Energy Consumption During Surface and Full-volume Hardening of Parts

Introduction

The current energy crisis forces us to look for ways to reduce consumption in all aspects of industry. **This article is an attempt to find possible sources for energy savings in the field of screw production. The biggest consumer in this area is heat treatment.** If we realize that heating to a quenching temperature of approximately 820°C globally requires a gigantic amount of heat energy, then the raised question is justified.

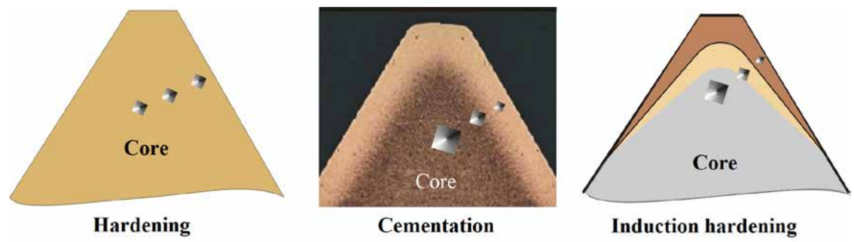

Fig. 1. Course of microhardness

Current Status

Because screws are produced on a mass scale, continuous hardening furnaces with a protective atmosphere are best suited for their heat treatment. At the same time, the entire volume of the parts is heated to the hardening temperature and immediately cooled sharply in the oil so that the martensitic structure in the entire volume **(Fig. 1 left)** forms. In specific cases, surface hardening is also used either by saturating the surface of the parts with carbon (cementation) - **Fig. 1** in the middle, or by induction hardening **(Fig. 1 – right, and Fig. 2)**. **Fig. 1** also provides information on the course of microhardness. It is clear from this figure that in volume hardening the hardness is uniform throughout the entire volume of the part, whereas in surface hardening the hardness gradually decreases to the unhardened core.

Since only the austenite structure is able to absorb sufficient amounts of carbon, the temperature during cementation (carburizing) is above 900 °C with a carburizing time of several hours. Carburization depths of 0.1 to about 5 mm can be achieved economically with this process. Since carburizing is a diffusion-controlled process, the carburizing times can be reduced by higher temperatures, but at the same time with the risk of coarse grain formation increasing.

After this short introduction, we can proceed with calculating the consumption of heat energy Q for individual methods of heat treatment. At the outset, it should be noted that the calculation is loaded with certain errors; however, it is suitable for the purposes of this topic.

Example by full-volume hardening (**left in Fig. 1**):

Heat capacity formula:

$Q = m \times c \times \Delta t$

Where: m = mass [kg], c=specific heat capacity (for steel 420 [J/kg x°C], Δt=temperature difference [°C]

$m = 0{,}05$ kg, $\Delta t = 840 - 20 = 820$°C and $c = 420 \times$ J/kg x °C

$Q = 0.05 \times 420 \times 820 = 17220$ J

Approximate calculation by induction hardening (on the right in **Fig. 1** and **Fig. 2**):

$\Delta t = 840 - 20 = 820$°C and $c = 420 \times$ J/kg x °C

p - specific heat capacity = 7750kg/m^3, r_1 = 5mm, r_2 =4mm, h = 80mm (height of the body)

$Q = p \times c \times \Delta t$

$Q = p \times \Pi \times h(r_1^2 - r_2^2) \times c \times \Delta t$

$Q = 7750 \times 3{,}14 \times 0{,}08(0{,}005^2 - 0{,}004^2) \times 420 \times 820$

$Q \approx 6037$J

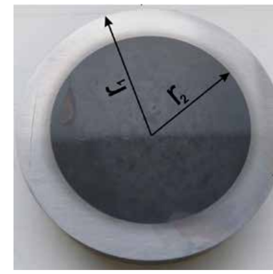

Fig. 2 Induction hardening

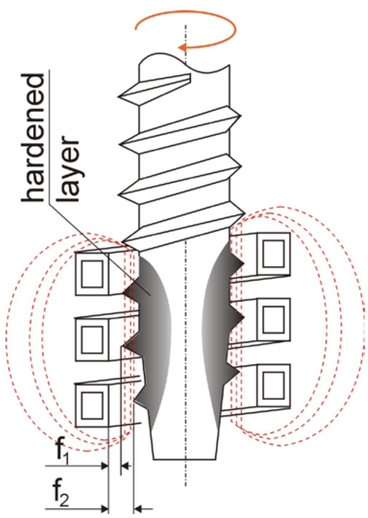

Fig. 3 Functional part of a component

Compared to other methods of hardening, induction hardening has the advantage that it allows partial hardening of the functional part of the component (Fig. 3). The thickness of the hardened layer can be regulated either by the size of the gap between the inductor and the surface of the component or by choice of time.

As for cementation, its advantage is the possibility of using cheaper low-carbon steels. However, it is not suitable for mass production, because continuous cementation furnaces do not exist.

Conclusion

The submitted contribution is an indication of the possibility of saving energy in heat treatment of screws. Of course, it cannot be considered as a universal method. Induction surface hardening is only suitable for selected types, e.g. for self-tapping screws. Unfortunately, it is not yet applicable for mass-used classical screws with a metric thread as a DIN 931 or DIN 912. ■

Article by: Jozef Dominik & Dominik Makuka
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