilisation offers great flexibility in terms of strip form correction during operation. On the whole, the movable outer magnets and the modular design guarantee the best stabilisation for every standard strip size during hot-dip galvanising.

**Inductive measurement and fine adjustments**

Below the magnets, a position measuring system is installed for each pair of magnets which continuously measures the distance to the strip in a non-contact manner, Figure 10. The strip position determined by this sensor is compared continuously with the target position in a quick control loop. By means of the variations in the current flowing through the stabilisation coils, the magnetic attraction for the steel strip can be controlled systematically in such a way that the strip movements are equalised. A high cushioning of the strip movements and a quiet strip travel can thus be guaranteed. The highly dynamic control system works with a response time of 1 to 2 msec.

Unlike a large stationary magnetic unit, the movable magnets arranged parallel to the strip width ensure that the fine adjustments can always be made optimised to the strip edge also during production.

![Figure 10.](image) Below the magnet, position measuring systems are installed which measure the distance to the strip in a non-contact manner (here in the workshop).
Increase in plant speed and reliability
With the use of DEMCO strip stabilisation, the line can be operated at a higher speed. Furthermore, the stabilisation enhances the reliability and reduces the rejects arising from surface defects. A smooth strip travel reduces the risk of contact between the strip and the air knives where the air knives could be damaged so severely that they need to be manually cleaned or replaced.

The DEMCO system offers advantages with regard to strip travel also in the production of GA strips. As the induction furnace is arranged between the air knives and the air cooling, the strip travel through the furnace is often very turbulent. With a strip stabilisation installed upstream of the induction furnace, the strip travel through the furnace is smooth even at higher speeds which results in a good quality of the GA product as a more uniform GA coating is produced at the top and bottom side.

Saving on zinc
The amount of zinc saved when using the DEMCO system depends on the relevant strip width and speed as well as on the zinc coats to be applied. On average, 1 to 2 g/m² of zinc can be saved per strip side due to the stabilisation. In case of strips on which a relatively thick zinc coat is applied, more than 3 g/m² can in fact be saved.

By saving 1 g/m² zinc per strip side, it is possible to save a total of 28.8 kg/h of zinc for a medium strip width of 1,500 mm and a medium speed of 160 m/min. At an assumed production time of 6500 h per
year, the total savings is then more than 185 t. Depending on the price of zinc which has been fluctuating between 900 and 3500 €/t in the last five years, savings of 160,000 to 650,000 € can be attained in a year by using the strip stabilisation.

By saving 2 g/m² per strip side, the amount of zinc saved for these parameters is 370 t a year. Depending on the price of zinc, this in turn amounts to savings of 330,000 to more than 1,000,000 €.

Depending on the structure of the galvanising line and its implementation and depending on the price of zinc, the plant design and the zinc savings attained, the strip stabilisation pays off between six months and 3 years.

Maintenance and retrofitting
Due to the quick-clamping device, the electromagnets can easily be removed for routine maintenance. In this way the maintenance of the strip stabilisation in the workshop can be performed on maintenance stands specifically designed for this purpose. The distance between the magnet and the measuring sensor is also adjusted here. The linear movement functions of the magnets as well as the pneumatic quick-opening of the magnets can also be easily examined, Figure 11.

The strip stabilisation can be retrofitted for all FOEN air knives. A DEMCO strip stabilisation can therefore be integrated in an existing galvanising line with a FOEN air-knife system without any difficulty. On the basis of previous experienced and given the compatibility of the systems, excellent results can be expected in case of a retrofitting.

OPERATING EXPERIENCE AND PRODUCTION RESULTS

Test phase
At first, various tests were carried out with a prototype of the DEMCO strip stabilisation system on the premises of SMS Elotherm in Remscheid. The desired results were obtained for a strip width of up to 1,100 mm at a strip speed of 60 m/min. Due to the maximum strip width of 1,100 mm, the prototype was equipped with three pairs of magnet coils.

Hysco
Since April 2007, a DEMCO prototype system has been successfully in operation in the annealing and galvanising line of HYSCO in Korea. Three pairs of magnets are installed here above the FOEN air knives. Depending on the strip width, the two outer magnet pairs are positioned at the strip edges while the middle magnet pair is aligned towards the strip centre. In this manner, the cross-bow in the strip is minimised for all strip widths and a vibration-free strip travel between the air knives is attained, Figure 12 and Figure 13. The distance between the gap of the air knife and the magnet centre is approx. 1,500 mm. It has been proved both for GI and for GA steels that the use of electromagnetic strip stabilisation reduces overcoating.

It was possible to reduce the overcoating due to two different effects. On the one hand, the strip vibration amplitudes in the centre of the strip were reduced by 40% and at the strip sides by 60%, so that the strip travel was considerably smoother. On the other hand, it was possible to eliminate the cross-bow effect due to the optimum positioning of the outer magnets, thus enabling a much more uniform coat over the strip width. Consequently, for each strip the standard deviation for the coating was able to be reduced on average by 1 to 3 g/m².
Another positive effect that was ascertained was an improved strip travel in the induction furnace when producing GA strip, in particular at strip speeds of 140 to 180 m/min. In this way, the use of strip stabilisation increases the line capacity during the production of high-grade GA steel strips.

Saving on zinc

To elucidate the zinc-saving potential, we wish to cite the example of the production of a GI strip in the annealing and galvanising line at Hysco where various non-destructive measurements of the coating thickness were carried out with and without strip stabilisation, thus providing accurate information on the coating thickness and the influence of strip stabilisation. The tests were carried out during the production of a steel strip with a width of 1,423 mm and a thickness of 0.66 mm at a speed of 165 m/min. Both sides of the strip were to be treated with a zinc coat of 140 g/m². This value had to thus be maintained along the width and length of the strip.

Without the help of strip stabilisation, an average of 143.184 g/m² of zinc had to be applied to the top and 143.192 g/m² to the bottom side of the strip in order to obtain the desired coating. After the strip stabilisation was activated, these values dropped to 141.860 g/m² and 141.920 g/m² respectively. Consequently, 1.324 g/m² less of zinc were applied to the top and 1.272 g/m² less to the bottom side. All in all, the savings amounted to 2.596 g/m² of zinc.

In relation to these parameters, a savings of 0.5 kg of zinc is obtained per ton of galvanised steel strip.

The improved coating value was measured downstream of the coating zone using a coating weight gauge (distance of 128 m). With a time delay after activating the stabilisation, the coatings on the top and bottom side showed drastically reduced amplitudes and an equalisation on both sides, Figure 14.
Another DEMCO strip stabilisation is meanwhile in use for testing purposes in the hot-strip galvanising line at Wuppermann in the Netherlands. Here, the version with five pairs of magnets is being put into practice for the first time. In this manner, extremely wide strips can also be optimised. For strip widths below 1,300 mm, only the inner three pairs of magnets are used for the stabilisation, Figure 15.

This arrangement also produced excellent results. Especially for larger strip widths, five pairs of magnets can bring about a considerable improvement by ensuring steady strip travel. Since the five pairs of magnets parallel to the strip width can be moved, an effective arrangement can be adjusted for all strip widths, and fine adjustments can be made to this arrangement also during operation.

All in all, the positive results gained at the cold strip galvanising line in Korea were able to be reproduced for hot strip galvanising in the Netherlands. Due to the DEMCO strip stabilisation and the ensuing steadier strip travel, less zinc has to be applied. Furthermore, the risk of standstills caused by turbulent strip travel is reduced. Owing to the design with 5 pairs of magnets, the travel of wide hot strip was also stabilised with positive effects on production.
CONCLUSION
The DEMCO system developed by SMS Siemag and Fontaine for electromagnetic non-contact strip stabilisation of the strip galvanising lines has proved its worth from the design to the test phase and right up to the first operating experience. The steadier strip travel guaranteed by the system not only makes it possible to save considerable amounts of zinc but also ensures greater plant reliability, thereby reducing surface defects. Due to the quick response time of the modular structure and the movable pairs of magnets, favourable results can be obtained for all strip widths and thicknesses both for hot strip and for cold strip. By means of a quick-clamping device, the stabilisation system can be easily installed on the knives and maintained. It can also be implemented without any difficulty in already existing galvanising lines with FOEN air knives.

Thanks to the amount of zinc saved as a result of the strip stabilisation, strip galvanising lines with an integrated DEMCO system are much more economical in their production. Depending on the strip steel produced, savings of 190 to 370 t/a of zinc are possible. This in conjunction with the zinc price produces annual savings of 160,000 € per year with the most favourable zinc price of the last years to more than 1 million € in the case of the highest zinc price in 2007.
The information provided in this brochure contains a general description of the performance characteristics of the products concerned. The actual products may not always have these characteristics as described and, in particular, these may change as a result of further developments of the products. The provision of this information is not intended to have and will not have legal effect. An obligation to deliver products having particular characteristics shall only exist if expressly agreed in the terms of the contract.