New Plasma Technology for Extrusion, Enamelling, Plating and Galvanising Applications

The main benefits of the new plasma technology as described in the previous two editions are related to the quality of the finished wire and output. An additional aspect of the technology is also the ability to substitute chemical cleaning processes such as pickling and descaling. These are becoming increasing important to the wire manufacturer due to the mounting pressure imposed by the European and US environmental regulations.

In the previous two issues of Wire Industry we introduced the new plasma technology for in-line wire cleaning and annealing. We set out the key concepts of plasma technology and described plasma treatment as a bombardment of ions on the wire surface. The consequence of such bombardment is rapid and efficient heating and surface cleaning. As such the new technology offers an effective and flexible wire treatment process for high quality finished wire that is demonstrated in extreme surface cleanliness, deoxidation, smoothness as well as homogenous mechanical properties of the treated wire material.

In this issue we will try to evaluate the above benefits on specific applications. We will also examine environmental aspects of the new technology and explore the technology as a replacement for pickling.

Plasma annealing and surface cleaning technology offers the greatest benefits to applications such as extrusion, enamelling, plating, high-temperature alloy annealing and galvanising. Below we individually examine the benefits plasma technology brings to each application.

Extruded Wire

In a simple definition we can describe extrusion as a process where cable insulator is applied onto a cable conductor. To ensure appropriate adhesion of the insulator with the metal surface the engineer must ensure (1) a high degree of surface cleanliness, (2) an appropriate micro roughness of the wire surface and (3) an accurate temperature before the conductor enters the extruder. Plasma treatment involves all three aspects and can therefore be used as an effective pre-treatment (pre-heating) module in an extrusion process. Ion bombardment on a wire surface is an effective cleaning process that descales, decreases and deoxidises the conductor before extrusion. Such ion treatment also results in a degree of wire polishing that decreases macro-roughness and increases micro-roughness of the conductor surface. This in turn improves the adhesion of the extruded material on the conductor surface. Plasma technology allows for a simple and accurate adjustment of temperature during the pre-heating process through the fine-tuning of electric power input. Plasma technology can therefore be used as an effective pre-heating module. The technology is particularly efficient for high-temperature extrusion materials (like PEEK) or extrusion applications that require extreme surface cleanliness or improved micro-roughness.

Enamelled Wire

Like extrusion, enamelling process requires wire with high quality of surface. Flaws and sharp edges on the wire surface distort electrical properties of enamelled wire in particular the mean Break Trough Voltage, and the number of pinholes. Inappropriate wire surface can make the wire unacceptable for the end user, resulting in high level of scrap.

The producers of enamelled wire have been using bell and tube annealers to ensure the sufficient surface quality. Plasma technology provides a credible new alternative. PlasmaAnnealer offers an in-line annealing with the processing speeds comparable to resistive annealers. In addition, ion bombardment in the Heating Chamber melts off the macroscopic

irregularities (nibs and sharp edges) on the wire surface and increases the microscopic roughness of the finished surface. The process also ensures thorough deoxidisation and degreasing, which in turn improves enamel adhesion.

As an example we provide a picture of 0.8mm Copper Wire that was processed in PlasmaAnnealer at the speed of 5 m/s. The hard wire from the drawing machine is dirty and oxidized (left). The wire after the treatment with PlasmaAnnealer is deoxidized and clean (right). The finished wire achieved the yield strength of 54 N/mm2. The roughness on the microscopic scale was clearly increased during the process.

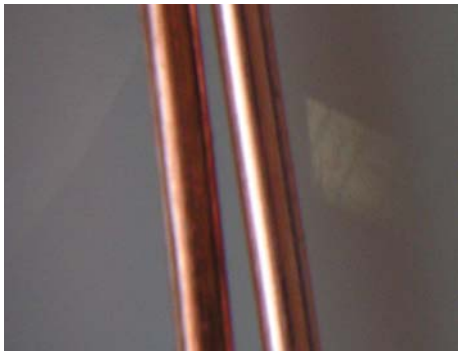

Figure 1: Treated (right) and untreated (left) copper wire

Plated Wire

Plating applications are also amongst those that require consistent quality in wire surface. Adhesion of the coating material on the wire surface depends largely on (1) the cleanliness of the wire surface (deoxidation, rescaling, removing of greases, oils, soaps, other residues and deposits) and (2) a high degree of microscopic roughness. As already mentioned above, ion bombardment in the Plasma Chamber ensures aggressive cleaning of the wire surface. High processing speed also allows PlasmaAnnealer to be placed inline with the plating process. This ensures efficient logistics of the process whilst replacing environmentally compromising chemical pickling.

High Temperature Materials and Special Alloys

PlasmaAnnealer is effective for high temperature applications such as high temperature materials and special alloys. Plasma technology has virtually no limitation in relation to annealing temperature. Plasma technology allows for a very efficient energy transfer into the material and can therefore heat wire conductors to the highest temperatures at very short annealing lengths and at high speeds. Remarkable in this context is the fact that the efficiency of the system increases with the temperature, which makes the technology particularly efficient for applications such as nickel alloys, tungsten and other high temperature materials.

During the annealing process the wire is also deoxidized and rescaled as a consequence of consistent ion bombardment on the wire surface. In such applications PlasmaAnnealer can replace the whole set of the equipment – from annealer to descaling, degreasing and deoxidizing equipment. In some cases drawing lubricants react in the plasma chamber, in others incineration of lubricants is not permitted (lubricant burns into toxic fumes). In those cases pre-cleaning is required to wipe off the lubricant from the wire surface prior to plasma processing.

PlasmaAnnealer achieves considerably greater processing speeds when compared to traditional tube annealers. For example, the processing speeds for a nickel alloy wire with a diameter of 1 mm[1] can be as high as 3m/s. In other words, a 10 cm (4 inch) Plasma Heating module can effectively substitute a 10 m long tube in the traditional tube annealer. However, the final production speed of PlasmaAnnealer is generally limited by the cooling section, which has to be designed to cool the wire down to the required temperature at the same rate.

[1] Depending on application and required set-up

When it comes to output PlasmaAnnealer can be considered as a good alternative to Tube or Batch type Annealers. The benefits can be much greater when PlasmaAnnealer is used for surface cleaning, degreasing, chemical and/or mechanical treatment.

Steel Applications and Galvanising

Figure 2 below outlines a typical steel processing/galvanising process line. The key steps in the process are pre-treatment, dry/wet drawing, heat treatment, and finishing. The steel wire production process involves a number environmentally compromising elements:

- Air pollution through pickling
- Acidic garbage and waste water
- Abraded soap dust (at dry drawing)
- Used lubricants and waste water
- Combustion gases and emissions from furnaces and ovens
- Lead contenting waste from lead bathes

Plasma as a cleaning/annealing technology provides an alternative for traditional annealing and chemical pickling processes in steel processing. One of the main advantages of Plasma technology in steel processing is environmental, such as abolishment of air pollution through pickling and wastewater pollution with acidic garbage. This is becoming an ever more important aspect due to the increasing pressure that governments put on the manufacturers that use hazardous chemicals in their manufacturing processes[2].

Plasma technology has not yet been commercially deployed on steel applications. Nevertheless, the initial trials on low carbon steel and stainless steel have shown very encouraging results. For example, a stainless steel wire with the diameter of 1mm was heated to 850°C at the speed of 3m/s in a one meter long Heating Chamber. The process also demonstrated the outstanding cleaning/deoxidation capabilities of the technology.

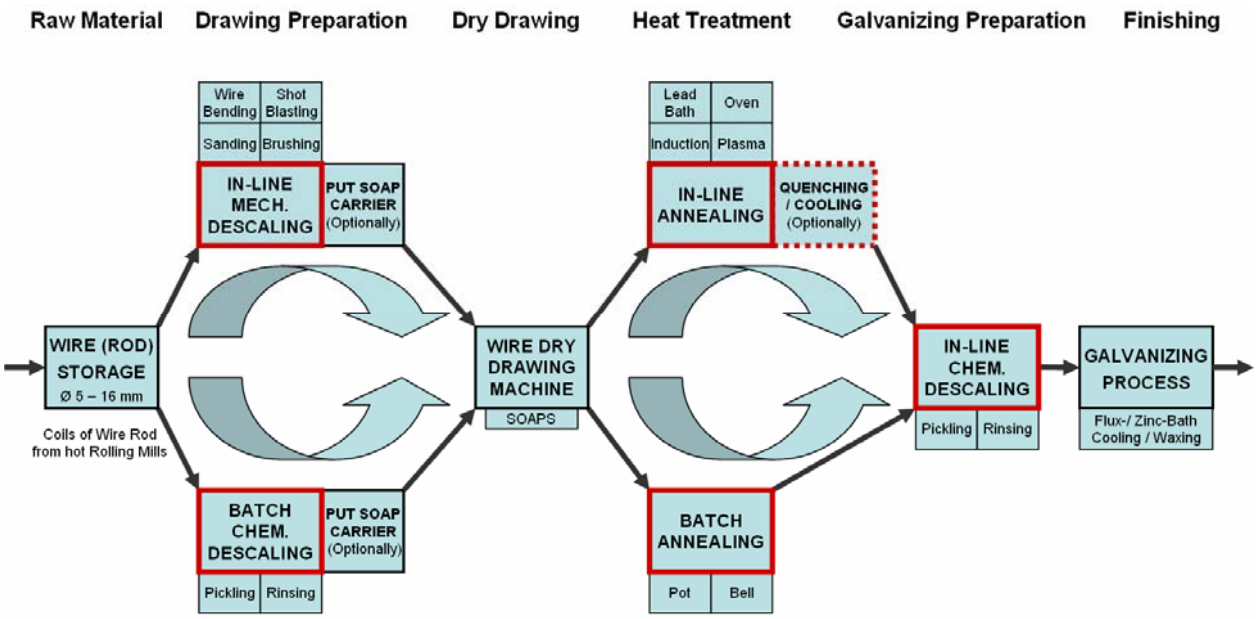

Figure 2: Schematic Production Line for Galvanized Low Carbon Steel Wire

[2] On 22nd of July 2002 the European Commission published the Sixth Environment Action Programme "Environment 2010". In 1996, the EU has ratified a so-called IPPC-Directive (Integrated Pollution Prevention and Control). The directive (guideline) is a set of common rules and recommendations for industrial installations throughout the European Union. The rule is obligating since 1999 for all new built installations and significant upgrades. From 2007 onwards the rules will apply also to all existing installations.

In Figure 2, the areas marked in red show the elements of the steel production process where plasma technology can play a suitable alternative. The important aspect of such substitution is the possibility to replace batch processes with a continuous in-line process. This improves the logistics and operations costs associated with off-line manufacturing.

In Figure 3 the input-output balance of steel manufacturing process is shown. The diagram helps to evaluate the dimensions of the environmental liability of a traditional steel manufacturing process. By the same token the diagram provides an indication of potential saving and improvements in case plasma technology is used as an alternative to traditional descaling and annealing processes in the steel manufacturing. The concrete ecological benefits may vary from application to application.

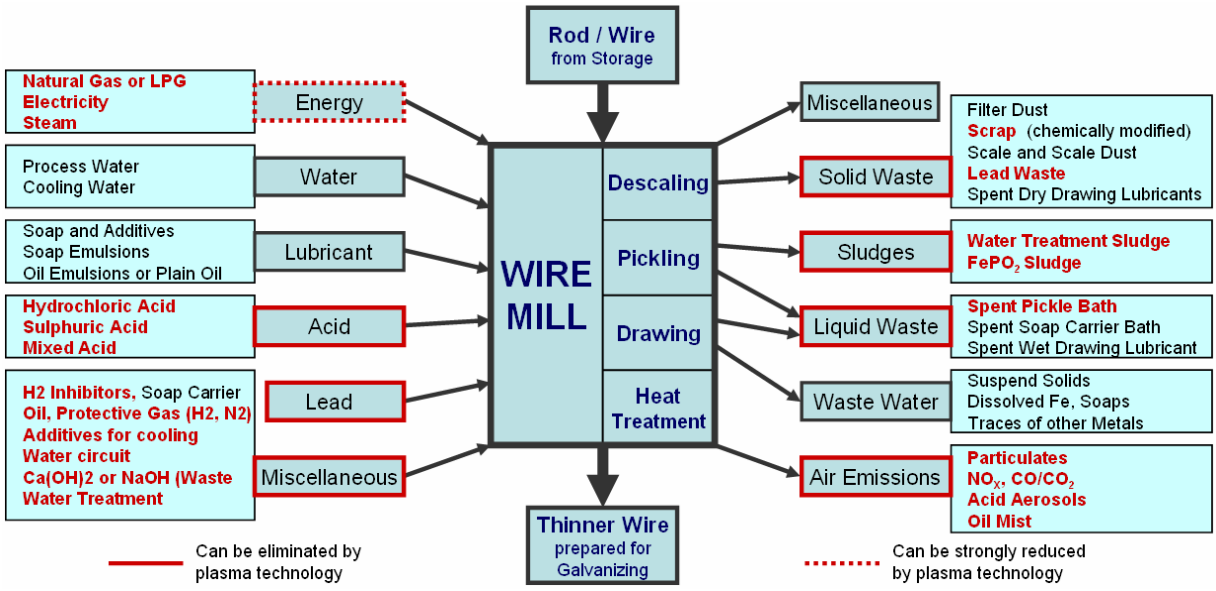

Figure 3: Input-output balance concerning environmental pollution for wire production

Conclusion

Plasma technology is commercially available for a wide variety of materials for diameters from 0.3 to 5.0 mm. PlasmaAnnealer for applications below 0.3mm can be developed if requested. The applications where plasma adds the most value are applications that above all need the highest quality mechanical properties and surface cleanliness combined with high process flexibility and efficiency. Each manufacturing process and application requires a specific solution. This means that PlasmaAnnealer has to be adapted to suit the existing production line/application.

The ongoing development of this truly new technology in wire manufacturing is most likely to result in further increases of process speeds across the whole range of materials and applications. However, when comparing plasma technology with traditional annealing/cleaning technologies one has to take into account not only processing speeds but above all energy and gas consumption parameters and distinguished finished wire qualities.

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