

Identify and Solve the Problem of Pressure Drop in Intensifier Unit of Abrasive Waterjet Machine

¹Ketul Gopalbhai Patel, ²Yogesh Kanjibhai Dharajiya, ³Prof. Kintu R. Patel, ⁴Harshit Jayendrakumar Gajjar,

⁵Surendrasing Bhimsing Bhil

^{1,2,4,5}Students, Mechanical Engineering Department at VGEC, Chandkheda, Ahmedabad

³Associate Professor, Mechanical Engineering Department of VGEC, Chandkheda, Ahmedabad

Abstract: The Intensifier pump is used in Abrasive Waterjet Machine to get high pressurized water and store it into the Accumulator. One of the most important components of the pump is two check valves attached with the two pistons' ends. In our project, we have first identified the causes of the problem of pressure drop, faced by almost every industry. Subsequently we tried to solve this with implementing four different solutions and analyzing their results to find the optimal solution and rectify the machine back to its initial configurations.

Keywords: Abrasive Water Jet Machine, Intensifier, Check valve, Pressure drop, Design, Analysis, CAD.

1. Introduction

1.1 Introduction of Abrasive water jet Machine

The abrasive water-jet machine is technology developed a lot in years. In 1971, the sample of high pressurized water-jet cutting machine comes into sight in the United States. It had to cut a variety of non-metallic soft materials.

In Abrasive Water Jet machining process, the work piece material is removed by the force of a high-grade velocity jet of water mixed with abrasive particles based on the principle of wear and erosion of the material upon which the water jet hits. Abrasive Water Jet is an advance method in manufacturing industries.

1.2 Pressure Drop

Pressure drop is a major problem in water jet cutting industries now a day. High-pressure water jet pumps are designed for bringing water up to the pressure required for cutting operation. And yet, frequently, the jets that approach the target are no longer capable of achieving the required pressure that was promised when the system was originally designed.

More regularly than not these drops in performance can trace to a way that the water directs through the delivery system. And outward through the nozzle that creates the jet.

1.3 Design methodology that we suggested

In order to diminish the problem faced by most industries, we came up with most possible solutions. Which are explained below:-

- A) Improvement in Lapping Technique
- B) Coating of the outer surface which is most venerable
- C) Design change of hole and inlet poppet where the wear is highest

1.4 The Implementation Strategy we followed:-

- Out of these few solutions we have to find what is best with respect to the Abrasive waterjet machine and the pressure required.
- Also, the economic factor also plays a very crucial role in the consideration.
- The most feasible approach to go for is,
 - [a] Determine the parameters like the pressure required and other tolerance in the system.
 - [b] Apply one solution and note down the life expectancy and resulted in pressure.
 - [c] Find out that, is this the most feasible option to go for.
 - [d] If not, try to implement other solution and go through the steps (i) to (iii) until we do not find the answer to the problem.

2. Lapping Process

2.1 Introduction

It is the one type of finishing process to get good quality of surface finish, highly polished ends and extraordinary flatness. By doing lapping process we get a very accurate flat surface. We can get tight tolerances on the part which requires accuracy at the microscopic level. In this process, two surfaces are rubbed together with abrasive material between them.

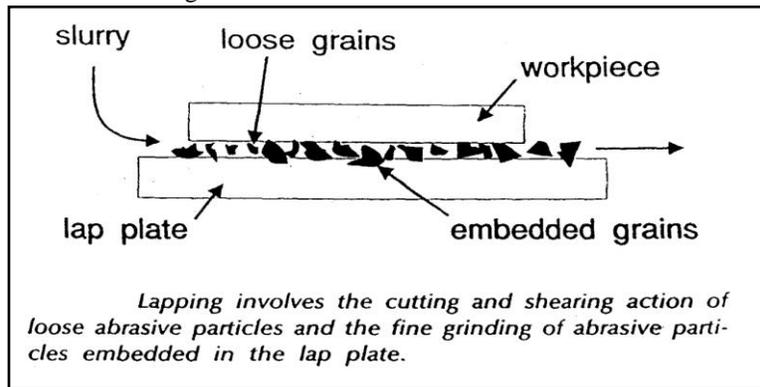


Fig. 1 Lapping Process

2.2 Why lapping is necessary for check valve?

Check valve assembly is used in intensifier unit of the water jet. It is one type of direction control valve which allows the flow of water only in one direction such that no backflow can occur. The surface of check valve and its subassemblies are continuously subjected to high pressure of water, so there should be good surface finish on those surfaces. If there are any scratches on the surfaces of valve, which cause water leakage in pump that slow down the plunger – piston stroke and due to this lag between two-stroke, the pump is continuously facing pressure drop.

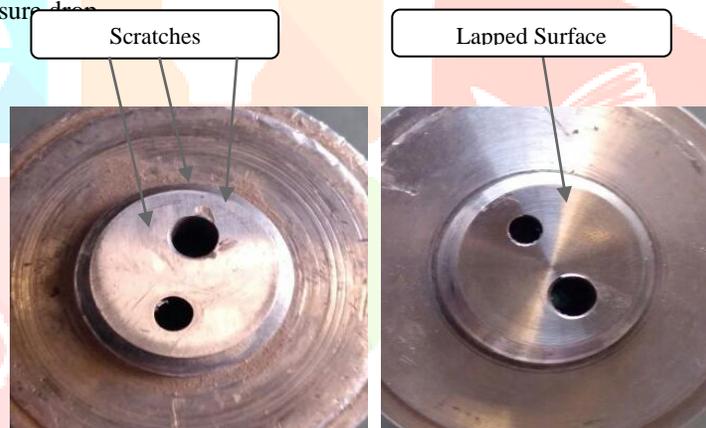


Fig. 2 Check valve before Lapping

Fig. 3 After Lapping

Because of the drop in pressure, we can't get constant cutting speed and feed. So our main aim is to eliminate the problem of Pressure Drop. For this, we need to apply proper lapping on the surface of the check valve, outlet poppet, and inlet poppet and on poppet seat. By doing lapping on the surface we get the mirror finish of surface and the scratches and other defects on the surface can be removed. So that there is no leakage of water and hence the problem of Pressure Drop is reduced.

2.3 Result we get –

For lapping, we need to manufacture different type of fixtures and it's hard to hold the part which is too small. And these fixtures are expensive considering small-scale industries in mind. We need to manufacture at least 2 or 3 fixtures which cost us too high. It is better to manufacture new valve instead.

All need different types of a fixture according to their specifications of the machine and also at a different cost. Total cost for lapping fixtures and labor work is around 10000 to 12000 rupee. And valve manufacturing cost is around 1600 to 2000 rupee. So, In conclusion, we came to the consensus that machine lapping is not a feasible solution for industrial purpose taking cost into consideration.

3. Change in Design

3.1 Introduction to Check Valve

The check valve is a one of the important parts of intensifier pump. This is used to control water flow and direction in the pump.

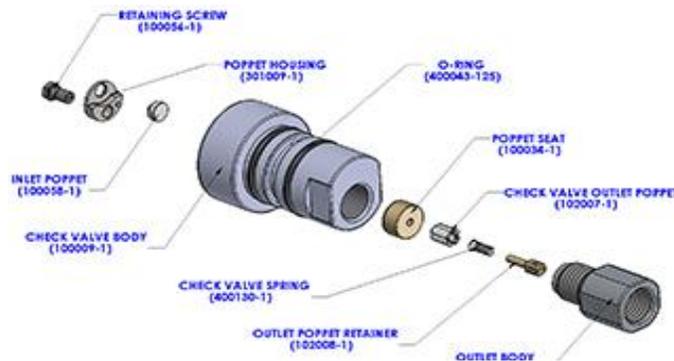


Fig. 4 Check valve assembly

Check valve assembly shown in the figure. There are different parts which have direct contact with high pressurized water like inlet poppet and check valve surface.

Poppet has a direct contact with water and we know that there is wearing damage on the surface of poppet due to pitting of high-pressure water. Due to this again we face the pressure drop because water tends to leak back into the pump. The problem with these circular structures is that whenever the surface either worn out or scraping occurs, it is always recommended to change the poppet and lap the surface of the valve. There are certainly no other options to choose from.

Now, as a solution, we had been thinking about a different design to apply in to increase the life of the tool. Two designs we gave as a solution and now is the time to work on those designs.

3.2 First is different shaped poppet end other than circular

The pyramid-like shape is also a great option to choose because of various reasons. It gives an option to attach a carbide tip for withstanding the impact force. But like the first design, this also has some drawbacks. After some researches, we find out that if we change poppet design we need to change whole valve design because the pressure is the most important factor.

In taper rod section we need to change the inlet-hole design and we don't know what effect cause after these changes. This may be dangerous because pump working on too high pressure this can damage the whole pump and we can't take that risk, this cost us too high and also not feasible for the company.

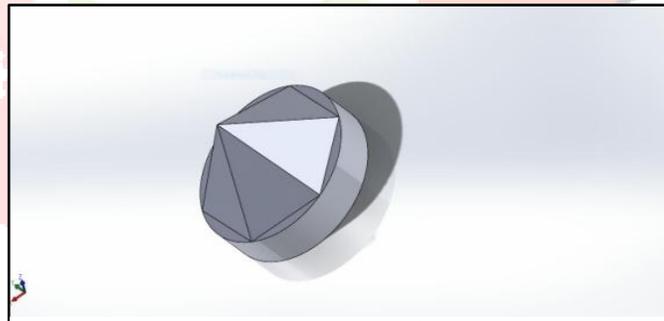


Fig. 5 Hexagonal end of Poppet

3.2.1 Results –

The main advantage of this design was that by spreading the water flow into different directions the proneness of the surface to face pitting and wearing can be significantly reduced. But, as we get into intense research on this phenomenon, we found an article which showed us a different problem with this polygon shaped pipes.

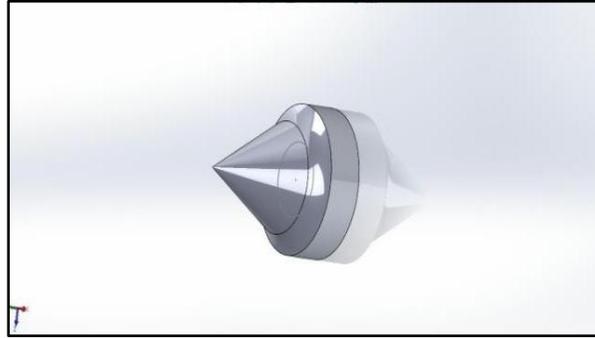
Firstly, to accommodate this poppet the hole on the valve is needed to change as well. And in this article, it is stated that "Calculation shows that round pipes produce symmetrical spreading along the flow direction, whereas rectangular or any other perfect shaped polygon pipes gives an asymmetry.

Secondly, this ends up in a rather turbulent flow of water. This fluctuates the orientation of poppet and in turn, affects the Intensifier unit to vibrate extensively. Also, turbulent flow means that there is not a uniform inlet of water into an accumulator which results in the slow filling.

Because of these results, it is safe to reject the possibility of this being the ultimate solution to the problem by any means.

3.3 Second is the taper cylinder end of the poppet.

Benefit from this design is that unlike the former design this one can work for a very long time. The general idea behind the



taper section is that this shape can actually adjust with the hole and always put a tight siege on the opening. Even when it worn out like previous one, taper design and spring action can come into the picture to nullify the effect. In the end, the life of the valve can gain much more improved than any other method. But as an outcome of this implementation, there are some drawbacks.

3.3.1 Results –

The problem we faced is that the original poppet was very small in size and no matter how we tried to build a new poppet with this design, it always was little bigger. And for better results against the high-pressure pitting, the carbide or any other high endurance tip is to be attached to the poppet. This effect on the assembly of the components and if we want to fit it into the system, the whole design of the pump from cover cap to the piston hole had to change to. So, for implementing this solution we practically had to change many of the parts' dimensions. This eventually can cost the industry lot more than the solution it can offer. In the end, we had to reject the possibility of this to be the optimal solution to the problem we are trying to solve.

4. Coating on the affected surfaces

4.1 What is Coating?

Coating is a process which changes the surface properties of the substrate, such as adhesion, wettability, corrosion resistance, or wear resistance.

In valve, if we increase the strength/hardness of body we can reduce the pitting and scratches from valve surface.

The coating can improve strength/hardness properties of the valve by applying hard material like ceramic, carbide as coating surface on a body.

4.2 Work done

Wereached to some industries that provide the coating and there we got more details about the process and we find out that coating process also depends on the material properties. So if we need to increase hardness by coating we have to consider material properties, valve working condition, and requirement for a better result.

4.3 Results

We gave them whole details about requirement and working conditions of the valve. After that they said coating is not possible because of its design and also the size of coating material used in the coating is thin and it's hard to coat on valve because there is not much process available and if we succeed to coating material on valve still there is a problem because of its working condition. The material may not stick to the surface for a long time due to its high water pressure.

So, again the same problem occurs, this can damage the machine. So, we have derived that it is not a possible solution in this context.

5. Change of valve Material

5.1 Introduction

We thought of improving the hardness of the valve material by going through the hardening processes like heat treatment so that it can withstand more pressure and the ultimate life of valve can be increased. We consulted a company which was in hardening processes. With the testing on the material, we found that the material which the valve is made of is SS316L and it cannot be hardened by these types of processes due to it becoming brittle and do more harm to the machine. Then we delve into the research of materials and their properties against wearing, tapping and scratching failures.

After going through all the possible materials, we found that Stainless steel 410 has the required properties and it would be the best material to make the check valve.

Current material – Stainless steel 310L

Testing material – Stainless steel 410

Both materials have same properties except some. The main difference is corrosion resistance and hardness.

5.2 Stainless Steel 316L

316L is an austenitic Chromium-Nickel stainless steel. It is a low carbon version of SS316. It is molybdenum bearing austenite grade of steel. Corrosion Resistance properties are good because of high Molybdenum content. 316L is low carbon steel. It also has high pitting resistance. Corrosion Resistance is good in an atmospheric environment, many corrosive media like steam, water, sulphuric acids, chlorides and another chemical. The Molybdenum provides excellent strength up to 800° F in applications. It is non-

magnetic in general but by applying cold working, it becomes magnetic. By heat treatment process we cannot increase the hardness of material SS316L because due to its austenitic structure when heat treatment process is applied it becomes brittle.

5.3 Stainless Steel 410

It is martensite steel having carbon 0.15%. It has 11.5% of Chromium which gives good corrosion resistance and wears resistance to steel. The corrosion resistance of grade 410 steels can be enhanced by a series of processes like hardening & tempering. Quenching and tempering can harden grade 410 steels. They are generally used for applications involving mild corrosion, heat resistance, and high strength. By hardening & tempering, we can increase hardness and corrosion resistance property of SS410.

Grade 410 stainless steels are resistant to steam, hot gases, mild acids, foods and alkalis, fresh water and dry air. These steels obtain maximum corrosion and heat resistance through hardening. SS410 has good scaling properties up to 650 °C.

Heat treatment of SS410:

It achieves maximum corrosion resistance when it has been tempered and hardened and then polished.

Hardening and annealing processes can be done on SS410.

1) Annealing: Between 815 to 900°C SS410 can be fully annealed.

2) Hardening – Hardening of 410 steels can be done at 925 to 1010 °C, followed by air and oil quenching. Heavy sections of grade 410 need to be oil quenched. Tempering is used to enhance the mechanical properties and hardness of SS410. It is not recommended to perform tempering at temperatures from 400 to 580 °C. It must be hardened to its maximum limits to get maximum corrosion resistance.

5.3 Why to selected Stainless Steel 410?

Chromium is the alloying element that imparts to Stainless Steel their corrosion-resistant qualities. Lower alloyed grades resist corrosion in atmospheric and pure water environments; high-alloyed grades can resist corrosion in most acids, alkaline solutions, and chlorine bearing environments making their properties useful in process plants. Stainless Steel 410 can be hardened by heat treatment. By Hardening of SS410, we can increase its wear resistant & corrosion resistant properties.

Properties of SS410 is suitable for the required application. The work hardening property of austenitic grades, that results in a significant strengthening of the material from cold working alone, After Hardening, SS410 attains higher strength. So check valve made from SS410 requires less maintenance and long service life.

After selecting new part we manufacture valve with new 410SS material and to increase the hardness and corrosion resistance of valve we applied heat treatment process on the valve.

5.4 Hardening/Heat treatment.

The medium of quenching was Oil. The quenched hardness of a metal depends on its chemical composition and quenching method. Cooling speeds, from fastest to slowest, go from brine, polymer, and fresh water, oil, and forced air.

• Details of heat treatment -

Temperature – 1050°C, Time require – 30 min, Hardness – 48.50 HRC

After getting hardness 48.50 HRC we need to do the further process, because of heat treatment valve loose surface finish due to temperature increase and grinding needed. As above described the surface finish of valve is an important factor.



Fig. 7 HRC measurement of Valve

5.7 Grinding:

We know that after heat treatment part dimensions will be changed so we already manufacture valve with more excess dimensions around 4 mm.

5.8 Cost

Material cost – 255 to 265 Rs. / kg

, Material needed – 1.45 kg

Manufacturing (labor) cost – 1500 to 1750 Rs.

, Heat Treatment cost – 100 Rs.

Grinding cost – 250 Rs.

6. End Result and our view on the solution

6.1 Results' Table:

Table 2 Results of each Solution

Solution	Results
1. Lapping	Not feasible by machine lapping
2. Coating	Not possible
3. Design Change	Elements of Risks in machine
4. Material change	Feasible in kinds of industries

6.2 Our Conclusion:

By going through all the solutions, we came to the conclusion that some of the solutions like Lapping and Design change may be considered by large-scale industries having more Abrasive Waterjet Machines, which will not even solve the problem, it will be economical for implement too. But those cannot be used by other industries like in which we had done this project on and they are available in large numbers.

What we have concluded is that the most feasible way to improve pressure and tool life and as a remedy of the problem of pressure drop, that we had identified in the last semester, is by changing the material of the check valve by SS410 instead of SS316L. This will cost the industries total of around Rs.1750-2000 for one valve change. And this can be used by each Abrasive Waterjet Industries.

• References

- [1] R. Kovacevic, M. Hashish, R. Mohan; State of the Art of Research and Development in Abrasive Waterjet Machining; *J. Manuf. Sci. Eng* 119(4B), 776-785 (Nov 01, 1997)
- [2] Andreas W. Momber, Radovan Kovacevic. *Principles of Abrasive Water Jet Machining*; 1998.
- [3] Lichtarowicz ed. *Jet Cutting Technology*. 1992.
- [4] Andreas W. Momber. *Water Jet Applications in Construction Engineering*; 1998
- [5] <http://triquenchindia.com/index.php>
- [6] <http://nptel.ac.in/courses/112105127/pdf>
- [7] <https://www.sciencedirect.com/science/article/pii/B9781437735147100054>
- [8] <https://www.scribd.com/document/319106792/Cylindrical-Grinding>
- [9] Hoogstrate, A. M.; Van Luttervelt, C. A.; Gosger, P.; Momber, A. W. *OPPORTUNITIES IN ABRASIVE WATER-JET MACHINING*. CIRP Annals - Manufacturing Technology 1997; Vol. 46, No. 2, p. 697-714.