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# Measuring the water temperature changes in Ice abrasive water jet prototype

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**Abstract**

Ice abrasive water jet (IAWJ) technology is a technology under development with the aim to breach the gap in productivity between the abrasive water jet (AWJ) and water jet (WJ) cutting by using ice particles instead of mineral abrasive. Such technology would be clean and environmentally friendlier in comparison with AWJ, while its cutting efficiency would be better than that of WJ. Due to heavy temperature dependence of the mechanical properties of ice used as an abrasive, it is essential that the temperatures occurring in the system are monitored and controlled. This paper presents the results from temperature measurements of water taken from different parts of the IAWJ prototype, both before and after the orifice, at different temperature and pressure conditions, using different orifice sizes.



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*Keywords:* Ice abrasiwe water jet, ice jet, temperature measurements, ice particles, AWJ

## 1. Introduction

The use of high speed water for the material removal is not a recent idea and has been used for centuries in terms of mining and soil removal. Because of their versatility, being able to cut virtually all types of materials, today both water jet (WJ) and abrasive water jet (AWJ) technologies are gaining in industrial implementation.

This paper reports on a novel AWJ technology, more specifically on its thermal aspects. The technology is called ice abrasive water jet (IAWJ) or ice jet (IJ) and compared to conventional AWJ uses ice grains instead of mineral abrasive. It is expected that the capability of this technology would be between pure WJ and AWJ.

The paper presents the results obtained from water temperature measurements taken at different parts of the custom built WJ machine, specially adapted to be used for IAWJ machining. The IAWJ prototype is a combination of a priori prepared ice particles injected into the cutting head together with gaseous cooling media and a subcooled water jet. In order to measure the thermal conditions that the ice grain abrasive will be exposed to, the temperatures of water were taken at normal operating conditions as well as when water under high pressure is cooled. Several research works are reported [1]–[6] which deal with water temperature measurement in order to analyse the AWJ process, but none deal specifically with temperature characterization of the AWJ machine at both normal and low temperatures.

Our research groups have performed preliminary work in this area [1], [2] by measuring temperatures on the commercial AWJ machine, which gave initial insight into thermal conditions on such machines. Kovačević et al.[3] and Mohan et al.[4] studied the temperature distribution in the AWJ focusing nozzle in order to monitor the wear of the nozzle using an infrared thermography method. Kovačević et al.[3] measured the temperature distribution for three differently worn focusing nozzles. Two relations were established: as the nozzle diameter increases due to wear, first the peak temperature decreases, and second the position of the temperature peak moves toward the nozzle exit. Liu and Schubert [5] measured the temperature on the focusing tube, on the

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Flash AWJ system in order to control the temperature of the water for piercing different materials. Bach et al.[6] monitored the temperature at the inlet and outlet of the pre-cooling system for their in-process ice particle generation system, where they cooled the water from 25 °C to -20°C.

Based on presented background and preliminary experiments[1], an experimental setup was built in order to test the influence of pressure, high pressure water temperature and orifice size on the water temperature variation throughout the IAWJ system.

## 2. Experimental Setup

In order to perform the water temperature measurements on our IAWJ prototype, a custom made 2-axis AWJ cutting system was designed and assembled in the laboratory of the authors and is shown in Figure 1. It is equipped with a high pressure direct drive pump (P-2040, Omax, USA), with maximal pressure up to 280 MPa and flow rate of 3.2 l/min.
The cutting head (Allfi, AT) was connected to the high pressure pump using two high pressure pipe lines controlled by two 3-way valves V2 and V3 and a check valve V4, so that the water could be directed either directly to the cutting head or through the heat exchanger unit, positioned in between as shown in Figure 2. A cooling compressor with 7.3 kW (Danfoss, SI) of cooling power was used to cool the cooling medium, a glycol-water solution, down to -25 °C. Submerged in this solution were high pressure pipes that were bent into a coil. The temperature of the cooling medium was regulated in order to achieve the desired temperature before the cutting head. Pipes leading from the heat exchanger to the cutting head were thermally insulated using 20 mm thick insulating foam (Armaflex, Armacel, DE).

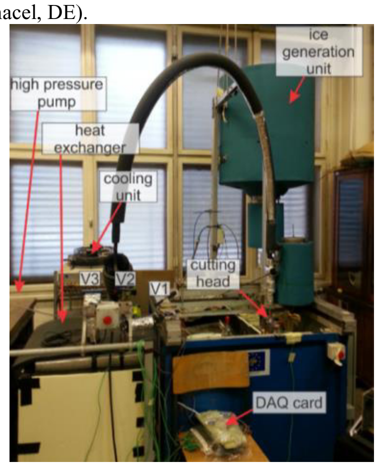


Figure 1. The experimental setup, showing the major components of the IAWJ prototype.

In order to measure and regulate the temperatures of different parts of the high pressure water system, six 1.5 mm thick K-type and one 0.5 mm T-type class 1 thermocouples (TC) were used. TCs were connected to a 24 bit USB-2416-4AO data acquisition card (DAQ) (Measurement computing, USA), with 16 differential channels for thermocouple readings, all with cold junction compensation. The data from the DAQ were acquired and stored using a program created in LabVIEW program package (National Instruments, USA). Different positions of the TCs are shown in Figure 2.

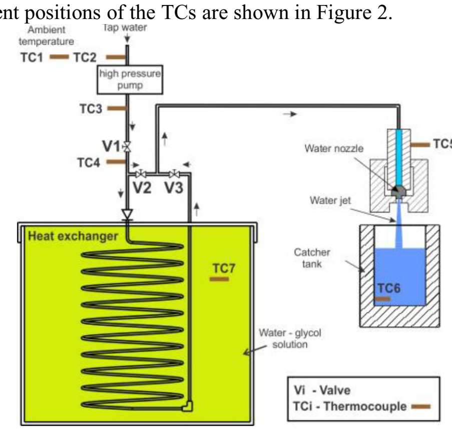


Figure 2. Schematic representation of the experimental setup.