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Paper

TWO SPECIAL MECHANISMS FOR CONTROLLING THE WATERJET GUN AND ELIMINATING THE REACTION FORCE OF THE JET

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ABSTRACT

Reactive forces generated by waterjet guns are an important safety issue in cleaning and stripping process. In this study, two special mechanisms have been designed to control the waterjet gun and eliminate the reaction force while using hand-held tools. These unique fixtures are installed on scaffold poles and provide a safe operation for waterjetting. Beyond safety, they decrease operator fatigue and increase the efficiency of operation. Hence, provide an opportunity to use hand-held guns particularly for cleaning and de-coating process of large buildings and structures.

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1. INTRODUCTION

Impressive progress and a fast-growing understanding of the diversified applications of waterjet technology are generating a growing excitement in industry. Waterjet technology, now being used in nearly all types of industry; manufacturing, mining, construction, concrete, stone, aerospace, engineering, oil and gas, power plants, process, and medical industries – to continue to expand at a rapid pace [1]. Waterjet technology has been used for a long time for cleaning and de-coating process. Applications that previously utilized sand blasting are converting to high and ultra high pressure water, which eliminates airborne contaminants and the need to collect and dispose of contaminated sand. Waterjetting can also reduce the amount of collection and treatment required of chemicals used for cleaning and the rising costs associated with disposal of these chemicals. Along with the increased utilization of high and ultra high pressure water jetting for maintenance of process equipment, comes the need and desire for faster and more productive cleaning equipment, increased safety of the operating personnel and ultimately reducing the downtime of the equipment or process being cleaned [2]. However, waterjeting has a high injury potential: high-speed water jets can damage skin, tissue, and if abrasives are involved – even bones. One of the main sources of danger to operators is the reactive forces generated by the waterjet while using hand-held tools. A hand-held tool can be used as long as the jet reaction force does not increase beyond a value of F_r= 250 N. For reaction force levels 150N < F_r < 250 N, hand-held guns can only be used with additional body support [3]. This problem becomes more serious when working on scaffold. Hence mechanical tools and robotic systems are usually applied for large-scale application such ship halls or large storage tanks [Fig. 1]. But robotic systems are expensive and hand-held tools are still the tool needed to do much of the work in the field today. Waterjet guns have experienced improvement in safety and reliable operation, but the search should continue to increase the operator's comfort and safety. In this study, two special mechanisms have been designed to control the waterjet gun and eliminate the reaction force while using hand-held tools.

2. WATERJET FUNDAMENTALS

Waterjet stripping involves the use of water at pressure above 10,000 psi to mechanically remove coatings. High-pressure pumps force water through specially designed nozzles that direct the high-velocity stream to impinge upon the coated substrate. The kinetic energy of the waterjet physically erodes the coating to expose the underlying substrate surface. Waterjet stripping uses the impact force of pressurized water to effectively remove a variety of coatings ranging from paints, rubbers and sealants to more tenacious coatings such as aerospace adhesive and metal flame spray coatings. These coatings may be removed from many different types of substrates, including metals, plastics, composites, and concrete. The effectiveness of waterjet stripping depends on a number of key parameters, including operating pressure, volumetric flow rate, nozzle diameter, stand-off distance, traverse rate and impact angle. By adjusting these parameters an optimal removal rate may by achieved while preventing damage to substrate surfaces. Waterjet stripping can be performed using manual or automated equipment. Manual systems include hand-held lances and manually propelled units for cleaning and removing coatings. These systems allow for increased mobility and flexibility at low capital cost. As mentioned before, a hand-held tool can be used as long as the jet reaction force does not increase beyond a value of F_r= 250 N. For reaction force levels 150N < F_r < 250 N, hand-held guns can only be used with additional body support. These relationships are illustrated in Fig. 3 which also shows critical combination of operating pressure and volumetric flow rate. The classical tool for manual hydroblasting application is the high-pressure gun as illustrated in Fig. 2. An average rule says that an operator may be capable of holding about one-third of his body weight [3]. The jet reaction force of a waterjet can be estimated through impulse flow conservation:

$$\dot{I} = \dot{m_w} \,.\, v_J = 0.743 \,.\, \dot{Q_N} \,.\, p^{1/2} = F_R$$

Here, $\dot{I}$ is the jet impulse flow, $\dot{m_w}$ is the water mass flow rate, and v_J is the jet velocity. In the right term of equation, p is in Mpa, $\dot{Q_N}$ is in l/min, and F_R is in N.

3. EXPERIMENTAL SET UP AND PROCEDURE

3.1. Ball joint fixture

The key matter in this mechanism is to transmit the reaction force of the jet to the scaffold poles. Accordingly, the operator can perform the cleaning and stripping process freely without any worry of reaction force. It consists of a rod with two clamps on both ends in order to fasten to scaffold horizontal poles. The adjusting part consists of a small bar which can move along the rod freely in order to select the suitable position. After choosing the proper location it can be fixed by a screw. In order to provide a good degree of freedom, a ball joint is attached to adjusting part which makes it possible to cover a wide range. The gun is fastened to the ball joint by another clamp. This mechanism is shown in Fig. 4, and 5. Experiments showed that this mechanism has a high capability to use in cleaning and de-coating process by eliminating the reaction force of the jet. However, it is recommended to be cautious while using on high altitudes.

3.2. Ball bearing fixture

This unique fixture is installed on scaffold horizontal poles through two holes which are made on each side. These holes let the mechanism move easily on the pole and revolve round it. Furthermore, by using two ball bearings the operator can rotate the gun along the horizon. Also the gun is fixed on the top revolving part by two clamps. This fixture has three degree of freedom and by controlling the waterjet gun and eliminating the reaction force of the jet, decreases operator fatigue and increases safety of the operator. More details of this mechanism are shown in Fig 6 to Fig. 9.

4. CONCLUSIONS

In this study, two special mechanisms were designed to mount on scaffold poles in order to control the waterjet gun and eliminate the reaction force while using hand-held tools. They provided a safe operation for waterjetting and decreased operator fatigue and enhanced the efficiency.

5. AKNOWLEDGMENTS

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6. REFERENCES

[1] American Waterjet Technology Association, www.wjta.org.
[2] Kupscznk, Ted. “Water jetting application in the petrochemical industries.” Proceedings of the 9th American Water Jet Conference, WJTA, St. Louis. 1997. 589-601.
[3] Momber, A.W. Hydroblasting and Coating of Steel Structures. London: Elsevier Advanced Technology, 2003.
[4] www.woma.de

7. NOMENCLATURE

F_R	reaction force
$\dot{I}$	jet impulse flow
$\dot{m}_W$	water mass flow rate
p	pump pressure
$\dot{Q}_N$	nominal volumetric flow rate
v_J	jet velocity

Figure 1. Robotic systems with remote control for emission-free large scale surface preparation [4].

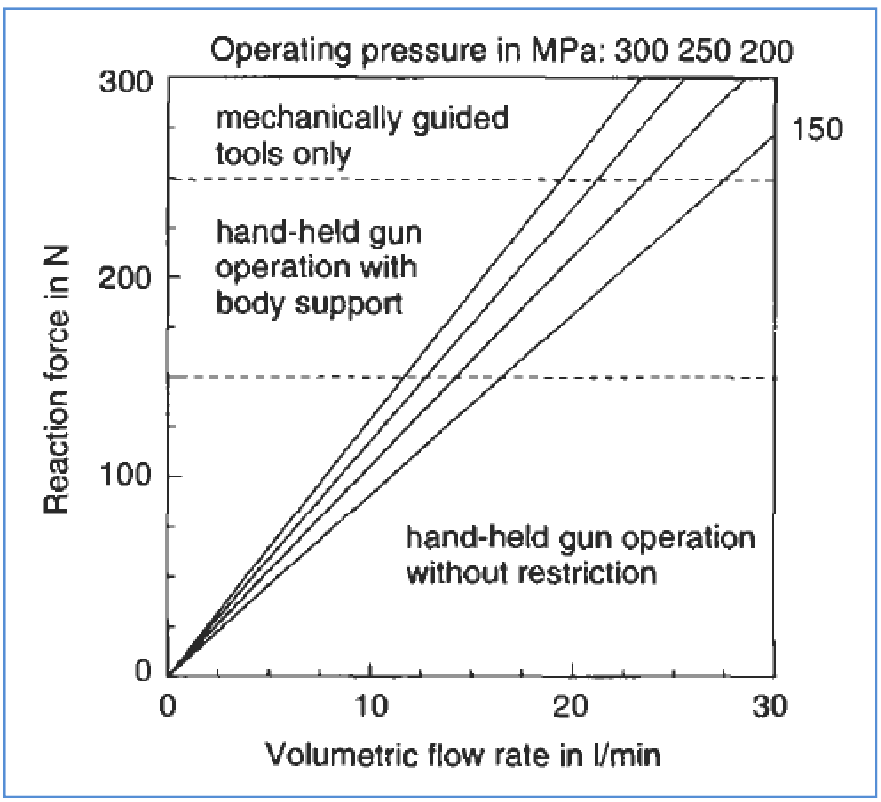

Figure 3. Critical conditions for hand held gun operator [3].

Figure 2. Manual waterjet gun.

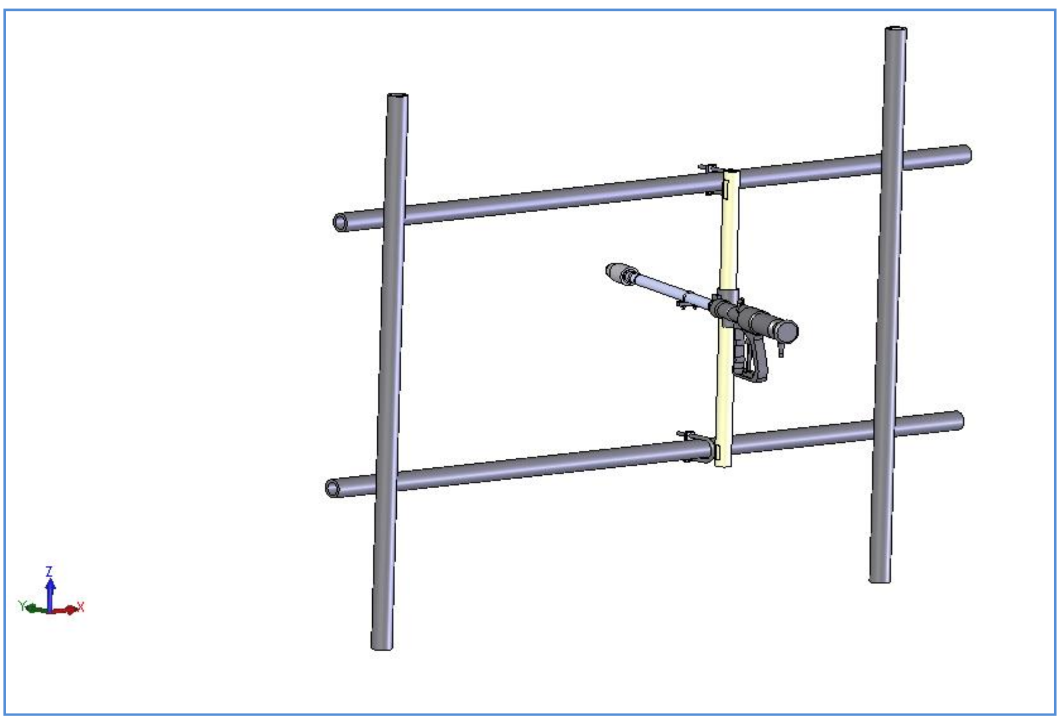

Figure 4. Ball joint fixture.

Figure 5. Ball joint fixture.

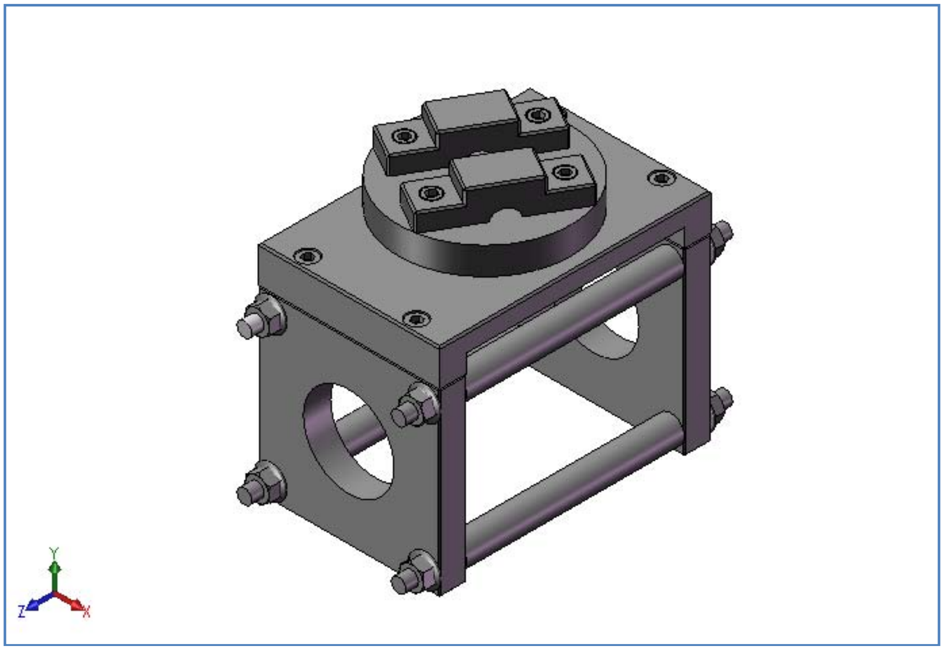

Figure 6. Ball bearing fixture.

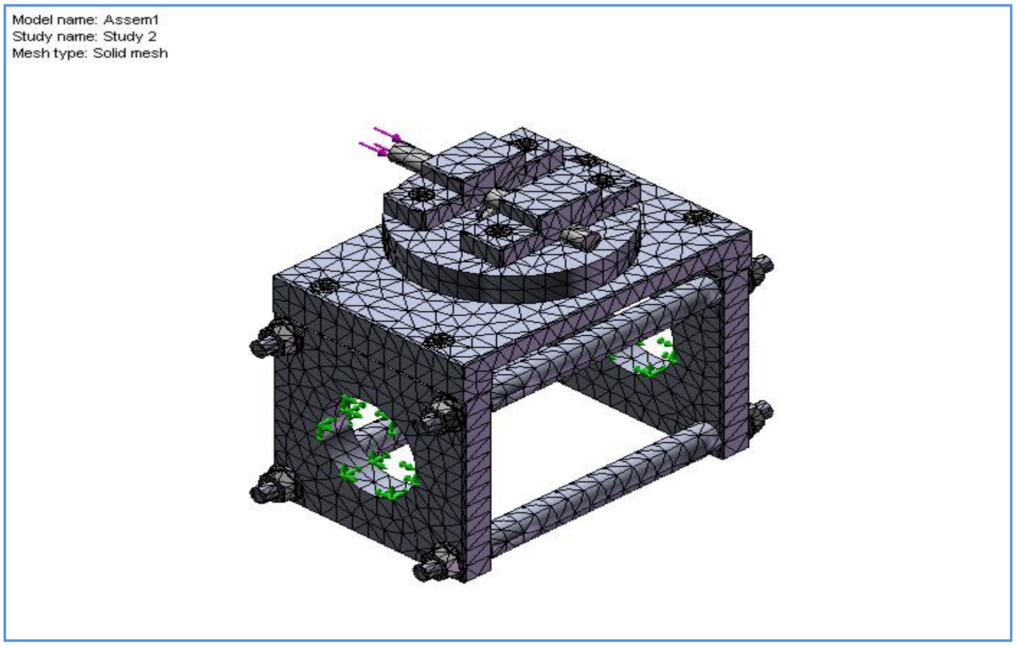

Figure 7. Ball bearing fixture.

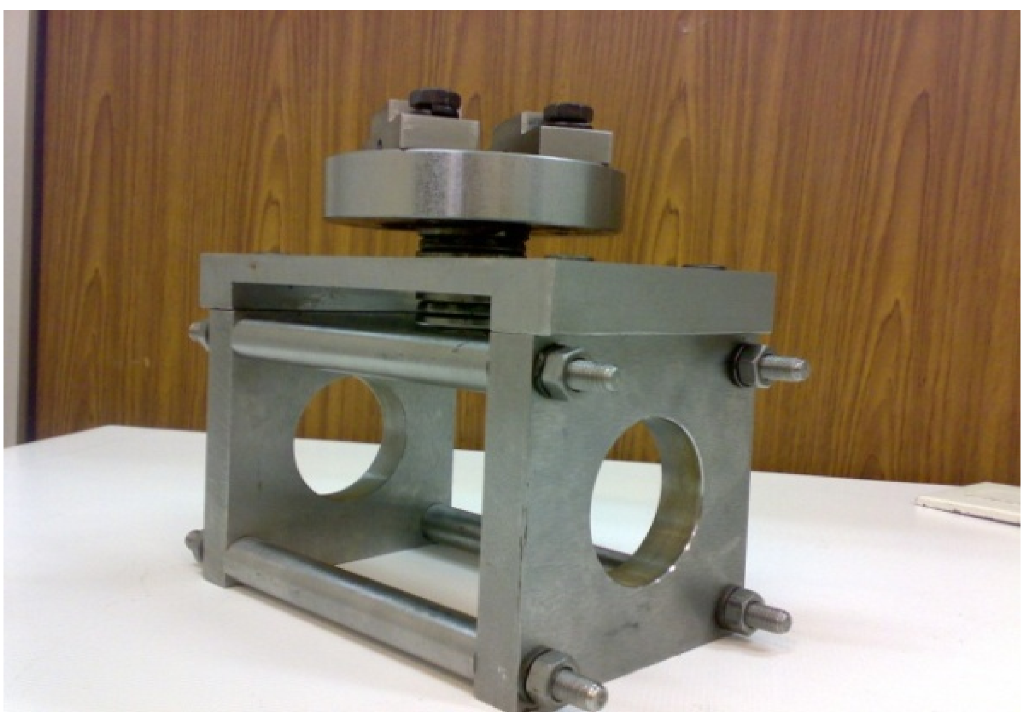

Figure 8. Ball bearing fixture

Figure 9. Ball bearing fixture.