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Development of a Water Jet Probe for inspection in difficult access areas

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Robots for inspection that can access to narrow spaces and are able to work in hazardous areas usually tend to utilize a large amount of actuators, and usually it is necessary to increase the thickness of the robot to make it longer. In this paper a new inspection system is proposed, which has a length of 40 meters with a constant diameter smaller than 20 millimeters and is actuated by three high pressure washing machines, through the variation of the pressure generated on each one. Experiments were carried out inside the water, on the ground and in a PVC tube to verify its mobility. First results are promising and confirm the applicability of the system for inspection tasks.

Key Words: Mobil robot, inspection, hydraulic.

1. Introduction

After several years, the infrastructure in cities and industries starts to deteriorate for natural degradation or normal use of it. For this reason, it is important to keep tracking the deterioration of it, in order to avoid its failure. The main problem for this task is that part of this infrastructure sometimes is located in areas of difficult access or it transports hazardous materials, as could be in the case of sewage system or piping in nuclear plants. Considering these cases, it is important the use of systems able to work in extreme environments, as in the water or under high radiation. Different kind of systems have been developed to overcome these scenarios, being the most common the serpentine and continuum robot configuration [1][2][3][4]. These configurations allow to place the actuators at the base of the robot and in this way, it is possible to reduce the weight of the arm, size of the motors and keep the electronic components far from the extreme environments [4]. Even though these systems have high maneuverability and can reach distant points, have the disadvantage of increase the diameter of the arm when the length of the system is increased, and the number of actuators is increased as well. As consequence, the control of the robot becomes complex due to the synchronization of several actuators; mechanical issues, as the friction between the wires and the mechanical parts, wires compliance, etc.

In this work, the authors introduce a system able to develop inspection in narrow and hazardous areas, using high pressure water jet as actuation element at the tip of the system. The pressure is generated via three commercial high pressure washers and the motion of the system is controlled regulating the speed in the washer's pumps.

2. Water Jet Probe description

2.1 Mechanical System

The Water Jet Probe consists of three high pressure net wire hoses with inner diameter of 3 mm, where each hose has one nozzle at the tip of 0.8 mm of diameter with an inclination of 45° respect to its longitudinal axis. The tip of the three hoses are attached together rigidly, keeping the output of the nozzle of each hose in a radial arrangement of 120° between each nozzle, as is shown in Fig. 1. The length of the hoses is 40 m and the input of each hose is connected to a commercial high pressure washer (IRIS OHYAMA: FBN-401) with the specification shown in Table 1. This kind of washer uses an axial piston pump of two cylinders to generate the high pressure and a universal motor to generate the rotation in the pumping system.

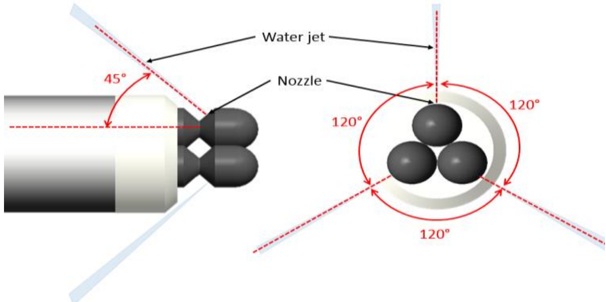

Fig. 1 Lateral and frontal view of tip of system

Table 1 High Pressure Washer Specifications

PRESSURE	6.0 MPa
FLOW RATE	270 l/h
POWER	1000 W

2.2 Electronic System

The high pressure washers are design to work with alternating current and ON/OFF control through a pressure switch, but due to the motor that drives the pump is a universal motor, it was possible to make it work with direct current and control the speed by PWM, using one motor driver 1XH Power Module (Hibot Corp.) for each motor and one TITechSH2 Tiny Controller (Hibot Corp.) to generate the PWM for the motors and process the input from a Joystick Controller 30JH 3-dimensional coordinate type (Sakae).

2.3 Thrusting force

Experiments were conducted to find the relationship between the thusting force and the voltage applied to the motor of the washer machine, the results are shown in Fig. 2.

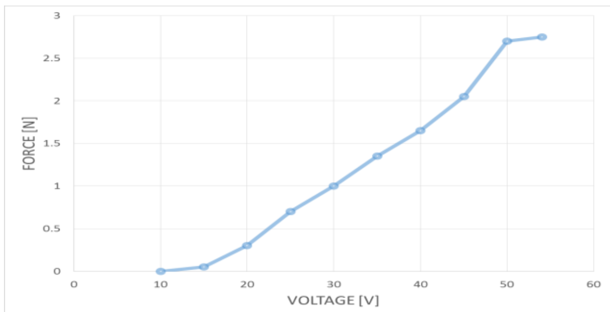

Fig. 2 Thrust Force-Voltage chart

This data help us to found out that the thrusting force generated up to 15 V is negligible because the minimal voltage required to start moving is 10 V, we considered this fact to develop a better control.

2.3 Control Strategy

As was explained above the motion for the system is generated by changing the thrusting force for each nozzle, therefore, the total force (F_T) is going to have always a positive component in the Z direction, meanwhile the components for X and Y could be positive, negative or null, Fig 3.

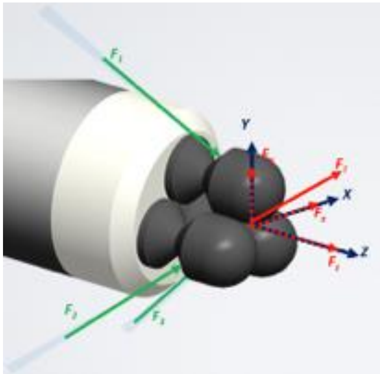

Fig. 3 Thrusting forces (green) and resultant force (red)

Since the component Z cannot be avoided, the main control is focus on the projection of F_T in the plane X-Y. Keeping this in mind, it is easy to figure out we just need two thrusting forces at time to control the movement of the system. The way how the two nozzle are selected can be explained using the Fig. 4. When the projection of the F_T on the X-Y plane is located between line *a* and *b*, the nozzles 2 and 3 will be throwing water, the force in the water jets will vary depending on the orientation of the projection. If the projection is between line *b* and *c*, the nozzles 1 and 3 will work and finally if the projection is located between the lines *c* and *a*, nozzles 1 and 2 will be activated. In the special case that the projection of the F_T is exactly over the line *a*, *b* or *c*, just the nozzle 2, 3 or 1 respectively, will be throwing water.

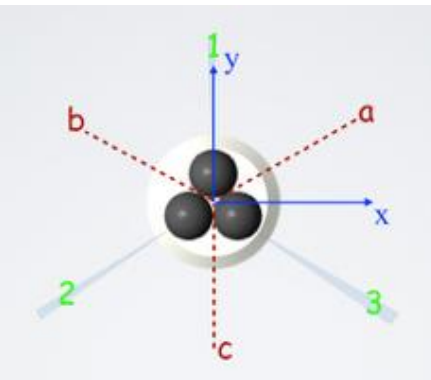

Fig. 4 Nozzle selection

3. Experiments

Experiments to verify the control of the system were done, inside the water, on the ground, and inside a PVC tube, Fig. 5. Three small fins were added at the tip of the hoses to increase resistances and in this way have a softer movement. The system had a good behavior in all the experiments but when the tip of the system rotated in its longitudinal axis the references was lost and it was difficult to find it again. It was notice that the system is able to move in the air, but it requires a more efficient control to do it properly. It was found that most part of the energy is lost due to the friction has the water when it moves through the hoses.

4. Conclusions and Future work

Even though the system requires continuous water flow for its propulsion, the maximum flow registered was about 6 l/min. A posture sensor at the tip will be implemented to avoid the loss of orientation when the system rotates longitudinally and to have a feedback in order to improve the control of the system. The water jet is strong enough to pull the hoses inside the water, but it is necessary add more nozzles along the hoses in case of the 40m need to be used in environments different from the water.

Fig. 5 Experiments inside water (top), on ground (middle), PVC tube (bottom)

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