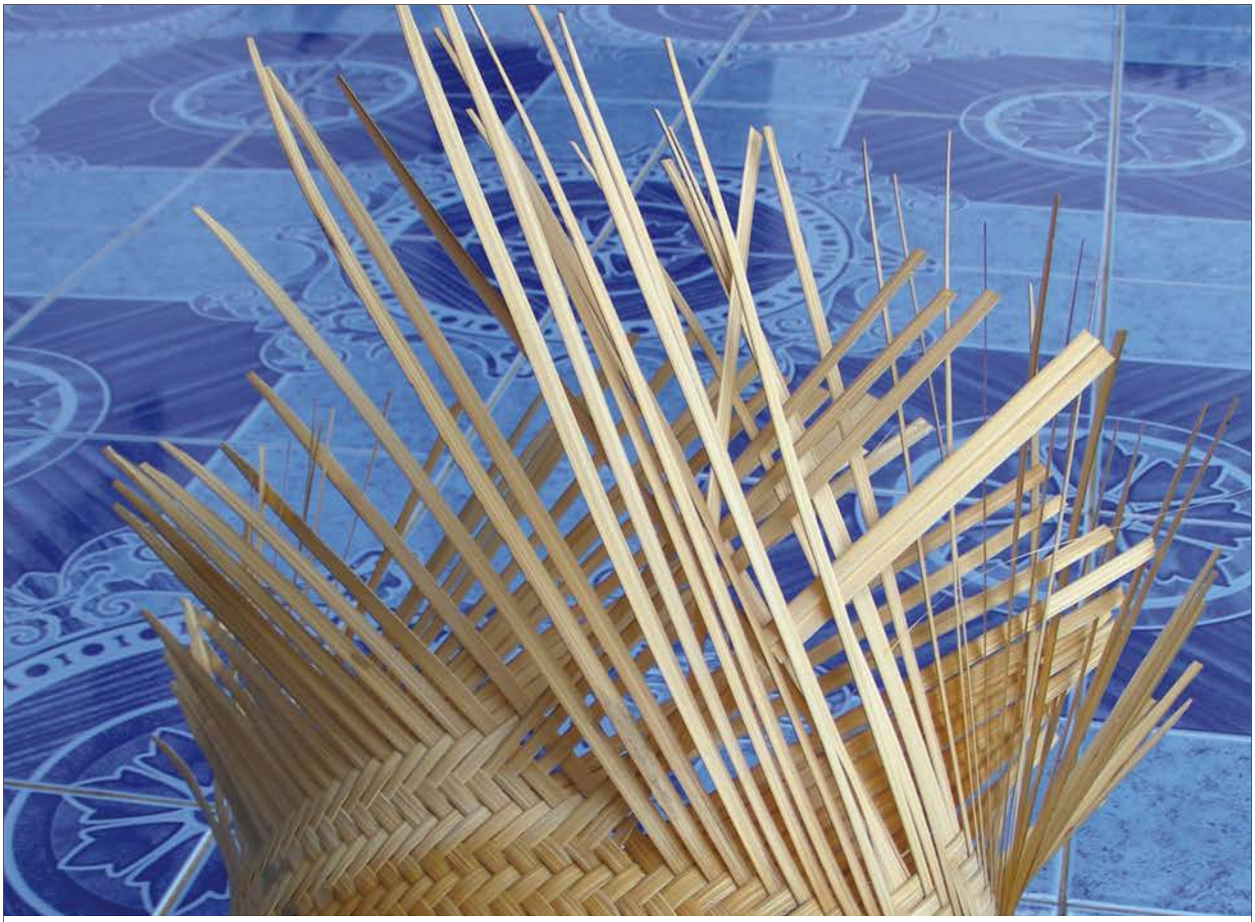

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Experimental Investigation of Effect of Abrasive Jet Nozzle Position and Angle on Coating Removal Rate

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ABSTRACT

Coating removal from the components and structures is an important process as it affects the surface quality and leads to various failures. This study deals with the study of coating removal by using abrasive jet and investigation of parameters which are affecting the coating removal rate. An experimental setup was designed and fabricated in order to investigate the effect of Standoff Distance (SOD), horizontal and vertical angel between the work piece and abrasive jet nozzle and the exit diameter of abrasive jet nozzle on coating removal rate. Experiments were conducted by varying the striking angle of abrasive jet from 0 to 70°, SOD from 150 to 200 mm and the nozzle diameter as 8 and 10 mm to evaluate the effect of various parameters on coating removal rate. The results of the experiments revealed that the time taken for removing the coating form the work piece is found to be reducing and which enhances the coating removal rate when the horizontal striking angle is between 0 to 50°, SOD is 160 mm and the nozzle diameter is 8 mm.

Key words: Coating removal, abrasive jet, mixing of jets, striking angle, standoff distance

INTRODUCTION

The coating removal from the machine components and work piece is essential in some of the fabrication, repainting, recoating processes in industries. Also it is essential to remove and clean the existing painting and coating from the vehicles, furniture, ships and machine components before repainting and coating process. When some of the coating parameters affects the colour and rheological properties (Nsib *et al.*, 2008) there is a need of coating removal and recoating. This study reports a study of using an abrasive jet system for coating removal and the results obtained from investigations were carried out to evaluate the effect of impingement of abrasive jet, Standoff Distance (SOD), nozzle diameter and the of angle of abrasive jet on coating removal rate. The abrasive jet machining is one of the essential processes in engineering (Kovacevic *et al.*, 1997) used in many engineering applications (Hoogstrate and van Luttervelt, 1997). It was reported that the SOD and material of abrasive has an effect on machining (Wang and Wong, 1998; Fan *et al.*, 2009) and the present work also focused on the same technology for removing paints, rust and coating from the components and structures.

The spray distance or Standoff Distance (SOD) is an important parameter to be analyzed in coating process as it affects the morphology (Cherigui *et al.*, 2007). In the present work investigation have been carried out with the help of an experimental set up which has been designed and developed. Experiments were conducted by changing the horizontal and vertical angle between the abrasive nozzle and the work piece from 0 to 70°, SOD 150 to 200 mm and the coating removal rate was found out. A research has been carried out on abrasive cutting considering the impact angle 60 to 90° which leads to better direct cutting action

(Venkatesh *et al.*, 1989; Oka *et al.*, 1997). Also it was revealed from the experiments that the impact angle has an effect on cutting (Ciampini *et al.*, 2003).

As the SOD, abrasive jet striking angle and the exit diameter of the nozzle are affecting the coating removal rate, it is essential to investigate and design an efficient abrasive coating removal system. The objectives of this research work are to evaluate a suitable angle between the work piece and the abrasive jet nozzle, SOD and the abrasive jet nozzle exit diameter which enhances the coating removal rate.

MATERIALS AND METHODS

To investigate the effect of angle between the work piece and abrasive jet nozzle, SOD and the diameter of the abrasive jet nozzle, an experimental set up was designed and fabricated. The Abrasive Water Jet (AWJ) machine with a maximum pressure of 250 bar, 8.9 kW electric motor and 1.420 L min^{-1} pump was used for conducting experiments. A painted steel plate was used as test material and SiO_2 used as abrasive. The experimental setup consist the arrangements for providing linear motion of AWJ nozzle by screw mechanism, adjusting the height of the abrasive jet nozzle, changing the angle between the work piece and the abrasive nozzle horizontally and vertically and for measuring the Vertical and horizontal impingement angle of the AWJ.

Screw rod is mainly used for obtaining the linear motion of the nozzle. Two guide bars mounted on the screw rod provide parallel movement of the nozzle. To arrest the movement of guide bar the ends are provided with bushes and screwed with guide bars. For the horizontal and vertical movements of the frame, a screw rod is fitted to the bushes and the bushes are mounted on the frame. To support the screw rod and guide bar two supports are provided at the ends of the frame. Fixture for supporting the motors and panel board are provided at the right side of the experimental set up.

Figure 1 and 2 shows an arrangement to vary the angle of abrasive jet nozzle vertically and horizontally. An abrasive jet system which has been shown in Fig. 3, was modified and designed

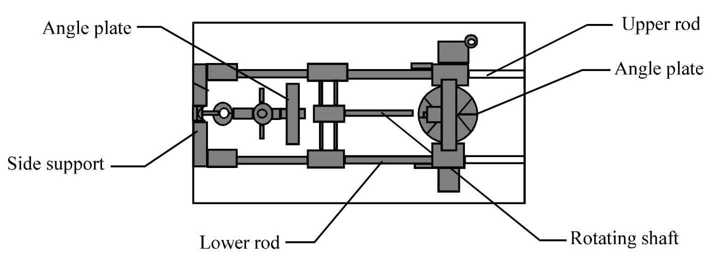

Fig. 1: Top view of experimental set up developed to change the horizontal and vertical angle of abrasive jet nozzle

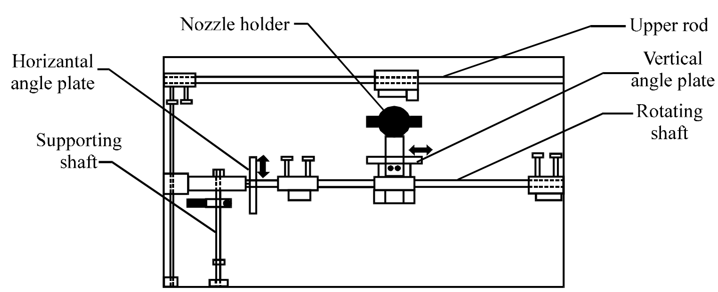

Fig. 2: Front view of experimental set up to change the horizontal and vertical angle of abrasive jet nozzle

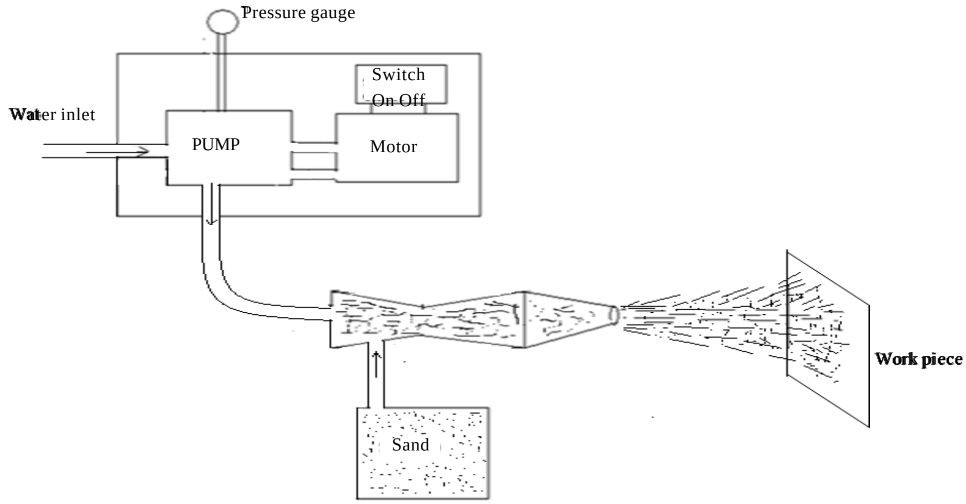

Fig. 3: Schematic diagram of abrasive jet arrangement

to obtain the horizontal and vertical movement of the abrasive jet nozzle. The pump supplies the high pressurized water which carries the abrasive particles and the mixture of water and abrasive particles flows through the nozzle and impinges on the work piece. The abrasive nozzle is connected to a rotary and swirl table with angular measurements system and it can be adjusted to any required angle and can be clamped tightly. A lead screw connected with an electrical motor with variable speed control is used to drive the abrasive jet nozzle holder to any required position. Also arrangements have been made to obtain vertical movement of the nozzle. Nozzles which are having 8 and 10 mm as exit diameters were machined.

Holding the coated work piece vertically by using a movable frame experiments are carried out. Initially the 8 mm abrasive jet nozzle was fitted to the nozzle holder and the angle between the nozzle and the work was adjusted to 10° horizontally. The Standoff Distance (SOD) is maintained as at least 150 mm. If the SOD is kept below 150 mm it was noticed that the abrasive particles are bouncing back towards the entrance of the nozzle after striking the work piece and blocking the abrasive jet. The high-pressure water jet is supplied by the power. As the high pressure water jet enters into the nozzle due to its high velocity, low pressure created and the pressure abrasive particles are entering into the nozzle and mixing with pressurized water and exit through the 8 mm nozzle and strikes the work piece. When the abrasive jet impinges on the work piece due to the impact and shear force the coating on the work piece will be removed. The time taken for removing 10 cm^2 coating from the work piece is recorded.

It has been reported that the abrasive jet can be used for surface processing and cleaning the heavier components (Raykowski *et al.*, 2001; Djurovic *et al.*, 1999).

The experimental set up was fabricated in the Special machines and lathe machine shop of Karunya University and the experiments were conducted during the year 2009-2010.

Table 1 shows the parameters which were changed for experimental investigations. Experiments were repeated by changing the angle between the abrasive jet nozzle and the work piece as 0, 10, 20, 30, 40, 50, 60 and 70° horizontally and vertically, the standoff distance from 150, 160, 170, 180,190 and 200 mm and the nozzle diameter as 8 and 10 mm. It was observed that the coating removal rate is drastically reduced when SOD becomes more than 200 mm and this due to the kinetic energy and the velocity of the abrasive jet begins to decrease. The time taken for

Table 1: Parameters for experimental investigations

Abrasive jet nozzle exit diameter in mm	Angle in deg and position of nozzle	SOD (mm)	Water pressure and pump delivery
8	0 to 70° Horizontal	150-200	250 bar, 1.420 L min^{-1}
0	0 to 70° Vertical	150-200	250 bar, 1.420 L min^{-1}
8	0 to 70° Horizontal	150-200	250 bar, 1.420 L min^{-1}
10	0 to 70° Vertical	150-200	250 bar, 1.420 L min^{-1}

SOD: Standoff distance

removing the coating from the 10 cm^2 area of work piece was recorded by changing the parameters as mentioned above.

RESULTS AND DISCUSSION

Effect of Standoff Distance (SOD) on coating removal rate: The distance between the work piece and the exit of the abrasive jet nozzle plays a major role in the coating removal rate and time. It was noticed that the coating removal time is increasing with increase of standoff distance (SOD). When the SOD is kept below 150 mm it was observed that some of the abrasive particles which are impinging on the work piece are bouncing back and blocking the jet which is coming out the nozzle and which affects the material removal rate.

Arola *et al*. (2002) also have selected and used SOD as 150 mm to have better performance. When the SOD is increasing from 160 to 200 mm and the angle is zero, the abrasive jet has to travel more distance and the jet velocity getting reduces and it begins to lose its kinetic energy, so there is a reduction in coating removal and coating removal time increases above 186 sec and reaches to 200 sec. The same effect also was found with the change in vertical angle between the work piece and the abrasive nozzle.

Effect of horizontal angle between the work piece and abrasive jet nozzle on coating removal rate: Figure 4 and 5 shows that the effect of horizontal angle between the work piece and the abrasive jet nozzle on coating removal when the abrasive jet nozzle is 8 and 10 mm. Also it shows the comparison of time taken for removal of 10 cm^2 coating for 8 and 10 mm nozzle when the horizontal striking angle is changed from 0, 40, 50 and 70° and SOD from 150 to 200 mm. However, only the best conditions have been considered for comparison.

The surface quality and texture of work pieces are depends on the process parameters and that are to be considered during the selection of process parameters (Hashish and Stewart, 2000; Deng and Lee, 2000). The horizontal angle between the work piece and the abrasive jet nozzle has been changed from 0 to 70°. For each condition Standoff Distance (SOD) also varied from 150 to 200 mm in step of 10 mm and the time taken for coating removal time was recorded for analysis.

The Fig. 4 shows the comparison between the time taken to remove the coating from the 10 cm^2 area of the work piece when the horizontal angle between the work piece and abrasive jet nozzle changed from 0 to 70° deg. It was noticed that the coating removal rate was increasing when the horizontal angle was increasing from 0 to 50°. This is due to the increase in penetration, shearing and slicing actions of the abrasive jet mixture. The coating removal time decreases form 72 to 47 sec when the SOD is 160 mm and the nozzle diameter was 8 mm.

The coating removal time increases from 47 to 102 sec when the angle changed from 50 to 70°. Above 50° it was noticed that most of the abrasive particles are passing the work piece without contacting the surface of the work piece and this leads to reduction in coating removal and increase in coating removal time. When the angle is zero the work piece becomes perpendicular to the

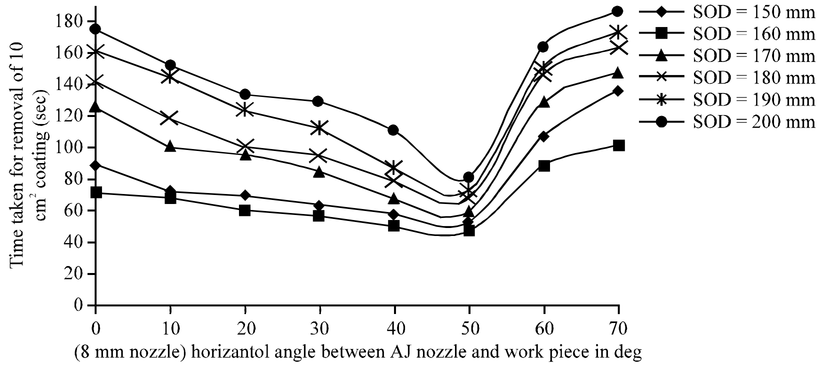

Fig. 4: Effect of horizontal angle between the work piece and abrasive jet nozzle on coating removal rate when the nozzle diameter is 8 mm

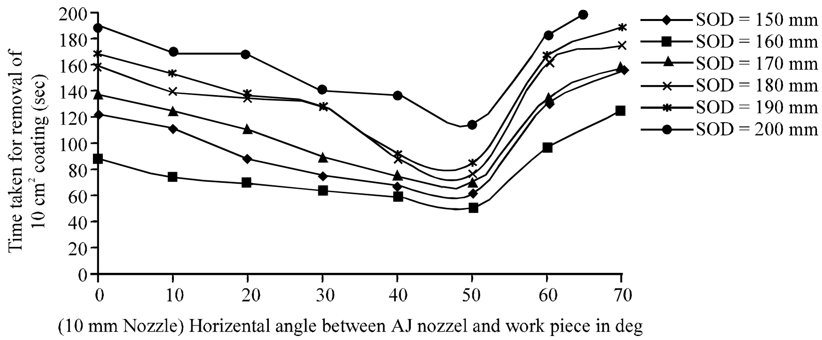

Fig. 5: Effect of horizontal angle between the work piece and abrasive jet nozzle on coating removal rate when the nozzle diameter is 10 mm

abrasive jet nozzle and the abrasive particles which are striking, the work piece becomes scattered and found to be less coating removal rate. However, due to the impact load and cutting action there will be coating removal with fewer rates and leads to more scratches and surface defects (Oka *et al.*, 1997).

The Fig. 5 shows the coating removal rate for 10 mm nozzle with various horizontal striking angles and it is clear that the coating removal rate was increasing when the horizontal angle changed from 0 to 50° and the time taken decreased from 89 sec to 51 sec when the angle has reached to 50° and the SOD is 160 mm. This is less than the performance of 8mm nozzle. The coating removal time increases from 51 to 125 sec when the SOD is 160 mm, horizontal angle changed from 50 to 70° and the nozzle diameter is 10 mm.

Effect of vertical angle between the work piece and abrasive jet nozzle on coating removal rate: The Fig. 6 shows the trend of coating removal rate when the exit diameter of abrasive jet nozzle is 8 mm. The coating removal time is decreasing from 93 to 60 sec when the vertical striking angle of jet becomes 0 to 40° and SOD is 150 mm. This is due to the higher shearing and slicing force applied by the abrasive particles on the work piece.

The coating removal time is increasing form 60 to 172 sec when the striking angle of the abrasive jet increase from 40 to 70°. During this condition the abrasive particles loses its energy while it travel in a inclined path. This is happening as the abrasive particles are slipping away from the work piece. When the striking angle becomes zero the work piece and abrasive jet are in

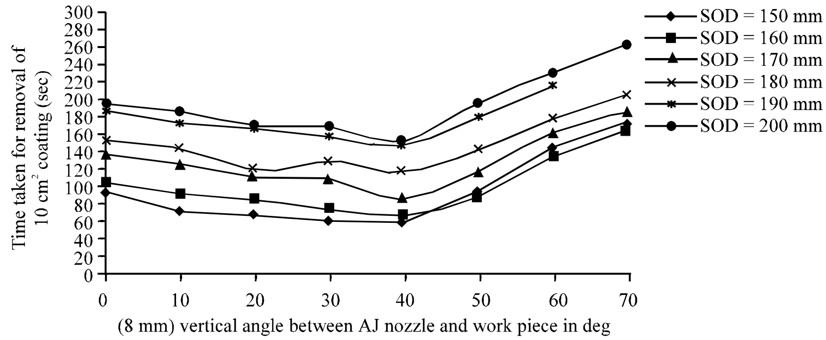

Fig. 6: Effect of vertical angle between the work piece and abrasive jet nozzle on coating removal rate when the nozzle diameter is 8 mm

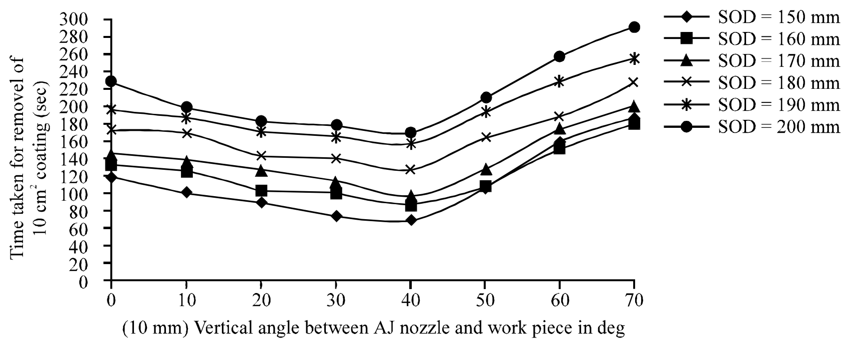

Fig. 7: Effect of vertical angle between the work piece and abrasive jet nozzle on coating removal rate when the nozzle diameter is 10 mm

90° and it was observed that the abrasive particles are impinging on the surface are getting scattered. This leads to less shearing, penetration and slicing action.

The Fig. 7 shows that the coating removal time is decreasing from 117 to 68 sec when the vertical striking angle of jet becomes 0 to 40°, SOD is 150 mm and the nozzle exit diameter is 10 mm as there is a reduction in shearing and slicing force applied by the abrasive particles on the work piece.

Effect of abrasive jet nozzle exit diameter on coating removal rate: The Fig. 8 shows the effect of coating removal rate when the exit diameter of the abrasive jet nozzle is changed. The variation in the coating removal time is due to the variation in jet velocity (Weston *et al.*, 2005). From comparison, it was revealed that the velocity of abrasive jet is increasing when the diameter is 8 mm, SOD is 160 mm and the horizontal striking angle of the abrasive jet is 50°. The time taken for removing 10 cm^2 coating was reduced to 47 from 51 sec.

When the exit diameter of abrasive jet nozzle is increased to 10 mm, SOD is 160 mm and horizontal angle is 50° the time taken for removing 10 cm^2 coating is increased to 51 from 47 sec. Similarly when the vertical striking angle of the abrasive jet is 40°, diameter of nozzle is 8 mm, SOD is 150 mm the time taken for removing 10 cm^2 coating was reduced to 60 from 68 sec. When the exit diameter of abrasive jet nozzle is increased to 10 mm, SOD was 150 mm and vertical angle was 40° the time taken for removing 10 cm^2 coating was increased to 68 from 60 sec.

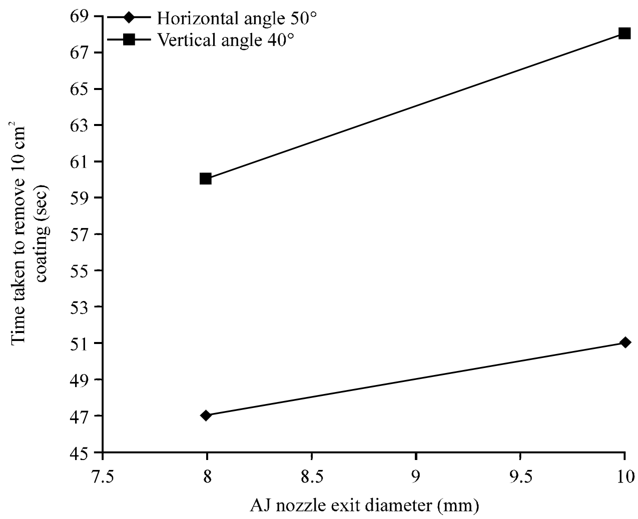

Fig. 8: Effect of abrasive jet nozzle exit diameter on coating removal rate when the horizontal and vertical angle of nozzle is 50 and 40°

Jegaraj and Babu (2005) also have conducted experiments on abrasive jet cutting and found that the increase in size of orifice is affecting the material removal rate in cutting operation and the same trend also been noticed through the present investigations during the coating removal. El-Domiaty *et al.* (2009) has analyzed the effect of nozzle diameter on material removal rate in drilling. The results of the analysis clearly shows that, when the nozzle diameter was increasing from 1 to 3 mm the material removal rate also increasing. As this analysis was related to cutting operation small diameter was used and also the same trend has been observed in the present investigation. Ciampini *et al.* (2003) and Hlavac *et al.* (2009) also have analyzed the effect of incident angle on cutting operation and it has been reported that the angle has an effect on cutting.

CONCLUSION

An arrangement for varying the angle of impingement of abrasive jet and SOD was designed and fabricated to study the effect of vertical and horizontally angle of abrasive jet and SOD on coating removal rate. Experimental investigations have been carried out to evaluate the effect of horizontal and vertical angle between the work piece and the abrasive jet nozzle, standoff distance and the exit diameter of nozzle. The time taken for removing the coating with the various conditions were found out and analyzed in detail. The experimental results will be very useful during the process of coating removal of larger components and structures in order to reduce the process time. The present investigations revealed that when the horizontal angle of nozzle is increasing from 0 to 50° and the SOD is 160 mm and the nozzle diameter is 8 mm the time taken for removing the coating from the work piece is reducing and increasing when the nozzle diameter becomes 10 mm. When the vertical angle of nozzle is increasing from 0 to 40°, the SOD is 150 mm and the nozzle diameter is 8 mm, the time taken for removing the coating from the work piece is increasing than the previous case and further increasing when the nozzle diameter increases to 10 mm. Also it was clear that the time taken for removing the coating is increasing when the abrasive jet striking position is adjusted to vertical position and decreasing when the abrasive jet nozzle is adjusted to 50° horizontally.

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