HIGH PRESSURE RINSING WATER JET CHARACTERIZATION

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Abstract

High pressure rinsing is widely used as the final wet step in the high field superconducting cavities production. The interaction of an high speed ultra pure water jet with the niobium surface depends on various parameters such as water pressure, water throughput, treatment duration, cavity rotation speed, etc. In this paper we illustrate a simple technique for the characterization of water jet parameters based on the momentum transfer between the water jet and a load cell. The jet profile and its dependence on water pressure as well as the force exerted by the jet on the surface are easily measured. Moreover a portable apparatus has been set up and the information gathered in different laboratories will be used for a quantitative comparison of the different HPR systems. These measurements allow to study the correlation of the jet parameters with the effects (surface status, oxide formation, corrosion, etc.) of the water interaction with the niobium surface. Furthermore a new analysis, based on the luminescence induced on transparent dielectric samples, is used for confirmation of the water jet structure.

INTRODUCTION

High pressure rinsing (HPR) is routinely used in the process of Superconducting Cavities assembly to remove residuals from the resonator wall [1]. Nevertheless, detailed studies have not yet been performed to investigate and optimize the HPR process. This activity is an important item, particularly for ILC (International Linear Collider), where performance improvement, reliability and cost reduction are mandatory. In this paper we address the problem of characterization of the water jet properties and of its profile.

EXPERIMENTAL SETUP

The HPR system used for this experiment is based on an Ultra Pure Water system, a high pressure pump, a filter and a spray head with six nozzles.

Fig. 1. HPR Test apparatus with luminescence glass plate mounted. Head with six nozzles mounted in the center.

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The high purity water (ρ ≥ 18 MΩ·cm), generated from a SuperQ Millipore plant, is fed to a high pressure pump (Kärcher HD 600 C) able to supply 10 liters per minute at 100 bar. The high pressure water is filtered by a 40 nm-100 bar filter and then sprayed by a head mounting 6 nozzles. A load cell TEDEA HUNTLEIGH mod. 505H-2M-2 (max load 2 kg, resolution 1 g), placed at proper distances from the nozzle, characterizes the force exerted by the water jet. Wedges are installed on the load cell to measure the angular dependence of water force as it will be described below. Fig. 1 shows the apparatus with the luminescence setup.

JET FORCE AND PROFILE

The first step in the characterization of the 100 bar water jet is the determination of its total force and its profile at different distances from the nozzle, moving the jet over the load cell [2]. Fig. 2 shows a typical scan of the jet impinging normally to the load cell for the L-0.55-L nozzle (see Table 1).

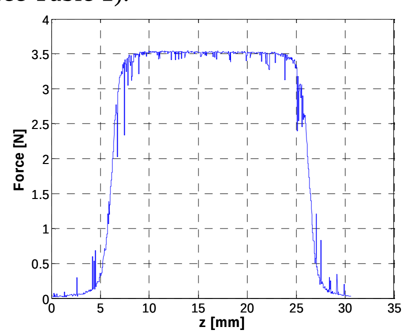

Fig. 2 Scan of the water jet profile on the load cell at 100 bar, 86 mm from the nozzle.

The same measurement, approximating the jet force radial dependence with a Gaussian profile, allows to measure the jet spot dimensions applying

$$F(z) = \frac{F_0}{2} \cdot \left[1 + Erf\left(\frac{z - z_0}{\sqrt{2} \cdot \sigma} \right) \right]$$

at the rising and falling edge of the scan. F_0 is the total force and σ is the spot size. The jet parameters are calculated fitting *F(z)* to the experimental values. The spot size variation vs. distance is discussed in the section on nozzle properties.

3 JET FORCE AND PROFILE ANGULAR DEPENDENCE

A further step in the water jet characterization is the measurement of the force and spot size versus the incidence angle on the sample.

This is important for the HPR parameter optimization especially for low beta cavities where the cavity wall is near to be perpendicular to the cavity axis. In this case, variation of force and spot size are significant and have to be taken into account.

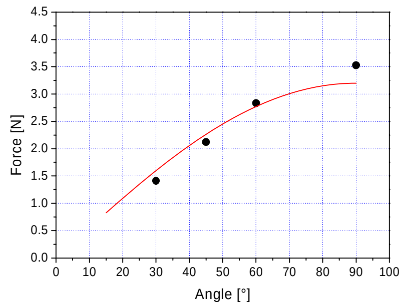

Fig. 3. Force angular dependence at 53 mm from the spraying nozzle axis @ 100 bar for a L-0.55-L nozzle (see Table 1).

The data reported in Fig. 3 show a sin dependence of the measured force with respect to the impact angle of the water jet on the force sensor.

DIFFERENT NOZZLE PROPERTIES

Different nozzle has been measured and a summary of their properties is reported in Table 1. The nozzles are identified by the laboratory where they come from (JL=Jefferson Lab (USA), L=INFN Milano–LASA (Italy)), the diameter of the nozzle and the lab where they have been characterized. A special nozzle is JL-Fan-L that has a fan jet instead of the usual round one. The JL-0.4D-L is a DESY-like nozzle. An updated summary of the nozzle measured so far is available online [3].

Table 1. Summary of the parameters for the nozzles measured so far. σ_{17} is the spot at 17 mm, σ_{52} at 52 mm and σ_{86} at 86 mm from nozzle exit that is at 17.5 mm from the head axis. The fan nozzle has been measured only in the plane of the thin part of jet. The pressure during these measurements is 100 bar.

Nozzle Type	Force [kg]	σ_{17} [mm]	σ_{52} [mm]	σ_{86} [mm]	Flow [l/min]
JL-03-L	0.09	0.30	0.57	0.87	0.43
JL-0.6-L	0.38	0.74	1.32	2.08	1.62
JL-1.0-L	1.35	0.82	1.43	2.16	5.14
JL-Fan-L	0.98	1.17	-	-	4.82
JL-0.4D-L	0.17	0.25	0.39	0.46	0.74
L-0.55-L	0.35	0.35	0.6	0.75	1.41

Measurements of the force profile at different distances from the nozzle allows to parameterize the jet spot variation with distance. Fig. 4 shows a typical spot trend versus distance for a JL-0.6-L nozzle. The pressure exerted by the jet on the cavity wall is related to the force of the impinging water jet and to the spot size. This problem has been previously considered [2] showing the pressure variation, induced by a changing spot, along a typical TESLA cavity.

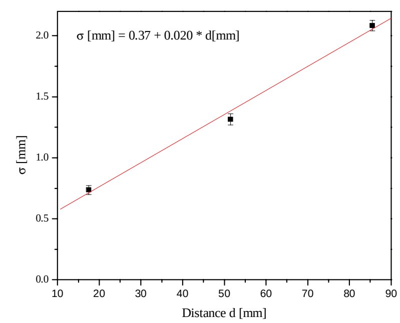

Fig. 4 Spot variation versus distance from the nozzle axis. The nozzle is positioned at 17.5 mm from the head axis. On this distance scale, a linear interpolation fits the experimental data.

WATER JET STRUCTURE

A further characterization of the jet has been done studying the luminescence induced by the water jet on a glass plate positioned in front of the nozzle at different distances. The luminescence pictures have been recorded using a digital camera. The exposition time and diaphragm of the camera has been chosen to have not saturated images. The resolution of the system is 40 µm per pixel. A typical example of images taken at different distances from the nozzles is reported in Fig. 5.

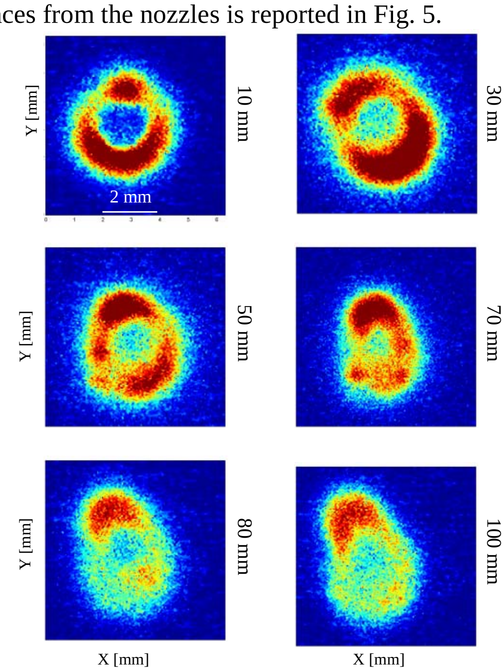

Fig. 5. Luminescence images from a JL-1.0-L nozzle at different distances (reported on the left side of each image) from the nozzle.

The core of the jet is clearly visible at 10 mm from the nozzle (upper left image), identified by the blue central area. The annulus around the core represents a turbulence region which surrounds the core itself. As the distance increases, the central core evolves in a completely turbulent jet characterized by the diffuse luminescence light. The jet outer shape also changes from an initial round form towards an elongate structure.

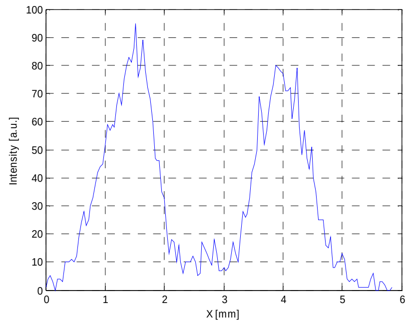

Fig. 6. Cross section of the luminescence image, through the center of the jet, at 10 mm (see Fig. 5) from the nozzle. The central minimum corresponds to the core of the water jet.

The profile of the 10 mm image (Fig. 6) shows a clear flat minimum in the center, corresponding to the jet core. A two side wings are the turbulence region that surround the jet. Assuming a Gaussian profile for the beam and considering the full beam at 6 σ from the center, the sigma value we calculate from Fig. 6 is about 0.8 mm in agreement with the spot size derived by the force measurement at 17 mm (see Table 1).

A more interesting case is the one from JL-0.4D-L nozzle, a TESLA like nozzle. As in the previous case, at 10 mm a well defined core is visible surrounded by the turbulence annulus. While moving away from the nozzle, the central core part vanishes and the jet profile changes from round to elliptical. Moreover at 70 mm, the core part completely disappeared and we have a two lobes jet that then smears out at larger distances. The profile of the "10 mm" image shows again a flat minimum corresponding to the core and a σ of about 0.33 mm comparable with the one derived by the force profile.

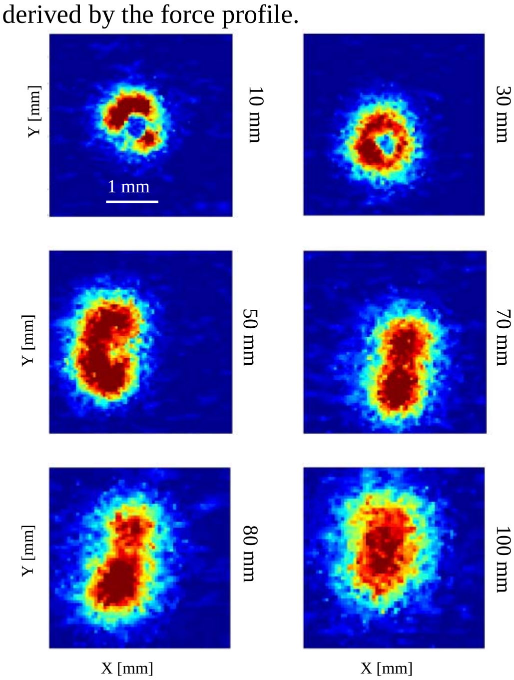

Fig. 5. Luminescence images taken for water jet from a JL-0.4D-L nozzle at different distances from the nozzle.

NIOBIUM SAMPLE PREPARATION

The effect of a prolonged impact of the high pressure water jet on a Nb sample was investigated by analyzing the formation of color rings on the sample surface [3]. The samples were polished by Buffered Chemical Polishing (BCP). We have repeated the same measurements on optically polished samples. The final surface polishing has been done with 50 nm diamond powder, guarantying a smoother surface than the BCP one. A clear influence of the surface different finishing has been observed. The optically finished sample show a much smaller oxidation with respect to the BCP one. Fig. 7 shows a comparison of the two samples.

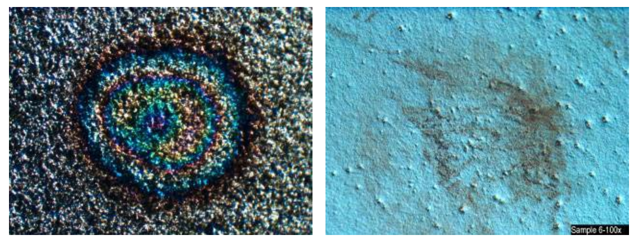

Fig. 7 Oxidation of Nb samples. Both samples have been exposed for 120 seconds to the 100 bar water jet. On the left, a Nb sample BCP treated. Many color rings are visible, meaning the formation of a thick oxide layer. On the right a optical polished sample. The oxidation is much smaller.

CONCLUSIONS

We have presented an improved characterization of a high pressure water jet used for final cleaning of SC-RF Cavities. The luminescence produced by the water jet impinging on a glass plate has been analyzed. The main feature of this technique is the possibility to study the evolution of the jet core with distance. A typical 0.4 mm nozzle shows a well defined core till 30 mm from the nozzle and then it spreads into a turbulent jet. This effect might influence the cavity cleaning at iris and equator. In fact, in the case of a TESLA like cavity, the iris is at about 13 mm from the nozzle (35 mm for the head axis), where the jet has its well-defined core, while at the equator (89 mm away) the jet is completely atomized and no core is visible anymore. We then might expect different cleaning efficiency at the two locations. We plan to continue this investigation towards a final optimization of the HPR process. Also for this purpose, we have set up a portable system to test HPR systems in different labs to collect information from the main laboratories involved in the SC cavities preparation.

REFERENCES

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