Two phase spray cooling for specific local quenching of workpieces in flexible flow fields

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Abstract

By quenching for hardening in association with heat treatment processes of workpieces a distortion compensation can be realized by impressing controlled asymmetric heat transfer conditions on workpiece surfaces by the use of liquid jet or spray arrangements. The controlled quenching in and with liquid media and especially the use of multiphase atomizers for spray cooling processes increases the possibility for generating specific local heat transfer conditions and therefore achieving results of asymmetric quenching on workpieces.

Introduction

The quenching for hardening of workpieces is often associated with a workpiece distortion after the final heat treatment process. This distortion is practically compensated by material allowance in the manufacturing and finishing rework after the final heat treatment process. The avoidance of workpiece distortion in heat treatment processes can also be realized by impressing asymmetric cooling conditions by the use of flexible flow fields based on fluid jets or sprays. The controlled liquid quenching (jet cooling) and especially the spray cooling enables the possibility to generate specific local heat transfer conditions on workpiece surfaces, which enables asymmetric quenching for reducing distortion.

For the analysis of workpiece distortion activated by heat treatment, the hardening process by quenching in adapted flexible flow fields is modelwise described in the framework of the Collaborative Research Centre (SFB570) "Distortion Engineering" at the University of Bremen [1]. Here, process conditions and the resulting heat transfer from workpiece surfaces to the ambient and quenching medium are crucial conditions for the quenching process and a possibly appearing distortion.

The asymmetric jet quenching has originally been developed for gaseous flow processes [2]. By controlled quenching in liquid media (like water or hardening oil) and by means of jet or spray cooling with these media, the heat transfer process can be heavily intensified [3].

By use of multiphase atomizers for impressing intensive local heat transfer on surfaces it is possible to avoid vapour layer formation on a heated workpiece surface [4]. For that, spray of fine liquid and an overlaid gaseous flow is impinged on the heated surface. The liquid fraction of that spray is restricted so that no closed liquid film with a vapour layer underneath is built. On that process, the efficiency of a complete evaporative cooling can be ideally reached.

In this contribution the spray cooling process by controlled two phase sprays of air and water is described. The use of this cooling method for quenching of workpieces in a spray field offers the potential to generate local cooling conditions in the heat treatment process. It builds the process technological basis for a specific distortion compensation during quenching processes on workpieces.

Methods

For analysis of the spray cooling process a twin fluid atomizer with water and air is used. This atomizer is typically used for cooling in steel casting processes and is assigned by very high (up to 26 l/min) mass fluxes for the liquid phase. The given operation parameters (gas pressure and liquid mass flow) and espatcially the operation boundaries (minimum and maximum mass flow) are examined and defined in experimental investigations. The analysed workpieces are steel cylinders of AISI 5120 (lengh 200 mm, diameter 20 mm) from the process chain of the SFB 570.

For efficient estimation of the spray process a spray characterization in combination with measurements of heat transfer coefficients, according to [5], are performed. The spray characterization consists of drop diameter measurements by using Laser Diffraction Techniques and droplet velocity examinations done by Particle Image Velocimetry (PIV). The measurement of liquid mass flux distribution is done by patternators.

These enable the calculation of local Weber numbers as

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$$We = \frac{u^2 \cdot \rho \cdot d}{\sigma}, \qquad (1)$$

whereby the drop behaviour during workpiece surface impact can be characterized and evaluated by approaches of Bolle/Moureau and Berg [6, 7]. In compliance with given boundary conditions the heat transfer coefficients α can be calculated in dependence of the impingement density dm/dt, accordingly to an approach of Puschmann [4]:

$$\alpha = \frac{dm}{dt} \cdot 16{,}8 \cdot u^{0,12} \cdot d^{-0,29}. \qquad (2)$$

The knowledge of the calculated heat transfer coefficients for chosen operation parameters builds the basis for continuous analysis and validation of the cooling effect by asymmetric quenching of workpieces by spray cooling. Specimen cooling curves in spray cooling processes will be discussed.

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Nomenclature

d	diameter [m]
dm/dt	impingement density [kg·m^{-2}·s^{-1}]
m	mass [kg]
t	time [s]
u	velocity [m·s^{-1}]
We	Weber number
α	heat transfer coefficient [W·m^{-2}·K^{-1}]
ρ	density [kg·m^{-3}]
σ	surface tension [N·m^{-1}]

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