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Heat transfer associated to a hot surface quenched by a jet of oil-in-water emulsion

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ABSTRACT

In hot rolling, the mechanical properties of steel alloys are conditioned by the rolling process but a great part is ensured by the cooling of the hot strip mill. Well controlling this cooling rate and its homogeneity is thus of primary importance for obtaining steels with desired mechanical properties. As the water used in the cooling stage of the rolling process can be polluted by oil (in hot mill strip, some oil is used to lubricate the rolls and a part of it can pollute the water), it is important to know how much varies the cooling rates when water is polluted. In this study, transient cooling has been investigated during quenching of a hot metal disk with various subcooled oil-in-water emulsion jets. The aim of this work is to compare the cooling efficiency of oil-in-water emulsion jet with a pure water jet. Experimental investigations of axisymmetric jet impingements on a preheated hot metal disk (500–600 °C) have been performed with various oil-in-water emulsions. The transient cooling heat fluxes on the quenched side are estimated by coupling the measurement of the temperature field of the other side (rear face) with a semi-analytical inverse heat conduction model.

1. Introduction

Impinging jets are very effective means for cooling solid media: a cold liquid jet that impacts a hot surface vaporizes partly. By this process, it is possible to remove a very important amount of energy: the latent heat associated with the phase change of the working fluid yields a high flux cooling level. This kind of technique is used in many engineering applications: cooling of powerful chips in electronics, cooling of tools during machining, cooling the metal strip in hot rolling processes. In hot rolling, the mechanical properties of steel alloys are conditioned by the rolling process but a great part is ensured by the cooling of the hot strip mill. Well controlling this cooling rate and its homogeneity is thus of primary importance to obtain steels with desired mechanical properties. Since the water used in the cooling stage of the rolling process can be polluted by oil (in hot mill strip, some oil is used to lubricate the rolls and a part of it can pollute the water), it is important to know how various are the cooling rates when water is polluted. In this study, transient cooling has been investigated during quenching of a hot metal disk with various subcooled oil-in-water emulsion jets. The aim of this work is to compare the cooling of oil-in-water emulsion jet with a water jet. Experimental investigations of axisymmetric jet impingements on a preheated hot metal disk (500–600 °C) have been conducted with various oil-in-water emulsions.

2. Literature survey

A lot of work has already been done on heat transfer by water jet impacting a hot surface (500–600 °C). The evolution of local heat transfer is usually plotted as function of the overheating of the wall (wall temperature – saturation temperature of the liquid) commonly called "boiling curve". It is now admitted that beneath the jet (in the impact zone), the boiling curve has a particular shape with a boiling transition regime extended to high overheating. This phenomenon was observed by Ishigai et al. [1], Miyasaka and Inada [2], Ochi et al. [3] and later by Robidou [4] and more recently by Gradeck et al. [5]. In fact, beneath the jet and in the early stage, the vapor film is unstable and can sometimes be broken by the jet, leading to partial rewetting of the wall and thus an increase of the heat flux. Outside the impact zone, the boiling curve is conventional, see Fig. 1.

The experiments we have made consist in quenching a metal disk with a subcooled liquid jet (water or mixing). These experiences are similar to those made by Woodfield et al. [6], Islam et al. [7] and Mozumder et al. [8]. These publications have focused on quenching of various metal blocks and their approach is similar to ours: the heat flux is also estimated from internal temperatures using an inverse method developed by Woodfield et Monde [9]. The originality of the present paper comes from the experimental set-up, the tested liquid (oil emulsions) and also from the inverse method. In what follows, after we have described the experimental set-up and apparatus, given some explanations on the inverse method, we will focus on mixing boiling in Section 4.

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