Advantage of Constant Frequency Inductive Heating in Quenching Dilatometry

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INTRODUCTION

TA Instruments DIL 805 quenching dilatometers allow rapid inductive heating of conductive samples with a constant frequency using proprietary technology. The sophisticated powerful inductive heating with constant sinus frequency is power controlled by amplitude adjustment and provides most homogeneous sample heating under all conditions.

INDUCTION HEATING PRINCIPLE

Induction heating is the process of heating an electrically conducting object by electromagnetic induction through heat generated in the object by eddy currents. An induction heater consists basically of a coil and an electronic oscillator that passes a high frequency alternating current (AC) through the coil. The coil generates a rapidly alternating magnetic field which penetrates the object. The alternating magnetic field generates electric currents inside the conducting object, called eddy currents. The eddy currents flowing through the resistance of the material heat it by Joule heating. In ferromagnetic materials like iron, heat may also be generated by magnetic hysteresis losses. The optimum frequency of current used depends on the object size, material type, coupling between the coil and the object to be heated and the desired penetration depth of the induction of eddy currents in the object.

An important feature of induction heating is that the heat is generated inside the object itself and is not limited by heat conductivity. Thus, objects can be heated very rapidly. This qualifies induction as ideal heating method for industrial and analytical heat treatment processes in metallurgy [1].

PENETRATION DEPTH

The frequency of the alternating magnetic field determines the depth it penetrates the object. The penetration affects the distribution of induced eddy currents in the material. In the simplest case of a solid round bar, the induced current decreases exponentially from the surface. An "effective" depth of the current-carrying layers can be derived as

$$\delta = \frac{1}{\sqrt{\pi \cdot f \cdot \mu \cdot \sigma}} \qquad (1)$$

where δ is the standard depth of penetration, f is the frequency of the AC field, μ is the magnetic permeability and σ the conductivity of the material [2].

The strongly non-linear relation between the penetration depth and the frequency of the AC field is shown in the double-logarithmic diagram below for different materials.

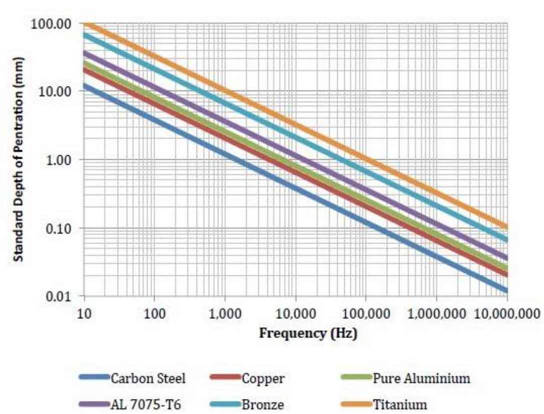

Figure 1: Influence of frequency on penetration depth in different materials [3].

FREQUENCY INFLUENE ON SAMPLE TEMPERATURE

If the frequency of the inductive field changes during the heating process – for instance while the heating power is adjusted – the penetration depth of the induced current in the metal sample changes (*cp. Figure 1 above*). The induced current generates the heating of the sample. Thus, changing the frequency changes the penetration depth of the induced current which then changes the temperature profile in the sample.

Generating a consistent, reproducible, and homogeneous temperature in the sample during the entire temperature program in a quenching test is inherent for an accurate determination of the phase transition temperatures. Generating the inductive heating of the sample at constant frequency is therefore a key feature for generating highly accurate data in quenching experiments.

TA PROPRIETARY INDUCTIVE HEATER WITH CONSTANT FREQUENCY

In TA Instruments' DIL 805 quenching dilatometers a proprietary high frequency generator is used. It allows heating power control by amplitude adjustment at a constant frequency.

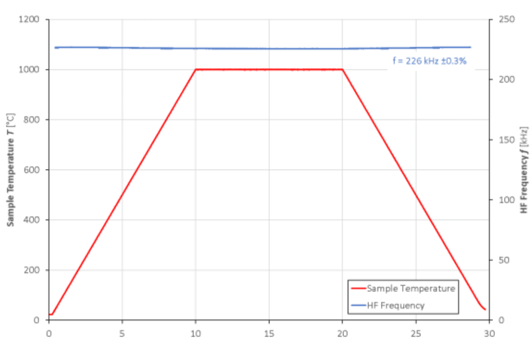

Diagram 1: Temperature of a Pt-sample heated and quenched in the DIL 805 and recording of inductive heating field frequency.

In diagram 1 above a temperature program of a Pt reference sample is recorded along with the frequency of the inductive heater in the DIL 805. The temperature program consists of a heating segment up to 1000°C with 100 K/min heating rate, 10 min isothermal dwell time, and a quench with 100 K/min cooling rate.

The frequency of the inductive heating field is constant within ±0.3% over the entire temperature program.

CONCLUSION

Inductive heating of conductive metal samples is effective for rapid sample temperature control in quenching dilatometers. Changing frequency of the inductive heating field is known to change the penetration depth and the distribution of the eddy currents induced in the sample. The alternation in current distribution leads to a changing and inhomogeneous temperature profile in the sample with the change in heating frequency.

TA Instruments' DIL 805 quenching dilatometers apply a proprietary high frequency generator allowing for constant frequency heating power control by amplitude adjustment. This constant frequency inductive heating is an essential feature for the superior accuracy and reproducibility of the quenching data measured with the DIL 805.

REFERENCES

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