

## STUDY OF THE HIGH PRESSURE RINSING WATER JET INTERACTIONS \*

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### Abstract

High Pressure Rinsing (HPR) is an important step in the cleaning of Superconducting Cavities. The understanding of the interaction of the high pressure water jet on the cavity is of primary importance for the optimization of this process for upcoming SC based projects like XFEL and ILC. In this paper, we present the results of our studies on water jet interaction on angled surfaces and its possible induced damages.

### INTRODUCTION

The reduction of the performance spread as well as an increase of the accelerating fields in superconducting RF cavities is an important issue for the future SCRF based project like the European XFEL and the proposed International Linear Collider (ILC). In these projects, a massive production of SCRF cavities is required and an optimization of the fabrication process is needed in order to reduce the overall project costs.

During the cavity preparation, High Pressure Rinsing is routinely used to remove chemical residuals and particles from the resonator walls [1, 2]. Besides its wide use, the understanding of the process and the characterization of the system used for this process are still not fully developed.

In this paper, we further exploit the potentiality of the apparatus we developed for HPR water jet characterization. In particular, we present the results of jets impinging oblique to the surface. These measurements reproduce the interaction of the jet with the wall of the SCRF cavities.

### EXPERIMENTAL SETUP

Our approach to the characterization of HPR systems has started from the study of the force exerted by the HPR jet on a surface. The experimental setup is based on a load cell, properly modified to withstand the wet environment of the HPR system [3], mounted at different positions from the nozzle to allow measuring the force at representative distances (i.e. iris or equator position). The load cell is a TEDEA HUNTLEIGH mod. 505H-2M-2 and has 2 kg dynamic range and 1 g resolution.

The measuring device is portable and it is easily installable in an HPR system [4]. It has its own acquisition system based on a LabVIEW program. These units can be used to characterize HPR systems but also to routinely check the status of the nozzles and of the overall HPR performances within a Quality Control loop

The high purity water ( $\rho \geq 18 \text{ M}\Omega\text{cm}$ ) used in this experiment is generated from a SuperQ Millipore plant

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and it 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 (40 nm) and then sprayed by a head mounting 6 nozzles.

Different target shapes are mountable on top of the load cell (Fig. 1) to simulate the interaction, at an angle, of the water jet with SCRF cavity wall. Changing not only the target shape but also the angle of the cell with respect to the jet, a wider range of water jet-target angle is accessible.

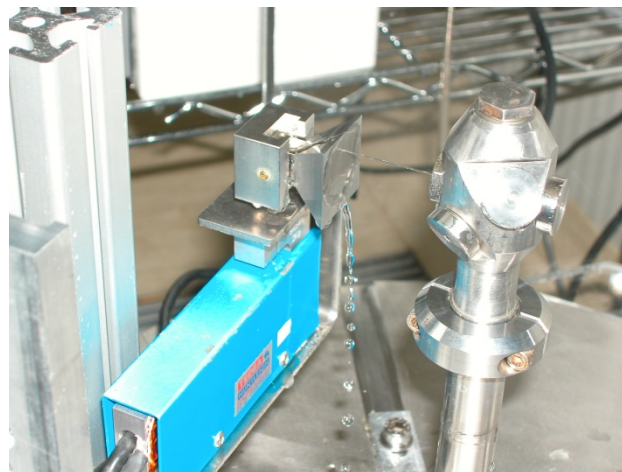


Figure 1: Setup for water jet force characterization. 90° wedge mounted on top of the TEDEA HUNTLEIGH load cell.

For the measurements presented in the present paper, we have three different setups (Fig. 2) for studying the force exerted by the water jet on the target, later referred as “A”, “B” and “C”.

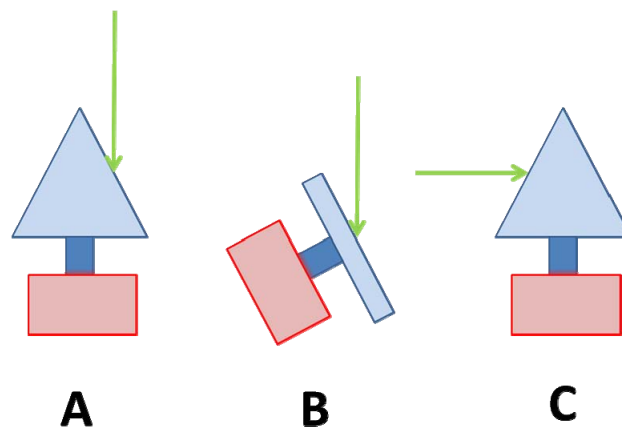


Figure 2: The three different setups used for measuring the force exerted by the HPR water jet impinging on oblique targets.

## EXPERIMENTAL RESULT

### Force vs. Angle

The theoretical force that a water jet exerts impinging on a perpendicular surface might be calculated referring to Bernoulli's law and momentum conservation [4]. For a water jet exiting a nozzle at pressure  $p$ , Bernoulli states that the velocity  $u$  is

$$u = \sqrt{\frac{2 \cdot p}{\rho}}$$

where  $\rho$  is the water density. If we now take into account the momentum conservation, the force on the target normal to the jet is

$$F = \rho \cdot Q \cdot u$$

where  $Q$  is the water flow from the nozzle. This theoretical value has to be corrected for the losses in the nozzle and the measured force is usually 10-20 % lower than expected. Typical force value at normal incidence to the target in configuration "B" is 3.5 N with respect to an expected value from the previous formula of 3.9 N. Typical parameters of our jets are  $p = 100$  bar and nozzle diameter  $\phi = 0.55$  mm. The water flow for each of the six nozzles is 1.66 l/min.

To analyze the force components for oblique jets, the general approach we follow, it is to decompose the force exerted by the water jet along the direction parallel and normal to the target. The component normal to the target is then decomposed again to get the contribution of the force in the direction of the load cell. Fig. 3 reports an example of such an analysis on an oblique target in configuration "A". In none of the case we present, the shear force exerted by the water jet on the target has been taken into account in the parallel component of the force.

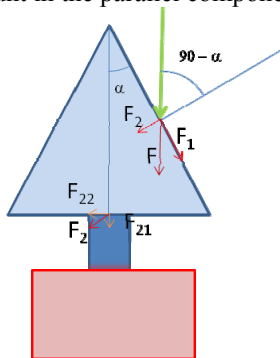


Figure 3: Force decomposition in case of water jet impinging oblique on a target. The measured force by the load cell is  $F_{21}$ .

We now present the results for the different cases reported in Fig. 2. Case "B" is discussed as first since it is the more straightforward and the results are well described by our simple model of force decomposition on the target. Case "A" and case "C" deserve instead more discussion and are presented then later.

### Case "B"

In case "B", the force decomposes parallel and normal to the target and the component normal to the target is then the force directly measured by the load cell. Fig. 4 shows the results with our typical water jet parameters. The expected sine dependence is well reproduced by the experimental data. The value at  $0^\circ$  incidence is the total force exerted by the water jet on the target.

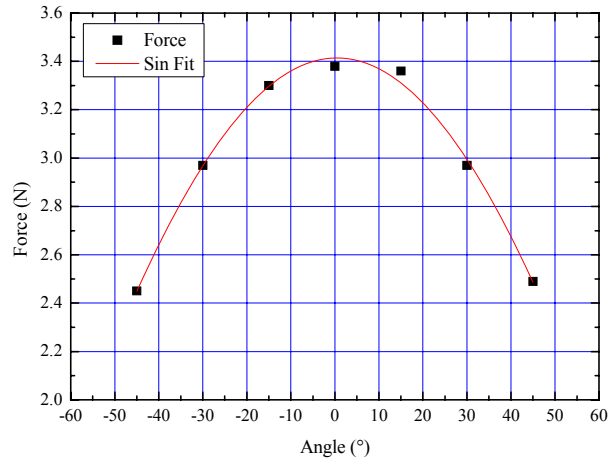


Figure 4: Case "B" interpolation with sine function. The pressure during this measurement is 100 bar. The nozzle to target distance is 90 mm.

### Case "A"

In this case, we used the four different targets mounted on the load cell that is kept in fix position and with the sensor in the direction of the impinging water jet. The force decomposition is more complex than in the previous case (see Fig. 3 for an example). The expected angular dependence of the force measured by the load cell is of the  $\sin^2$  type. Fig. 5 reports the measured values with standard water jet parameters.

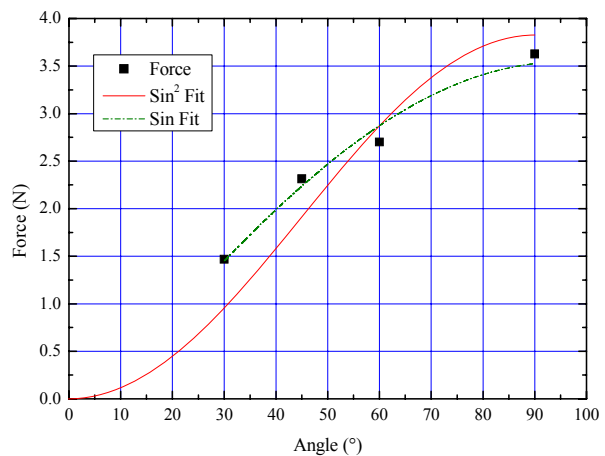


Figure 5: Case "A" interpolation with sine square function. The pressure during this measurement is 100 bar. The nozzle to target distance is 25 mm. The fit constrains are that the force at  $0^\circ$  is null and the maximum is at  $90^\circ$ . A sine function is reported for comparison.

The expected angular dependence in this case is not as well reproduced as in “B”. The values measured at smaller angles are larger than expected and the opposite happens for values at larger angles. The maximum calculated value from the fit is slightly larger than the measured one. On the same plot, we report also a fit with a sine function which seems to represent better the measured data than the theoretical sine square function.

### Case “C”

In case “C”, we used the four different targets mounted on the load cell that is kept in fix position and with the sensor in the direction normal to the impinging water jet. Given this arrangement, the total water jet force has to be measured with a different setup. Keeping the same nozzle to target distance, we measured 3.38 N as the total force exerted by the water jet. We then change the setup to the “C” configuration and Fig. 6 reports the measured results with standard parameters. The expected angular dependence of the force in this case is of the sine cosine type.

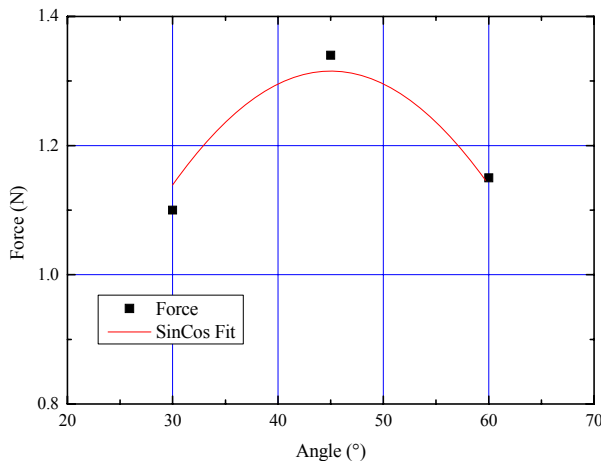


Figure 6: Case “C” interpolation with sine cosine function. The pressure during this measurement is 100 bar. The nozzle to target distance is 85 mm. The maximum force exerted by the water jet from the fit is 2.76 N.

While the expected angular dependence is reproduced in this case, the value extrapolated from the fit of the total force that the water jet exerts on the target is  $F_0=2.76$  N which is about 0.6 N smaller than the measured value at  $0^\circ$  incidence.

### DISCUSSION

As stated in the introduction, there is not a clear model of the HPR cleaning process. Our approach is, up to now, based on the characterization of the water jet and on the understanding of the water jet-cavity wall interaction. The work we have done in the past allowed to set a standard procedure to characterize the HPR water jet produced in different labs by measuring the total force and the force profile at normal incidence to the target [6]. Nevertheless, the complex shape of the SCRF cavities requires the study

also of jets that are not normal to the cavity surface. The different cases presented in this paper try to address this problem. The results we obtained are encouraging since all of them reproduce the expected angular behaviour as from simple decomposition. Case “A” seems better interpolated with a sine function instead of a  $\sin^2$ . A not such good agreement between measured and expected values has been obtained for the absolute value of the force. While case “A” and “B” reproduce, within the experimental error, the expected value of the normal force, with small discrepancies in case “A” at lower angular values, case “C” reports a maximum force of only 2.76 N instead of the measured 3.38 N. This difference has not been yet explained. To exclude instrumental related problem, we check the response of the load cell with loads that simulate the water jet force and the measurements are in agreements with the expected values. The possible influence of the water shear stress, which was not initially included in the analysis of the data, on the force exerted on target surface is under investigation. We are also considering if this effect could explain the angular dependence in case “A”. Indeed, according to Gim’s model [7] is the water shear stress of the jet impinging on the wall that is responsible for the removal of particle from the wall itself.

### CONCLUSION

The force exerted by HPR water jets impinging with an angle to the wall of a SCRF resonant cavity has been studied and presented in this paper. We have considered three different experimental setups in order to understand the water jet – target interaction. The angular dependence has been well reproduced in all of the three cases. From these measurements we have calculated the total force of the jet. Case “A” and case “B” give values within expectation while case “C” shows a lower value of the total jet force. Investigation to understand this discrepancy is ongoing.

### REFERENCES

- [1] P. Kneisel and B. Lewis, “Advance Surface Cleaning Methods”, Particle Accelerators **53** (1-4) (1996), 97.
- [2] T. Higo, J. Hong, P. Michelato and M. Fusetti, “SEM Inspection of HPR Nozzles of Four Labs for SC LC”, ILC ASIA Note, 2007-01
- [3] E. Cavaliere et al., “High Pressure Rinsing Parameters Measurements”, Physica C **441** (2006), 254-257.
- [4] D. Sertore et al, “High Pressure Rinsing System Comparison”, Proc. PAC07, Albuquerque, USA.
- [5] S. Whitaker, “Introduction to Fluid Mechanics”, Krieger Publishing Company, 1992.
- [6] D: Sertore et al., “High Pressure Rinsing System Studies”, Proc. SRF07, Beijing, China.
- [7] R. Gim, T. Lesniewski and S. Middleman, “Fluid Dynamics of Liquid Jets Used for Particle Removal from Surfaces”, Proc. Fourth Symp. On Particle on Surfaces, Las Vegas, Nevada, USA.