Advantage of using He as Cooling Gas in Quenching Dilatometry

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INTRODUCTION

TA Instruments DIL 805 quenching dilatometers allow performing measurements with a choice of quenching gases other than nitrogen. In this document, the advantages of using helium as cooling gas for quenching dilatometry with metal samples are described. Helium is chosen because it extends the cooling range to sub-ambient temperatures and enables accurate MF-temperature detection.

The choice of nitrogen as the cooling gas appears to be the simplest and cheapest solution for quenching dilatometers. Besides the low costs and generally good availability nitrogen simplifies sub-ambient temperature applications. A flow of cold nitrogen gas can simply be generated by evaporation from a liquid nitrogen reservoir. However, there are serious negative impacts on the performance of the quenching dilatometer measurements caused by the application of nitrogen.

The potential problems caused by using nitrogen as quenching gas and the advantages of using helium instead are elucidated below.

NITRATION REACTIONS

In the nitriding reaction

$$N_2 \rightarrow 2\,N$$

a nitrogen molecule from the gas surrounding a metal sample, N_2, dissociates into two nitrogen atoms, 2 N, which dissolve in the metal. This reaction is likely for stainless steels, where chromium attracts nitrogen and considerable amounts of nitrogen may dissolve in the steel [1].

The possible consequences of unwanted nitrogen pick-up embrittlement and formation of a surface layer. This layer consists of non-metallic phases called nitrides. The proportion of such nitrides depends on the chemical composition of the steel [1].

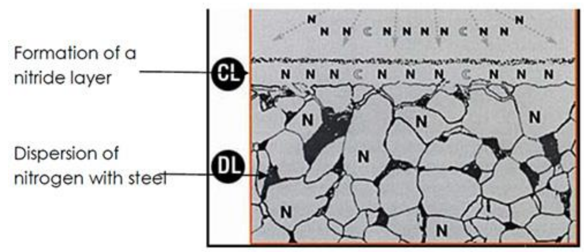

Figure 1: Dispersion of nitrogen in steel.

Nitration reactions cause unwanted inhomogeneous mechanical properties across the sample. Subsequent metallurgical analysis of the quenched sample leads to incorrect results.

In TA Instruments' DIL 805 helium, argon and other inert and reducing gases can used for quenching the metal samples. These gases prevent the nitration of the sample and preserve an unaffected metallurgical structure of the sample after the quenching measurement.

LEIDENFROST EFFECT

The Leidenfrost effect is a physical phenomenon in which a liquid, close to a surface that is significantly hotter than the liquid's boiling point, produces an insulating vapor layer that prevents the liquid from boiling rapidly. Because of this 'repulsive force', a droplet hovers over the surface rather than making physical contact with the hot surface.

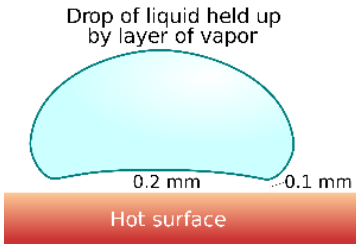

Figure 2: Leidenfrost effect – liquid droplet hovering above hot surface on a insulating vapor layer.

In quenching dilatometry this happens when cold nitrogen gas is generated from liquid nitrogen by evaporation for cooling to sub-ambient temperatures. A high flow of cold gas is required to achieve high quenching rates. The cold nitrogen gas flow can carry away droplets of liquid nitrogen. When these droplets are blown with the nitrogen gas on the hotter sample the droplets will hover over the sample's surface. Evaporation of these droplets takes long time since the insulating vapor layer reduces the heat transfer between the droplet and the sample.

The boiling nitrogen droplets will remain at liquid nitrogen temperature until they are completely evaporated. This causes temperature inhomogeneities in the sample. The spots which are close to a droplet may be too cold when the sample is cooled by the evaporation. Or these spots can be too hot since the insulating vapor layer prevents effective heat transfer. In any case the temperature at these spots is unknown and not well defined [2, 3]. The result is an inhomogeneous temperature distribution in the sample when cooled with nitrogen.

In TA Instruments' DIL 805 helium gas is used for sub-ambient quenching. The helium gas is cooled in a heat exchanger by liquid nitrogen. The cold helium gas is then blown on the sample for cooling. Helium cannot condense at liquid nitrogen temperature. Thus, the cold helium flow will always be in gas phase and generates a homogeneous temperature in the sample.

In addition, the thermal conductivity of helium is orders of magnitude higher than the thermal conductivity of nitrogen. This allows to cool the sample much more efficiently with helium compared to nitrogen.

CONCLUSION

Although nitrogen is the technically simplest and cheapest solution as cooling gas for quenching dilatometers, it has serious disadvantages. Therefore, TA Instruments DIL 805 quenching dilatometers allow using other inert and reducing gases as cooling gas. Especially in sub-ambient temperature applications, helium has proven to be an effective cooling gas that provides a homogeneous temperature distribution in the metallic sample.

REFERENCES

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