New Plasma Technology Transforms the Economics of In-line Wire Cleaning and Annealing

The benefits offered by the new plasma technology are not limited to the homogenous mechanical properties of the finished wire and ultra-clean wire surface. PlasmaAnnealer is set to shake the traditional views of in-line wire processing for a range of applications and materials. The technology offers a high-speed, efficient and environmentally friendly in-line process for the cleaning and annealing of wire.

In the July edition of Wire Industry we presented a new plasma technology for in-line cleaning and annealing of wire. In the article we introduced plasma as gas of ionised particles (flame). We described the plasma treatment as a bombardment of ions on the wire surface. The result of such bombardment is rapid heating, cleaning, pickling (that means, that the plasma technology is an effective substitute for pickling) , deoxidation, and surface polishing.

In this edition we are pleased to introduce PlasmaAnnealer, a machine designed by Plasmait GmbH, Austria and examine its key components. We will summarise the key benefits and advantages of the plasma technology from the operational, ecological and product quality points of view.

PlasmaAnnealer is made up of three key components: Heating Chamber, Sealing System and Cooling Section. The Heating Chamber is the heart of the device (**Figure 1**).

Figure 1: 10 KW Heating Chamber deployed in PlasmaAnnealer.

Wire is led through the Heating Chamber where it is exposed to high-density plasma. The intensity of plasma treatment is regulated by the power supply unit, the integral part of the Heating Chamber. The maximum annealing processing speeds (output) for the standard 10 KW Heating Chamber are calculated in the diagram in **Figure 2.**

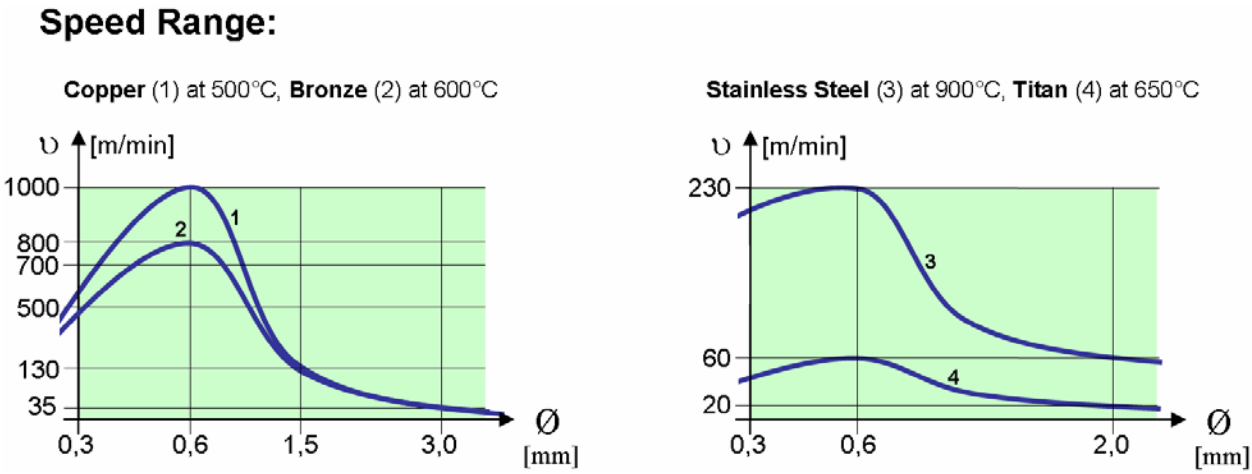

Figure 2: Calculated processing speeds for plasma annealing of copper, bronze, stainless steel and titan wire in relation to wire diameter with one 10 kW heating chamber system.

To achieve higher processing speeds than the ones realised by a 10 KW Heating Chamber a larger custom-made Heating Chamber and Power Supply unit is required. Alternatively, multiple Heating Chambers can be added into the processing line. The maximum achievable processing speeds are different when Plasma Annealer is set up solely as a cleaning (including deoxidation and pickling) or polishing device. The maximum processing speed for cleaning and polishing depends mainly on the material, wire surface and required surface cleanliness.

The Sealing System is deployed to maintain low-pressure inert gas atmosphere in the heating chamber and to prevent air from entering the heating chamber **(Figure 3).**

Figure 3: The module of the Sealing System deployed at the inlet point of PlasmaAnnealer.

Two sealing modules are installed on each side of the Heating Chamber. The Sealing System makes the use of a contact-less technique. The system's design allows a range of wire diameters to be processed through the same sealing module. The small sealing module can be utilised on wire diameters of between 0.5 mm and 2 mm and the large module on diameters of between 1.5 mm and 3 mm. This simplifies the process handling and shortens the downtime during the batch changeover. It takes a few simple steps and a maximum of 5 minutes to up-load new material and start the process. Stringing in a wire with a different dimension would take no more than 2 minutes.

The Cooling Section is an optional element of PlasmaAnnealer. It is used to prevent oxidation of the wire surface at the point when the wire exits the machine. The Cooling Section can in-

volve water cooling, gas cooling or a combined system, depending on the surface quality requirements of the finished wire.

In the previous article we explained that plasma treatment achieves a remarkable quality of processed wire. Extreme surface cleanliness and deoxidation and a smooth surface with a high degree of micro-roughness are the benefits plasma technology can bring to the applications such as wire plating, welding wire, extrusion, enamelling and galvanising. The two photographs in **Figure 4.** show the 1.2 mm stainless steel samples before and after plasma the annealing process at a speed of 3m/s and at 900˚C. The pictures indicate the cleaning, deoxidation and polishing (increased micro-roughness and decreased macro-roughness) effects as a result of plasma treatment during the annealing process in PlasmaAnnealer**.** Whilst not the ideal medium in which to demonstrate the effect of plasma treatment, the photographs nevertheless indicate proven results.

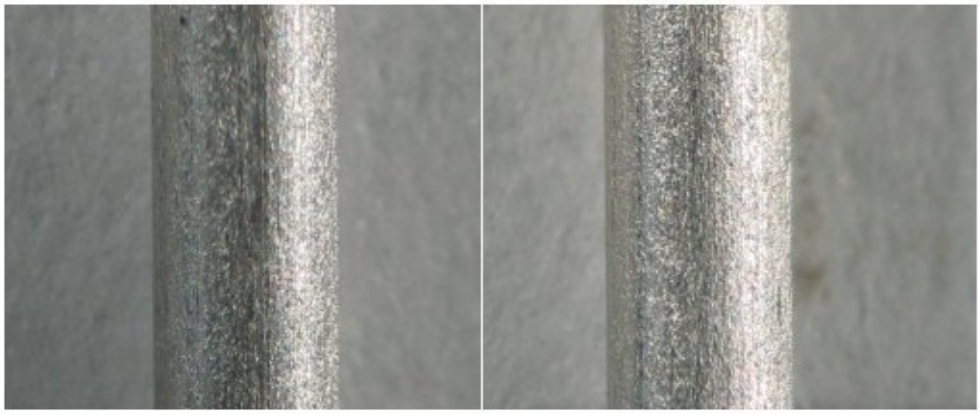

Figure 4: Microscopic Photographs (50 x enlarged) of the 1.2 mm stainless steel samples annealed at 3m/s and 900˚C. LEFT: Unprocessed wire sample (after pre-cleaning) is slightly shaded, due to a thin oxidation layer. RIGHT: Annealed wire sample is bright, deoxidised and with increased micro-roughness.

Plasma treatment offers homogenous mechanical properties such as yield strength, tensile strength and grain size. The consistency and low deviation from the required mechanical properties can benefit many applications, in particular special metal processing. Typically, the tensile strength of the wire annealed in PlasmaAnnealer does not vary more that ± 2N/mm from the set value. In addition, the process control system allows for highly accurate control of wire softness during the production process. The annealing temperature can be changed during the process in less than one second making it possible for wire softness to be manipulated on-line to the desired grade during the process.

We also introduced plasma technology as an energy-efficient heating/annealing process. In addition to energy savings, plasma technology benefits from low-cost processing and maintenance. The cost of operation of PlasmaAnnealer was quantified in four trials on copper, stainless steel and bronze wire provided in Table below.

Table: Examples of PlasmaAnnealer Processing and Maintenance Costs [1]					
Material		Copper	Copper	Stainless Steel	Bronze
Diameter	mm	1.6 mm	1.6 mm		0.8
Type of Annealing		re-crystallisation	"soft annealing"		"soft annealing"
Inlet Temperature	°C	20	20		20
Annealing Temperature	°C	550	230		600
Tensile Strength [4]	N/mm^2	220 - 230[5]	260		360
Wire Speed	[m/s]	3	7.5		7
Power Consumption [3]	kWh/kg	0.08	0.035		0.08
Gas Consumption [3]	Nl/kg [2]	0.9	0.5		1.37
Maintenance Expenditure	€/kg	0.008	0.005		0.005

[1] Single Heating Module and 95% Up-Time

[2] Litre of gas at Normal Conditions per kilogram of wire material

[3] Per Kilogram of wire material

[4] Values depend on material quality and treatment history

[5] Depends on the material

Plasma technology provides the benefits of contact-free processing, which contributes to a low cost of maintenance. The maintenance is limited to changing of oil and air filters and replacement of electrical contacts. The Plasma Chamber (the tube) may have to be wiped with a dry cloth as required, depending on the amount of dust deposit on the inlet wire. In the case of a high degree of dirt on the wire surface pre-cleaning is required.

PlasmaAnnealer can further reduce the cost of wire cleaning and annealing due to its in-line processing capability and the ability to simultaneously perform up to 4 process steps in a single run. For example, in the case of 1 mm steel wire PlasmaAnnealer can carry out annealing, cleaning, chemical-free pickling and deoxidation in one step. In the case of 1 mm copper wire PlasmaAnnealer could perform pre-heating and annealing in one step at the speed of up to 20 m/s. PlasmaAnnealer can also be configured to perform any of the 4 processes individually or in any required combination. Such manipulation capability makes PlasmaAnnealer operationally efficient and flexile and above all a very cost effective tool for small batch manufacturing.

Plasma technology is a credible alternative to traditional annealing processes. The output of Plasma Annealer is comparable to the outputs achieved by traditional resistive annealers for copper wire with diameters up to 1 mm. However, the surface quality of the end product achieved with plasma technology is considerably higher, which is a consequence of the surface cleaning and polishing effect during the plasma treatment. This makes plasma technology particularly suitable for applications that require uncompromising surface quality such as enamelled and extruded wire.

The processing speeds achieved by plasma technology can be more than 10 times the processing speed of traditional tube annealers. Replacement of a tube annealer with plasma technology would allow for radical reduction in the number of processing lines, including the pay-off and take-up facilities. By the same token, the potential reduction in working capital can be of great benefit to the manufacturers of expensive wires.

So far bell (batch) annealers proved to be irreplaceable for many high-output annealing applications. For some low-output, high-quality applications in-line plasma technology could prove to be a credible future alternative to what has now been the exclusive territory of bell annealers.

In the next edition of Wire Industry we will expand further on the environmental aspects of plasma technology and the use of the technology as an alternative to traditional pickling. We will also look at the use of plasma technology in applications such as extrusion, enamelling, welding wire, plated and galvanised wire, special alloy wire and in the processing of high temperature materials.

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