RAPID COOLING OF A CYLINDER IN A LIQUID BATH WITH INJECTION OF FRESH LIQUID

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Rapid developments in industry and the demand for higher performance and lower cost forces engineers to look for more efficient techniques to produce materials with the best mechanical properties such as hardness, strength and others. In this context, the quenching phase during a heat treatment process plays an important role in improving material hardness. Different cooling techniques are used, such as quenching in a liquid bath or spray quenching. Several studies have dealt with quenching process but these were more concerned with the metallurgical performances and were experimental analyses. These is a scarcity of numerical simulation in this area.

Reti *et al.*[1] considered prediction of hardness after rapid austenitization and cooling. Bernardin and Mudawar[2] explored the relationship between the heat transfer mechanisms and metallurgical transformations associated with spray quenching of aluminum alloys. They showed in their study that it is possible to reduce the temperature gradients within an aluminum workpiece during quenching without compromising hardness or strength. Chen *et al.*[3] analyzed heat conduction with variable phase transformation composition during quench hardening of a thick wall tube. Liu *et al.*[4] investigated, in their work, mechanical properties and microstructure after continuous cooling and isothermal treatment of high carbon hot rolled high strength steels.

The present study analyzes rapid cooling of a cylindrical specimen of a Nickel workpiece quenched in a liquid bath. Numerical simulations are carried out to fundamentally examine heat transfer mechanisms and performances. The work focuses on the effect of forced convection by changing the velocity of the cooling fluid and the nature of the liquid bath through the physical properties of the quenchant fluid.

Results show that increasing the fluid motion reduces the temperature at the center of the specimen as well as at the external surface. This is mainly true after approximately 4 seconds of cooling i.e. at small cooling rate (less than 100 K/s). This is illustrated in Figs. 1 and 2.

A detailed analysis of the heat transfer coefficient on each face of the workpiece: bottom face subject to an impinging flow, lateral face subject to a parallel flow and the top face less exposed to the fluid motion is carried out. Figure 3 exhibits the convective coefficient. Paradoxically, the upper face is less cooled when the fluid is in motion. This induces that less heat is evacuated from this face. Consequently, the upper part of the specimen will not be cooled as much as the lower part.

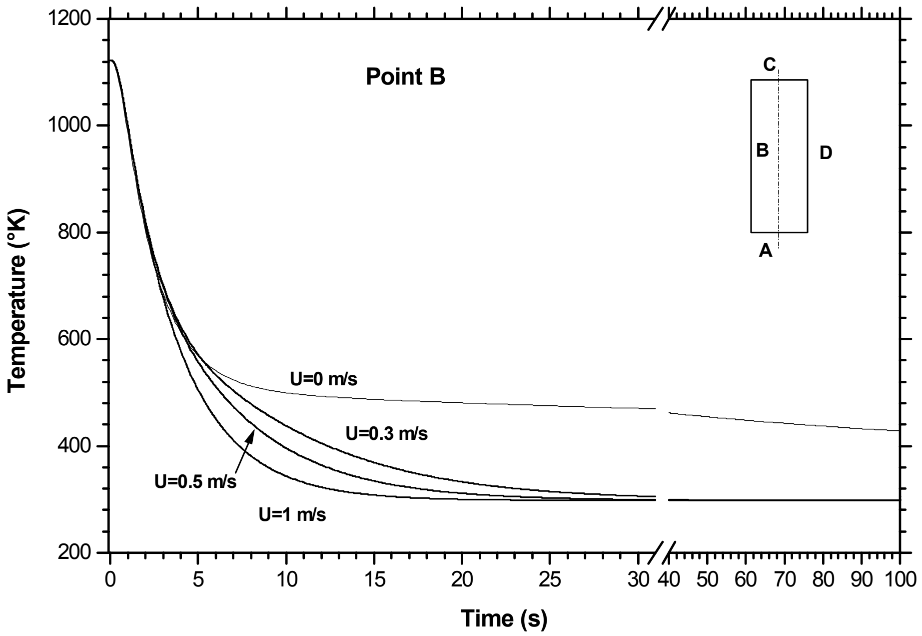

Fig. 1 : Effect of fluid velocity on center temperature

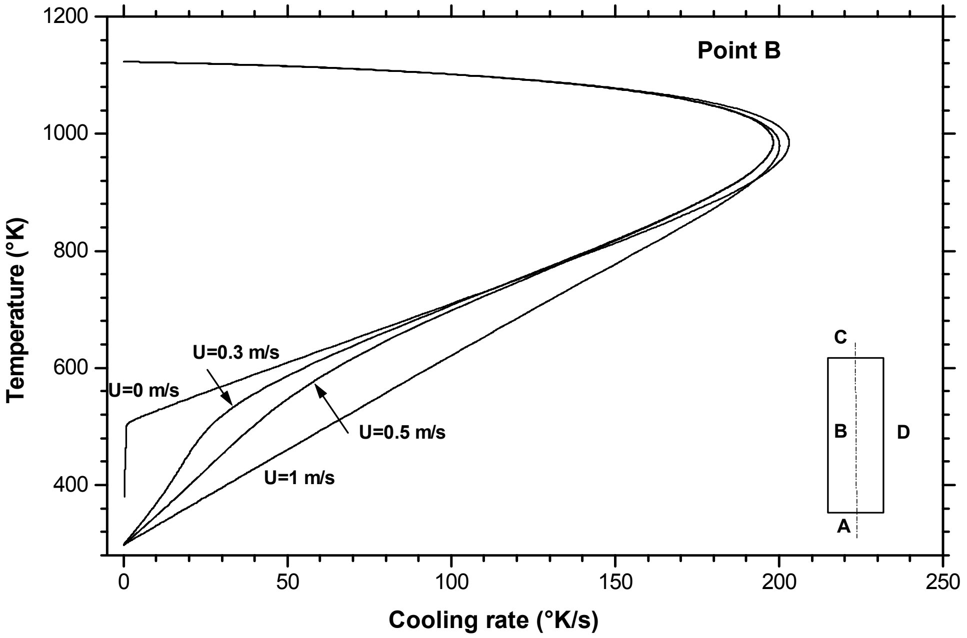

Fig. 2 : Effect of fluid velocity on cooling rate

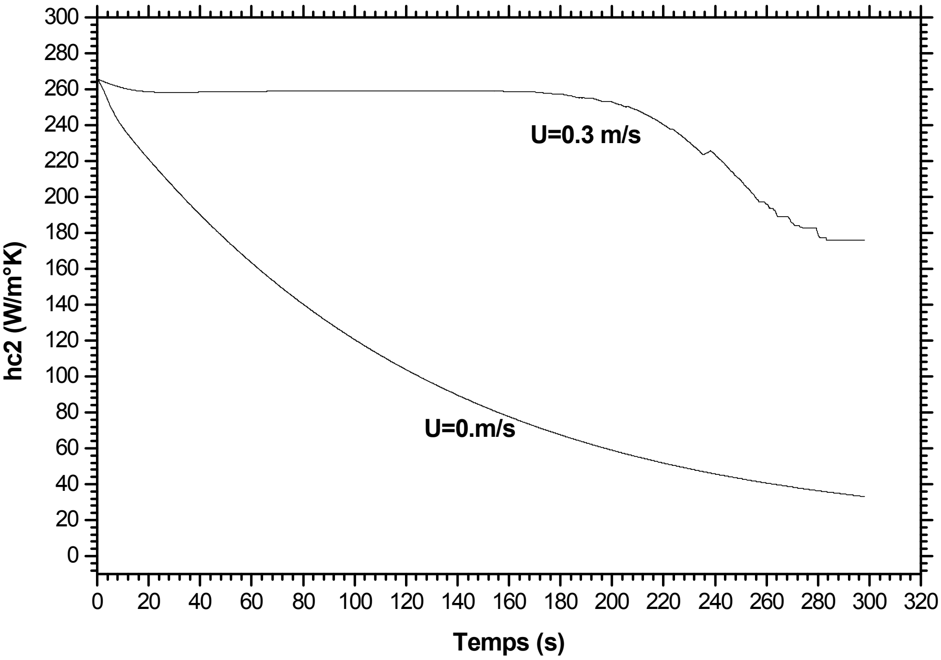

Fig. 3: Heat transfer coefficient evolution

In conclusion, one can say that increasing the fluid velocity yields higher cooling rates. But, in a counter part, the upper zone of the specimen is less cooled the remaining of the workpiece.

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