

Pulsed Plasma Nitriding of Tools

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Abstract

Plasma nitriding is now well established as a flexible, cost effective alternative to salt bath and gaseous nitriding. Since introducing the pulsed plasma process into industrial heat treatment a broad range of applications for tools with complicated shapes is possible.

1 Introduction

Nitriding to enhance the wear, friction, fatigue and/or corrosion properties of production tools and components made of ferrous alloys is widely applied throughout industry and the high level of flexibility and reproducibility achieved by modern plasma surface treatments provides many opportunities for end users to improve performance and reduce life cycle costs.

2 Pulsed Plasma Nitriding

With conventional dc plasma operation, overheating of thin sections can occur due to the voltages and current densities required to obtain a glow discharge that completely surrounds the workpiece. Localised heating can further concentrate the energy input from the plasma in such areas, leading to arcing, which damages the surface finish.

Within deep slots or narrow openings, there is a possibility of workpiece melting via the 'hollow cathode effect': therefore the treatment of tools was restricted to simple geometries. Otherwise big problems with distortions are obtained.

The Eltropuls system solves the overheating problem by decoupling the heating and surface treatment functions, limiting the plasma energy input to that required to affect the metallurgical changes sought. This is achieved by replacing the steady state plasma with spiked current and voltage pulses (see Fig.1 – Ignition pulse system).

The pulse duration, of the order of microseconds, reduces the heat input.

During the "plasma on" - time active nitrogen for nitriding is created. In the pulse repetition time the concentration of active is slightly lowered. But this lowering of active nitrogen has no significant influence on the nitriding effect at typical industrial used duty cycles.

The pulsing effect on the heat input is shown in Fig. 2.

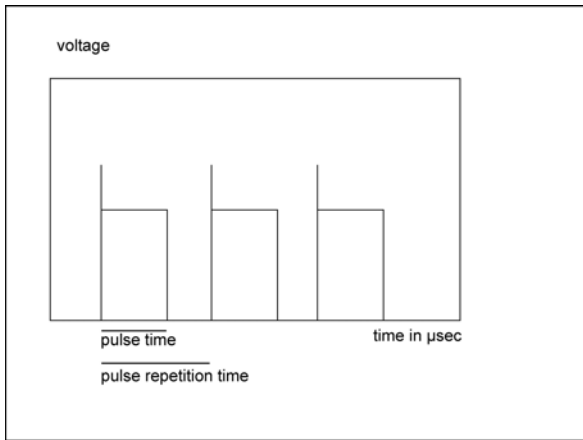


Fig.1: Ignition pulse system

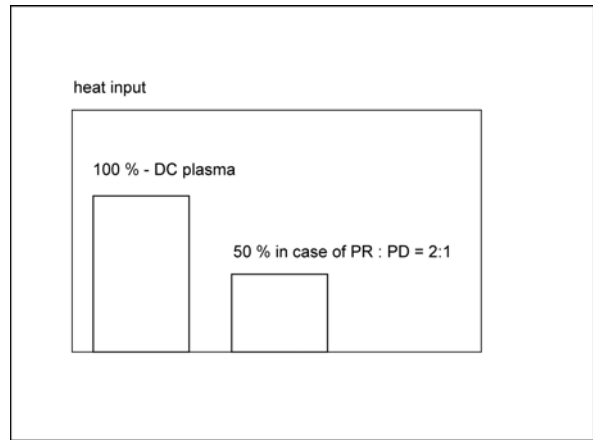


Fig.2: Pulsing effect on the heat input

3 Nitriding of Tools

Nitriding is a thermo-chemical heat treatment process introducing nitrogen into the outermost surface of parts and components. The process time is diffusion controlled. Therefore higher temperature results in shorter treatment time compared to lower treatment temperatures. The maximum nitriding temperature is limited by the material (tempering temperature, grain boundary precipitation, hardness profile) and by distortions especially in the case of shape complicated tools. For hot forging dies nitriding depth of 0,2 - 0,3 mm are recommended. Typical results for the steel grades X38CrMo53, X60WCrMoV9.4 and 57NiCrMoV7.7 after nitriding at 530°C, 16 hours are shown in Fig. 3.

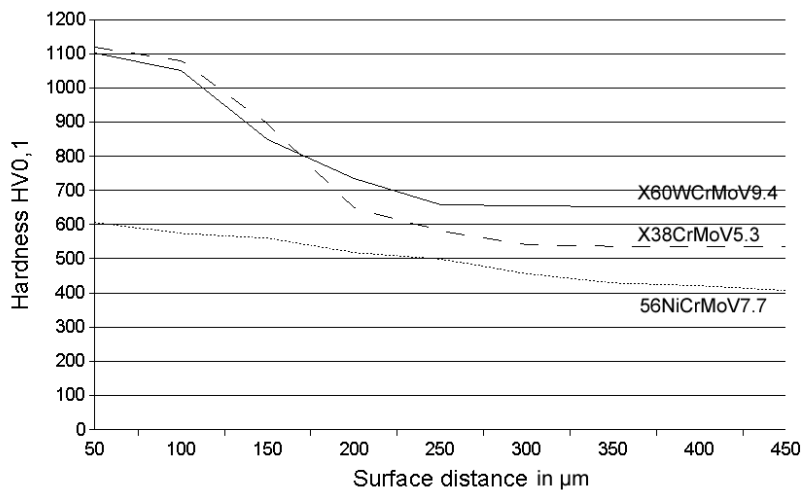


Fig.3 Hardness Profiles

By increasing the nitriding temperature to 550°C the nitriding time was reduced to 11 hours. This resulted in a more cost effective process with the same good properties of the tools.

Extrusion dies, made of X38CrMoV5.3, also show a very good performance after treatment in plasma. The best results are obtained with compound layers of the ϵ - type with 5 - 10 μm compound layer thickness. The nitrided depth should be limited due to the thin sections of the press channel. Pulsed plasma nitriding can penetrate narrow slots greater than 0,8 mm without any problems. Typical cycle times of a complete load from heating up to cooling down are in the range of 12 hours. This is realised by effective internal cooling devices like gas - water - heat exchangers. They reduce the cooling time significantly and have positive effects of the metallurgical structure of many materials.

Cutting - tools with thin and sharp edges require a limited nitrided depth. The nitrogen activity in the pulsed plasma furnace must be adjusted to obtain ductile layers. The best reproducibility for such applications is given at lower temperatures.

The plasma is able to work at lowest temperatures. After nitriding at lower temperatures many tools show a very good performance. Mandrels, made of 1.2631 (see Fig. 4), are nitrided at 480°C, 10 hours. Very high surface hardness is obtained after this treatment. They are in the range of 1380 - 1430 HV1. This treatment results in the best performance for sheet profiling tools. Another example for low temperature nitriding is the nitriding of cores for plastic moulds (see Fig 5). Before nitriding the parts are hardened and polished. After a short nitriding at 380°C, 4 hours the performance is increased. No additional polishing is required.



Fig.4 Pulsed Plasma Nitrided Mandrel

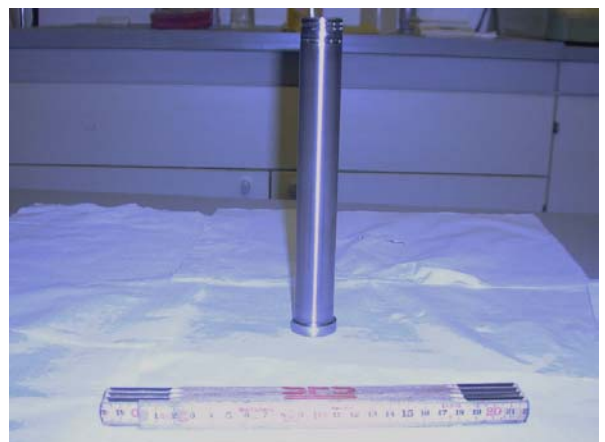


Fig.5 Pulsed Plasma Nitrided Mould Core

4 Furnaces for tool nitriding

Successful operation of a plasma nitriding unit depends on the control of several interlinked parameters. This complex task is achieved through a microprocessor control system capable of controlling automatically without operator intervention.

Part surface temperature is measured by direct contact thermocouples. Nitrogen availability is determined by the partial pressure of nitrogen in the process gas mixture and regulated by a supply side mass flow controller. Furnace temperature is measured by external thermocouples.

An operator interface permits set points to be listed and operating parameters and system status to be monitored. A complete record of the parameters over the cycle is recorded for quality control and

certification purposes and to allow the treatment to be duplicated as required. Modem links enable remote monitoring or diagnosis.

The pulse plasma nitriding units produced by ELTRO are compact in terms of floor space. Since they have little environmental impact, they are also well suited to being integrated into manufacturing lines.

For the nitriding of tools bell furnaces are recommended (see Fig. 6). After opening the receptacle, the furnace can be loaded from all sides easily. To improve the availability of the furnace and to lower the process costs so called double bottom furnaces are widely used.

While the nitriding process on one bottom is in operation the other bottom can be loaded. So the equipment can be used 24 hours 7 days per week without an operator present over the whole time.

A double bottom furnace is shown in Fig. 7.



Fig.6 Bell Furnace



Fig.7 Double Bottom Furnace

5 Summary

Plasma nitriding is now well established as a flexible, cost effective alternative to salt bath and gaseous nitriding. Since introducing the pulsed plasma process into industrial heat treatment a broad range of applications for tools with complicated shapes is possible. The treatment parameters can be varied in a very large range to obtain best tool performance.