Abstract

Modern steels used in the manufacturing of ships, buildings, automobile industries and large gas pipe lines require high tensile strength and toughness combined with good weldability which are directly related to the microstructure of the steel. These properties in the steel can be achieved by using ultra fast cooling technology in which fast cooling rate is the desired criteria. But, this is difficult to obtain in case of cooling by conventional cooling methods. This happens because the conventional cooling methods are highly affected by the Leidenfrost effect at high initial surface temperatures. However, in open literature, the mechanism of heat transfer and the process to achieve UFC have never been disclosed. Therefore, the requirement of a high cooling rate is the main thrust for the invention of the ultra fast cooling (UFC) technique. Hence, in the current research, attempt has been made to produce ultra fast cooling rate by using different cooling methodologies. In the present investigation, for water jet and air atomized spray experimentations, separate experimental setups with adequate instrumentation facilities to monitor the operating variables have been designed and fabricated. For the quantification of heat transfer rate and its interpretation, the surface heat flux and the surface temperatures have been calculated by using INTEMP software. The first cooling methodology used in the current work is the surfactant added water jet. The results depict that the dissolved surfactant enhances the cooling rate by increasing the wettability characteristics of the water jet at high surface temperatures and as a consequence significant heat removal rate (140 ^{O}C/s) has been observed. Air atomized spray with low and high mass flux have been used as other cooling methodologies. The heat transfer analysis depicts that a maximum cooling rate of 165 ^{O}C/s has been attained in case of low mass flux air atomized spray and a cooling rate of 182 ^{O}C/s has been achieved in the case of air atomized spray with high mass flux due to the superposed flow effect of air. Further, for achieving better cooling rate, air atomized spray has been tried with surfactant and salt added to it. The dissolved surfactant in water droplet decreases the droplet contact angle with the hot surface which in turn provides higher heat transfer area and as a result a maximum cooling rate of 191 ^{O}C/s has been achieved in the case of air atomized spray with surfactant. In addition to the above, it is also observed that the dissolved salt in water droplet in the case of air atomized spray with salt enhances the cooling rate and attains a maximum cooling rate of 242 ^{O}C/s. The cooling rates obtained in the current research for all the aforesaid cooling methodologies are found to be in the ultra fast cooling domain of a 6 mm thick AISI-304 steel plate. Furthermore, this study also includes the effect of ultra fast cooling rate on oxide layer and the improvement of mechanical properties of the treated steel. By using Box-Behnken factorial design methodology, the interactional effects have been studied separately for each of the cooling process and also empirical correlations for the average heat flux and cooling rate as a function of the process parameters have been developed.

Keywords: Atomized spray; Cooling rate; Nucleate boiling; Response surface methodology; Salt; Surfactant; Transition boiling; Water droplet; Water jet