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Paper

APPLICATION OF ABRASIVE SUSPENSIONS JET (ASJ) TO CUT BOLTS IN UNDERGROUND COAL MINE

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ABSTRACT

In this paper, Abrasive Suspension Jet is used to cut the bolts in underground of coal mine. In coal mine roadway, there are some bolts need to cut. Taking into account of the complex conditions in roadway such as coal bed methane content, waterjet cutting technology is a perfect tool. Little heat generation can not lead to the explosion of coal bed methane. Although some intensifier pumps used in underground of coal mine are developed, the structure of those intensifier pumps is complicated, and it is difficult to maintain with the high cost. A portable Abrasive Suspension Jet is introduced to cut bolts in underground of coal mine. The structure of the portable Abrasive Suspension Jet is simpler, and the cost is much lower. The volume of the high pressure abrasive vessel is 16L. The portable Abrasive Suspension Jet with one vessel can not work continuously. However, the charging is very simple, which can be finished within 2 minutes. The portable Abrasive Suspension Jet can meet the cutting requirement in underground of coal mine. The results show that Abrasive Suspension Jet can cut the tray of bolt with 30MPa operating pressure compared with Abrasive Water Jet with 300MPa operation pressure.

1. INTRODUCTION

With the coal industry development, the fully mechanized mining technology has been employed widely to meet the request of the fast growing energy consumption. In many places, the roadways are supported by bolts or cables. The cutter of coal mining machine can not cut off the bolts. In general, the bolts made from steel with 30mm diameter are used to support coal roadways in mine. In the cutter of the coal mining machine cutting the coal, it will cut the bolts, leading to the cutter demolition and sparks generation. Sparks generation is forbidden in the fully-mechanized mining face where the methane and coal powder content are high. It is easy to produce methane explosions. Although there are some bolts which can be cut by the cutter of the coal mining machine with the high price and the low strength, those bolts are only used under some special conditions, and can not be used to replace steel bolts widely. Hence, an efficient, safe approach is needed to cut bolts in the mine industry.

High pressure waterjet cutting technology, called as a technology can cut everything, has been widely used to cut metal and nonmetal in many fields. The outstanding advantage of high pressure waterjet cutting technology is only a small amount of heat generation in the cutting process. The workpiece has not thermal deformation in kerfs. Therefore, the waterjet cutting technology can be used to cut bolts in the mine. Currently, for cutting metal, most of the waterjet cutters are Abrasive Waterjet (AWJ) with 250~500MPa operating pump pressure. Compared with Abrasive Suspension Jet (ASJ), AWJ is easy to achieve working continuously. For ASJ, the system has to equip at least with two high pressure vessels to work continuously. The maintaining and manufacturing costs are higher than that of AWJ. However, the operating pump pressure of ASJ is much lower than that of AWJ in cutting the same workpiece. In previous experiments, the operating pump pressure of ASJ is less than 70MPa.

In fact, cutting bolts are not required working continuously in underground roadway. It may be only one time each week. The surfaces of coal roadways are rugged. The arrays of bolts are not regular. It is impossible to cut the bolts automatically under the control of preset programs. The process of cutting bolts had to be done by workers in underground mine. In this paper, a portable ASJ system was presented. The cutting abilities of ASJ and AWJ were compared. A supplementary experiment system of cutting platform was given to simulate the effect of methane on the cutting process. The temperature increases of work piece were studied under different operating pressure of ASJ and AWJ.

2. EXPERIMENTS

An AWJ cutter (Model: DPSB9-3040) is made by Nanjing Dadi Water Cutter Company. The maximum pressure is 380MPa, and the maximum flow is 3.7L/min. The operating pump pressure changes from 250~350MPa, and the diameter of the cutting nozzle is 0.8mm. The schematic of ASJ is shown in Figure 1. It is composed of three parts: the high pressure water

generation, the Abrasive Suspension slurry generation, cutting head. High pressure water is generated from a three-plunger piston pump. The pump is driven by a diesel engine. The flow rate of the pump is 50L/min, and the maximum pressure is 70MPa. Abrasive Suspension slurry is the most important part of the system. After the high pressure water entering the under of the high pressure vessel, the high pressure water is divided into two streams: one stream to the top of the vessel, another one to a mixing chamber. The abrasive is mixed with high pressure water, and then goes to the mixing chamber. In the mixing chamber, the abrasive slurry is mixed with another stream of the high pressure water. The high pressure abrasive water slurry issues from a cutting nozzle, then the high speed ASJ is formed. The height of the high pressure vessel is 560mm with 155 mm inner diameter. The volume of the high pressure vessel is some 16liter. For ASJ, the operating pump pressure ranges from 25~45MPa, and the abrasive consumption can be adjusted with the concentration range from 5~50%. The cutting nozzle used in our ASJ system is the same with that of used in AWJ system. The length of the cutting nozzle system is about 40mm, and the diameter is 0.7mm. The tray of bolt is fixed on the working platform, and the traveling speed of the cutter head is controlled by a PC. The dimension of the bolt tray is shown in Figure 2. The bolt tray is made from 45# steel with 50mm length and 45mm diameter. The maximum thickness of wall is 15mm.

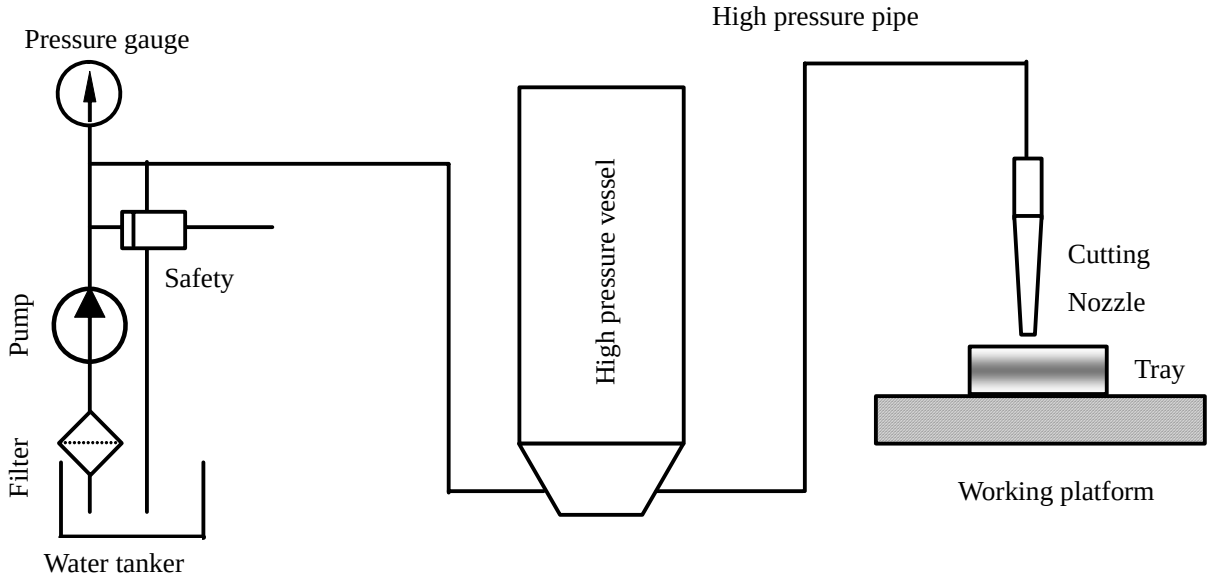

Figure 1. The schematic of Abrasive Suspension Jet system

3. RESULTS AND DISCUSSIONS

3.1 Comparison of the traverse speed

Figure 3 shows the cutting capacity of ASJ and AWJ. It can be seen that as the pump pressure increase, the traverse speeds are increase. In our experiment, the traverse speed of AWJ is higher than that of ASJ. The traverse speed of ASJ is 13mm/min at 25MPa pump pressure. It means that cutting 50mm length tray will cost about 4min. when the operating pump becomes 30MPa, the traverse speed is 26mm/min.The process of cutting the tray can be finished within 2mintures. With the same traverse speed such as 30mm/min, the pump pressure of ASJ is 35MPa, but for AWJ, the pump pressure is about 270MPa. It is about 8 times of ASJ. Figure 4 shows the kerfs quality obtained from different operating pump pressure. It can be seen that the kerfs becomes smoother as the pump pressure increases. As a whole, the quality of kerfs obtained from AWJ is better than that of ASJ.

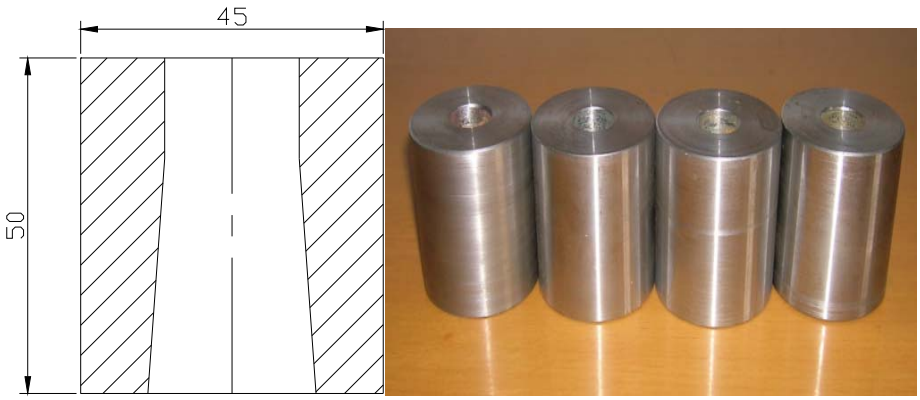

Figure 2. The dimension of the tray

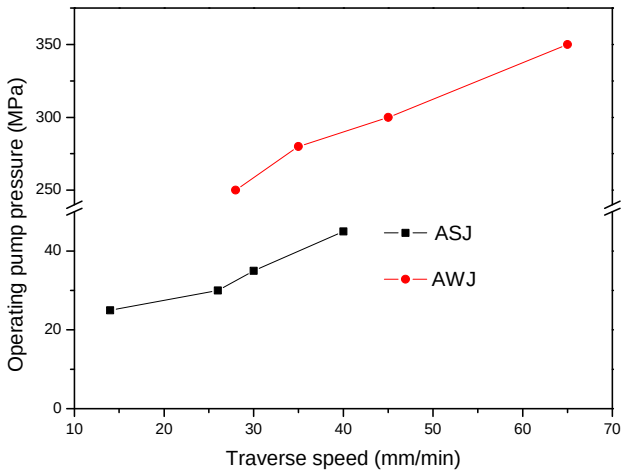

Figure 3. Comparison cutting ability of ASJ and AWJ

In fact, the purpose of the cutting is just to cut off the tray of bolt. Hence, in the cutting process, the cutting speed and the quality of kerfs are minor. The most important thing is to easily achieve the cutting process in the underground roadway. Although some intensifier pumps which can be used in underground have been developed, the high price and maintain cost, large volume limited its application to the underground mine. There are high pressure emulsion pump stations which are used to provide emulsion to hydraulic supports. So, the high pressure emulsion can be used as high pressure water in ASJ system. In general, the pressure of the emulsion is 31.5MPa. For cutting the tray by ASJ, the pressure of emulsion is enough.

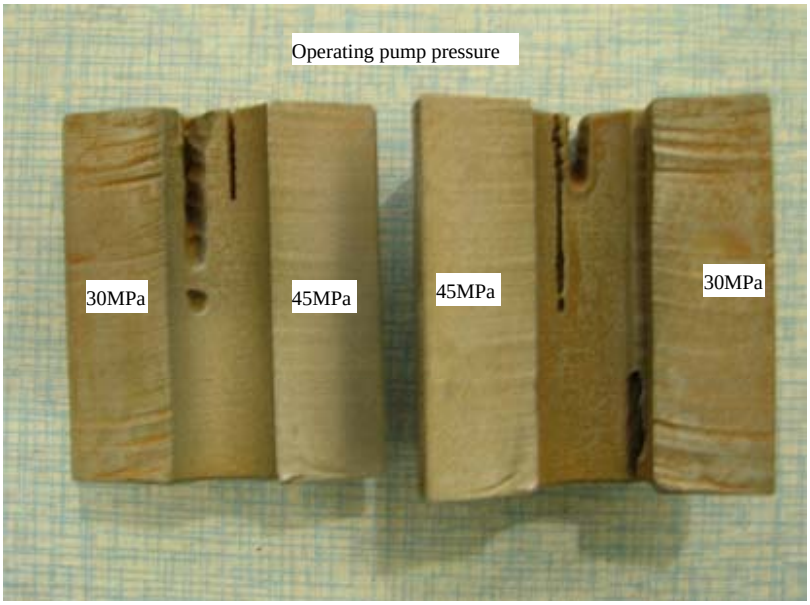

Figure 4. The quality of kerfs cut by ASJ with different pressures

3.2 Abrasives flow rate

The volume of the high pressure vessel is 16L. The diameter of the cutting nozzle is 0.7mm. The flow rate is a constant under 31.5MPa working pressure, which determine the continuously working time. The carborundum is used as abrasives in our experiment, which density is about 2.6kg/l. For one time charging-up, the total mass of abrasives is about 35kg. The abrasive concentration in ASJ is more important. The high solid concentration reduces the continuously working time, and the low solid concentration may decrease the cutting capacity of ASJ. Therefore, the relationship between the cutting capacity and the abrasive flow rate should be reveal. Figure 5 shows the relationship between the traverse speed and the abrasive concentration. The traverse speed increases as the abrasive concentration increases until the peak is reached, and the decrease happens. The maximum traverse speed occurs at abrasive concentration 30%. The results indicate that as the concentration increases, the interference among abrasives is enhanced in the cutting process. It leads to the cutting capacity decrease. Additionally, the increase in abrasive concentration leads to the increase in suspension density and the friction

between abrasives and the nozzle. As a result, the slurry jet speed is dropped. With 30% solid concentration, the traverse speed is higher than that of 25% solid concentration. Take into account the cutting efficiency, the abrasive flow rate and continuous working time for one charging –up, 25% solid concentration is used to cut the tray in the underground roadway.

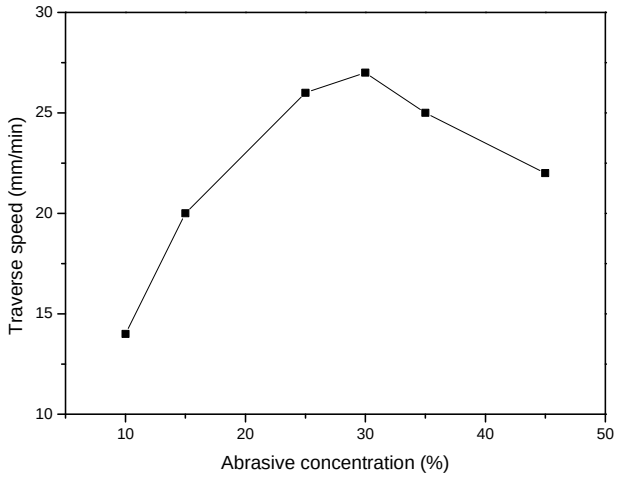

Figure 5. The relationship between the traverse speed and the abrasive concentration

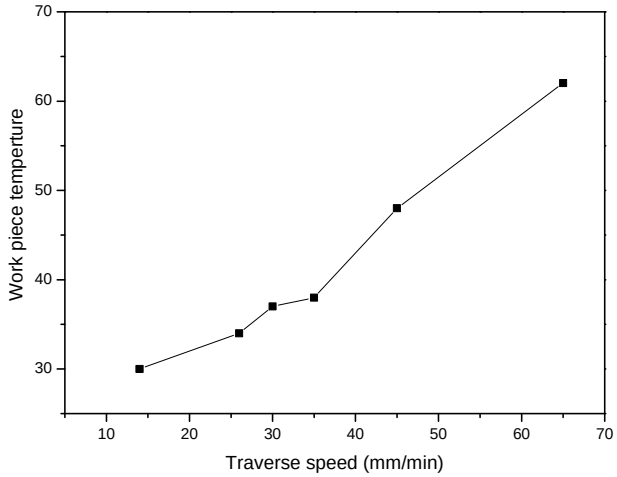

Figure 6. The temperature of work pieces versus the traverse speed

3.3 Coal methane content

Water jet cutting technology is away treated as a cool cutting technology. In practice however, there is heat generated in the cutting process, especially, in cutting the metal material with a high

traverse speed. Only the relationships between the temperature increase of work pieces and the traverse speed are studied in ASJ and AWJ. Figure 6 plots the effect of the traverse speed on the temperature increase of work pieces. It can be seen that as the traverse speed increase, the temperature of work pieces is increased. The temperature is about 30°C at a traverse speed of 15 mm/min. The temperature can reach about 70°C with high traverse speed. As the traverse speed increase, there are no enough water to cool the work pieces, and then the work pieces have higher temperature than that of in low traverse speed.

In our cutting experiment, some sparks are also observed in the high traverse speed. Although the temperatures of work pieces cut by ASJ are not very high, sparks may lead to coal methane explosion in the underground roadway. To simulate the roadway conditions, the experiment of cutting tray with coal methane should be done at different concentrations. A supplementary system of cutting platform is designed, shown in Figure 7.

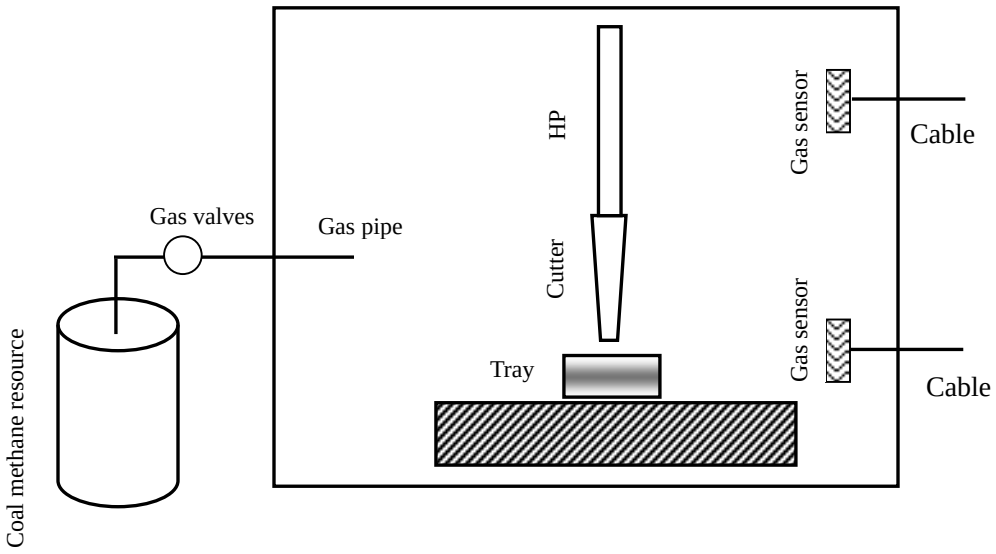

Figure 7. The schematic of supplementary experimental system

The platform and the cutter with some high pressure pipe are put into a big box, and sealed up. A coal methane source is employed to provide coal methane into the box. Two sensors are used to measure gas concentration, which are put into the inner of the box. One of the coal methane explosion conditions is the methane concentration. Previous studies and accident statistics show that only the methane concentration ranging from 5%~16% with fire source such as spark can cause coal methane explosion. The optimal concentration is 9.5%. In our experiments, the methane concentration is changed from 5%~16% with the traverse speed covering 10~70mm/min. In the cutting process, no explosion occurs. Especially, in the 9.5% concentration, the cutting experiments are repeated many times. The result shows that it is safe to the cut the tray of bolt by ASJ in the underground roadway.

3.4 Cutting nozzle design

As mentioned above that, using AWJ with the high traverse speed may generate some sparks. The traverse speed of ASJ is lower than AWJ. The low traverse speed can not lead to sparks. The experiments of cutting the tray with the different methane concentration show that no explosion happens. However, sparks generating in the cutting process is a hidden danger for coal mine. To eliminate the hidden danger, a special cutting nozzle is designed. In figure 8, we give the schematic of the nozzle.

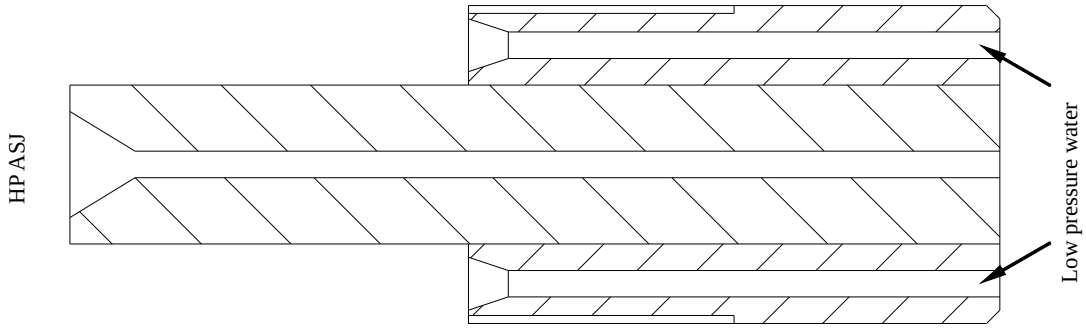

Figure 8. The schematic of the cutting nozzle used in underground roadway

The nozzle is composed of two parties: the inner is a tradition nozzle for issuing high speed ASJ to cut the tray; the outer is a low pressure water nozzle with 8 orifices. The diameter of the orifice is1mm. The outer low pressure water nozzle is used to separate the sparks from the coal methane in the cutting process. It also can reduce the work piece temperature. No sparks are found when the combining nozzle is used to cut the tray, even in a very high traverse speed. The tray temperature is reduced by about 20%, especially in a high traverse speed. For instance, using combining nozzle, the tray temperature is about 45°C, but the temperature is about 70°C when using the traditional nozzle. Hence, using the combining nozzle to cut the tray is more safety in underground roadway.

4. CONCLUSIONS

In this paper, a portable ASJ system is developed to cut the bolts tray in underground roadway. The whole ASJ cutting system can be carried freely by two workers. The cutting pressure of ASJ is much lower than that of AWJ. Experiments show that 30MPa working pressure is enough to the tray with 15mm thickness wall, and the cutting process can be finished within 2 minutes. The traverse speed can reach 25mm/min with 25% abrasive concentration, and a charging-up abrasives can use about 14min. The tray temperature increase is obvious, especially in high traverse speed. The experiments of cutting tray with the coal methane concentration ranging from 5~16% is carried out. No explosion occurs. Some sparks can be found in the cutting

process. To eliminate the hidden danger, a combining nozzle is designed. In the experiment of cutting the tray by the combining nozzle, no sparks is found. Therefore, a portable ASJ system with the combining nozzle is a safe, convenient tool used to cut trays in underground roadway. It also can be used to cut others metal material in underground.

5. ACKNOWLEDGMENTS

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