World Academy of Science, Engineering and Technology
International Journal of Mechanical and Industrial Engineering
Vol:14, No:06, 2020

Uniform and Controlled Cooling of a Steel Block by Multiple Jet Impingement and Airflow

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Abstract : During the cooling of hot metals by the circulation of water in canals formed by boring holes in the metal, the rapid phase change of the water due to the high initial temperature of the metal leads to a non homogenous distribution of the phases within the canals. The liquid phase dominates towards the entrance of the canal while the gaseous phase dominates towards the exit. As a result of the different thermal properties of both phases, the metal is not uniformly cooled. This poses a problem during the cooling of moulds, where a uniform temperature distribution is needed in order to ensure the integrity of the part being formed. In this study, the simultaneous use of multiple water jets and an airflow for the uniform and controlled cooling of a steel block is investigated. A circular hole is bored at the centre of the steel block along its length and a perforated steel pipe is inserted along the central axis of the hole. Water jets that impact the internal surface of the steel block are generated from the perforations in the steel pipe when the water within it is put under pressure. These jets are oriented in the opposite direction to that of gravity. An intermittent airflow is imposed in the annular space between the steel pipe and the surface of hole bored in the steel block. The evolution of the temperature with respect to time of the external surface of the block is measured with the help of thermocouples and an infrared camera. Due to the high initial temperature of the steel block (350 °C), the water changes phase when it impacts the internal surface of the block. This leads to high heat fluxes. The strategy used to control the cooling speed of the block is the intermittent impingement of its internal surface by the jets. The intervals of impingement and of non impingement are varied in order to achieve the desired result. An airflow is used during the non impingement periods as an additional regulator of the cooling speed and to improve the temperature homogeneity of the impinged surface. After testing different jet positions, jet speeds and impingement intervals, it's observed that the external surface of the steel block has a uniform temperature distribution along its length. However, the temperature distribution along its width isn't uniform with the maximum temperature difference being between the centre of the block and its edge. Changing the positions of the jets has no significant effect on the temperature distribution on the external surface of the steel block. It's also observed that reducing the jet impingement interval and increasing the non impingement interval slows down the cooling of the block and improves upon the temperature homogeneity of its external surface while increasing the duration of jet impingement speeds up the cooling process.

Keywords : cooling speed, homogenous cooling, jet impingement, phase change
Conference Title : ICHTA 2020 : International Conference on Heat Transfer and Applications
Conference Location : Tokyo, Japan
Conference Dates : June 11-12, 2020