Development of Suction Head Pressure for Spent Garnet

(Pembangunan Tekanan Permulaan Penyedutan untuk Garnet Terpakai)

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Abstract

Waterjet cutting operates by injecting water at high pressure together with abrasive material known as garnet to corrode the base material in the cutting process. The mixture of water, garnet and residue of corroded material is accumulated in the accumulation tank. The current practice in waterjet cutting industries do not recycle spent garnet and normally disposed in the landfill or mixed with cement in concrete for construction purpose. Hence, this research aims to investigate the optimum suction head for the recycling system of the spent garnet. The development of suction head in the recycling system is crucial to ensure the separation of spent abrasive garnet with material residue in forms of sludge. A closed-loop continuous flow filtering system is developed featuring venturi type sludge suction pump and multi-stage filters/separation. The venturi suction is connected to a primary pump and the secondary pump is attached at the other's end of the extraction flow. Findings show the highest extraction at 1.4833 liters per second of the spent garnet was achieved when the primary pump pressure is constant at 100 bar and secondary pump at 125 bar. Therefore, future works on a more comprehensive study can be conducted by deploying the significant results for field-testing in an industrial waterjet cutting.

Keywords: Spent garnet, Suction head pressure, venturi

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INTRODUCTION

Abrasive waterjet is one of the advanced manufacturing processes in the role of subtractive machining has evolved to align with technology advancement. Though the cost of abrasive water jet machining (AWJM) is rather high in comparison with the conventional machining process, its advantages in assembly cost, independent of the machining materials and system reliability lunge the applications in industries because it is pros, especially to materials are sensitive of high-temperature processing and shearing without any micro-cracking. The machining process may vary in cutting, forming, and reaming in as aerospace, mining, and automotive industries (Melentiev & Fang, 2018; Hoogstrate & van Luttervelt, 1997; Ahmed & Qian, 2020; Prashanth et al., 2020; Liwszyc, Liwszyc, Liwszyc, & Perec, 2011).

The removed material during the AWJM process and mixed with the garnet which applied in the machining process labelled as the spent garnet. The spent garnet collected in the machining platform during the machining process needs to be transferred with the attention for disposal or recycle.

There are various methods to extract the abrasive spent garnet from the accumulation tank. The developed venturi suction is one of the optimal approaches in transferring the spent garnet from the collection tank. The venturi suction head which taken shape of a funnel and the pressure injector is placed at the centre of the funnel as the area to inject the water pressure. The converging constricted area of the pump head converting the pressure head to the velocity head. This state fulfilled the venturi effect physically and Bernoulli’s Principle is met when the pressure leaving the pressure injector with high-velocity results with low pressure and created a vacuum state (Waltham, Bendall, & Kotlicki, 2003). The vacuum state succeeds the flow of the spent garnet from the accumulation tank into the venture suction head.

The previous studies showed when the mixture of abrasive material in the jet stream increases the erosive forces and the mixture changes the momentum of the erosion effect during the machining process (Azmir & Ahsan, 2009; Parikh & Liam, 2009; Brown, 1998). The calibration assured with a beneficial machining outcome.

It is found that limited studies are available on the suction head pressure for recycling spent garnet especially in waterjet sludge and this has motivated the present study. Hence, this research embarks on the objective to use fabricated venturi meter to investigate the best suction head pressure in the primary and secondary pump of spent garnet. The contribution of this study is obvious as the resulting outcomes can be capitalized as guidelines to the waterjet recycling system.

LITERATURE REVIEW

The spent garnet suction head is taken the concept of venturi concept and fulfilled the Bernoulli’s Principle. When an ample amount of pressure difference coexists at the area of the inlet and outlet of the venturi, a vacuum phenomenon occurs at the suction hole of the venturi (Fig. 2). It is because when the pressure energized fluid flow into the venturi inlet, constriction took place hence the flow formed with high velocity. Due to the increased velocity at the throat of the venturi section, an outcome with pressure difference, a decrease of pressure taken place. This vacuum state enabled the spent garnet vacuumed into the venturi section and flow together with the pressure energized fluid flow. As the venturi suction phenomenon activated in less than 20% differential of pressure (Baylar, Aydin, Unsal, & Ozkan, 2009).

Venturi suction has been applied in the varsity of applications. It has been used as water aeration for healthy and quality ecology, dust particles removal for filtration purpose, transferring mass from gas phase to liquid phase in waste-treatment and fermentation, and so as with abrasive waterjet machining in mining and manufacturing industries [8, 10, 12, 13, 14]. Venturi suction has been used for suction of dust which density is 0.00423 kgm^{-3}, density of water 997 kgm^{-3}, oxygen gas 1.4290 kgm^{-3}, and dry abrasive 2400 kgm^{-3} [7, 10, 12, 14] (Azmir & Ahsan, 2009; Baylar, Aydin, Unsal, & Ozkan, 2009; Ali, Yan, Sun, Su, Gu, & Mehboob, 2013; Bauer, Fredrickson, & Tsuchiya, 1963).

The study showed that the vacuum condition can be enhanced with a fine altered size of the orifice, the energized fluid pressure which flows through the orifice, level of the medium at the suction chamber, the diameter of the venturi throat (Balamurugan, Lad, Gaikar, & Patwardhan, 2007). So as the difference of gas velocity at the throat of the venturi and the flow rate of the fluid (Ali et al., 2013). Yet the increase of the flow rate will also make the machining process with a smoother surface and fine edges (Prashanth et al., 2020).

METHODOLOGY

The initial step to develop the spent garnet suction head was to draw the base of the suction head using Autodesk Inventor (Fig. 1(a)). The file was then saved into an STL format before being transferred into Cura 4.0.0 software. Subsequently, the file was converted into a G – code (.gcode) format and saved in SD card. Finally, it was transferred to a 3D printer for the printing process.

(a) (b)

Figure 1. (a) Spent Garnet Suction Head, (b) Fabricated venturi suction head

The next process involved the machining of the venturi suction head by lathe machine. The final fabricated venturi suction head is shown in Fig. 1(b).

When doing the spent garnet transfer, the head of the venturi suction pump is placed in the tank filled with the spent garnet and water with a density of 2835kgm^{-3}. When the primary pump is energized, high pressured water is forced into the venturi suction head before jetting out from an orifice with 2mm into the conical section at different pressure. This condition creates a low-pressure state in the region of the throat of the suction pump head to provide a sludge hydraulic pump head for spent garnet flow (Fig. 2). The further flow rate control managed by controlling the secondary pressure pump. The design of a suction pump with less mechanical parts is more reliable to use as the sludge may flow without direct contact any moving parts in comparison with a conventional suction pump. This is because a conventional suction pump has to transport the medium with the aid of direct contact with the turbines of the pump had reduced its reliability (Baylar et al., 2009).

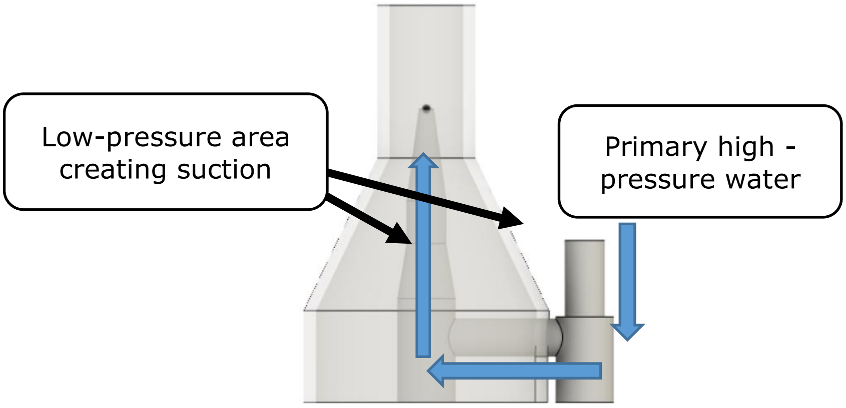

Figure 2. Principles of the venturi suction

The rate of spend garnet sludge extraction is dependent on the pressure from the primary and the secondary high-pressure pump. In this experiment, the primary pump is supplied with uncontrolled constant baseline pressure at 100 bar. Meanwhile, the pressure from the secondary pump is regulated via Variable Frequency Drive (VFD) to provide pressure at 25 bar, 50 bar 75 bar, 100 bar and 125 bar (Fig. 3). The function of the secondary pump is also to escalate the venturi effects on the mass flow rate. The total volumetric discharge at constant height is calculated by measuring the times required to reach a volume of 4 litres. Based on the setup and preparation completed, the flow rate measurement for different secondary pump pressures was performed with at least three repetitions per each experimental run. The flowrate is given by the volume per unit time (l/s).

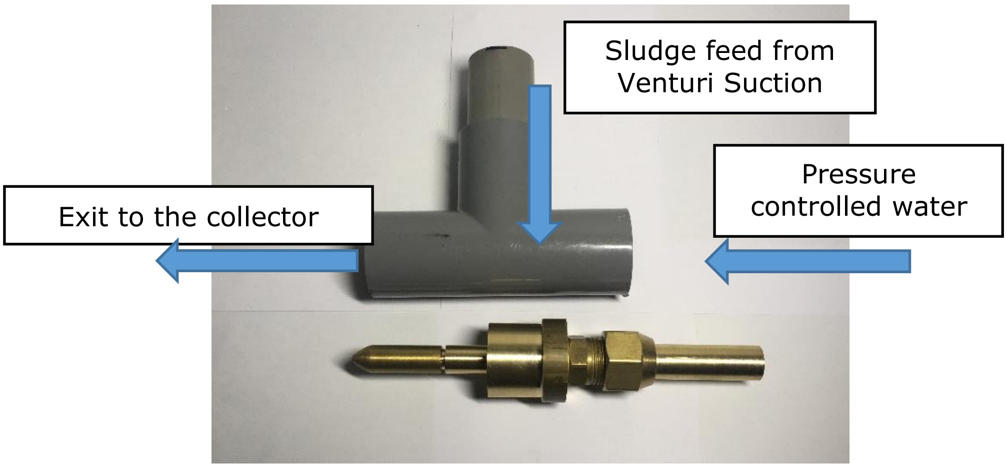

Figure 3. Pressure controlled secondary injection coupling.

RESULT

The initial step to develop the spent garnet suction head was to draw the base of the suction head using Autodesk Inventor (Fig. 1(a)). The file was then saved into an STL format before being transferred into Cura 4.0.0 software. Subsequently, the file was converted into a G – code (.gcode) format and saved in SD card. Finally, it was transferred to a 3D printer for the printing process.

Table 1. Performance of sludge extraction flowrate of the venturi suction head

Controlled Variable	VFD Frequency(hz)	Flowrate 1 (liters/s)	Flowrate 2 (liters/s)	Flowrate 3 (liters/s)	Average (liters/s)
Baseline	Nil	0.6700	0.6231	0.6768	0.6566
25 Bar	16.6	0.9324	0.9174	0.8791	0.9096
50 Bar	18.9	1.0417	0.978	1.0256	1.0151
75 Bar	21.7	1.0782	1.039	1.0283	1.0485
100 Bar	25	1.2539	1.1396	1.1204	1.1713
125 Bar	30.4	1.3889	1.4545	1.6064	1.4833

The testing onto developed venturi pump head had been tabulated as in Table 1. The results indicate an increase in spent garnet extraction with higher secondary injection pump pressure. As observed in the condition with merely the baseline and no activation of the VFD, the sludge extraction rate averaged at 0.6566 litres per second. Subsequently, when the secondary pressure pump is activated at a minimum 25 bar, the flow rate increases to 0.9096 litres per second. It showed the secondary pressure pump contributed by further escalate the extraction flow rate of the spent garnet in comparison with a single suction pump in process (Wang, Wang, Yang, Zhang, & Ma, 2020; Ali et al., 2013).

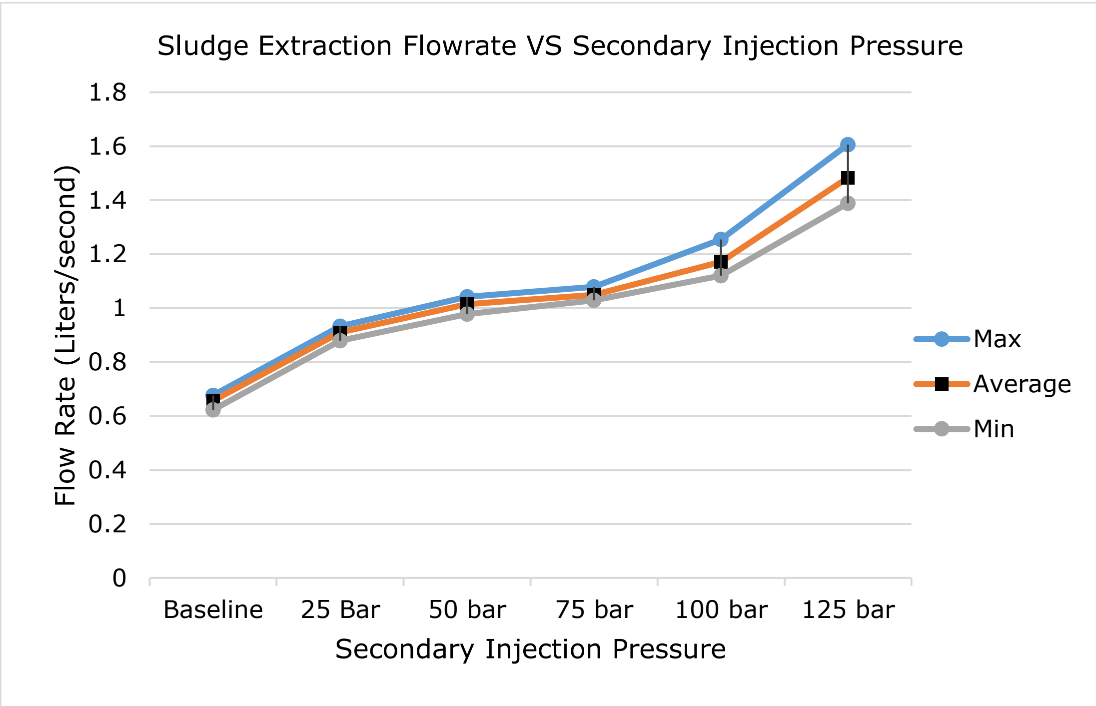

Figure 4. Performance of the venturi suction head.

The performance of the secondary pressure pump is further illustrating in Figure 4. From the figure, during higher secondary pump pressure has indicated increasing in the spent garnet flow rate. Insignificant increases in flow rate can be observed when secondary pump pressure is in the range of 25 bar to 75 bar in comparison to increment in 75 bar to 125 bar. With the limitation of maximum operating pressure for the secondary pump capped at 125 bar, the maximum spent garnet extraction rate obtained was 1.6 litres per second. Hence, the findings suggested optimum secondary pump pressure should be above 100 bar. The performance of the spent garnet suction pump indicated a promising prospect in flow rate application in a way suction pump does not in contact directly with substances. In contrast, the conventional approaches where substances such as spent garnet mixture with mechanical components of the pump can cause jamming to the whole system (Balamurugan et al., 2007; Bauer et al., 1963).

CONCLUSION

The present study was designed to determine the effect of fabricated spent garnet suction head energized by a primary pump and escalates by a secondary pump. The results of this investigation show that the highest mean value of spent garnet extraction is $1.4833 ls^{-1}$ when the secondary pressure pump regulated at 125 bar. The following conclusions can be made is the secondary pump pressure should be regulated above 100 bar for an adequate extraction flow rate. These findings provide the following insights for future research of the investigation of venturi suction head development in the waterjet cutting industries.

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