A NOVEL WORK TABLE DESIGN FOR TURNING IN ABRASIVE WATER JET MACHINE

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Abstract

Abrasive water jet had proven to be a suitable unconventional machine technique for cut-through operation. Using abrasive water jet turning only limited studies are available. Apart from usual machining practice in Abrasive Water Jet Machine (AWJM), the installation of the chuck with motor assembly as a unit similar set up like conventional lathe machine will enhance the machinability of AWJM. From the earlier studies, it is understood that the author has performed the machinability studies using this experimental set up in AWJM. But no standard procedure is described as the installation procedure of chuck and motor assembly in AWJM. Considering this, a review is conducted on the design and implementation of turning setup in an abrasive water jet machine. Based on the acquired knowledge through a literature survey and also, considering vibration, assembly, and safety factors, a new design is proposed. The author ensures that implementing this setup in an abrasive water jet machine will enhance the research work to a higher level of significance.

Keywords : AWJM, Turning, Chuck and motor assembly, Worktable design.

I. Introduction

Abrasive water jet machining (AWJM) is one of the non-conventional type machining process that used in manufacturing and R & D sectors for increasing productivity. In that, the detrimental possibility of kerf angle will reduce at high water pressure flow [I]. With the optimized working conditions, it became possible to increases the Material Removal Rate (MRR) based on the work material. The cyclic change in axial deflection of the jet pressure over the kerf region induces less repulsion force [II]. Ansari et al. [III] proposed the new design for AWJM. In that the
The macro mechanism behind the AWJM is discussed and concludes the depth of cut plays the major role and that affects the material removal rate (MRR) while turning. Zohourkari et al. [IV] conducted the turning operation in AWJM and reported about the relations that exist between the transverse speed, pressure and mass flow rate of abrasives. Accordingly, the specific hydraulic pressure, abrasive and mixing ratio are the parameters relevant to the development of water jet and consist of water jet pressure up steam by the AWJ nozzle. Depth of cut and pressure plays a significant role in MRR. If the depth of cut and pressure increases, the MRR also increases and it is predicted through the second-order model. Ansari et al. [V] carried out the AWJ turning operation and report the effect of input parameters such as abrasive discharge, proportions, water jet pressure, diameter of orifice on material removal. The change in the co-efficient of water flow rate is affected by the course of orifice however, the influence of the water jet velocity is not limited by this effect. The properties of abrasive particles such as modulus of elasticity, hardness, density, strength will enhance the cutting performance of the workpiece. The volume of material removal rate linearly depends on the abrasive particles along with transverse speed.

Kartel et al. [VI] proposed an experimental setup that decreases the noise pollution produced when using AWJ turning. Accordingly, the researcher develops a new technique respective to take out the ripple effect produced by the water jet pool and the splash by AWJ. By using the developed model, the polymer-based plastics are machined with the help of abrasive water jet at below the water level. According to Flogel et al. [VII], a submerged nozzle condition, the workpiece gets machined by the high-pressure water flow. In that, the material removal of titanium alloy Ti6Al4V by using AWJ turning and also, the effects of a parameter are discussed. The experimental design was used to recognize the effect of various parameters namely they are feed rate, abrasive discharge, particle size, cutting depth, and cutting velocity on output responses MRR and surface roughness. Gupta et al. [VIII] conducted the AWJ turning operation on Unidirectional Glass Fiber Reinforced polymer composites (UD-GFRP) as a sample in AWJM. The experiments using the turning setup is used to examine the machinability of UD-DFRP. The effect of output (cutting force) is measured by the following six parameters they are; tool nose radius, rake angle, feed rate, cutting velocity, cutting environment and cutting depth. The cutting force is an important factor while machining. From this study, the cutting force is rapidly increased while increasing the depth of cut and feed rate. Hlavacek et al. [IX] had designed a set up for turning in AWJM. The workpiece is rotated in clockwise and anti-clockwise direction in AWJ turning for a constant machining time. By these arrangements, the material removal and surface finish or surface roughness of workpiece material are measured and reported, the surface quality of the sample was moreover increased.

Hutyrova et al. [X] prepared a material cellulose-based plastic composite material (40×60×3600mm) is made by using injection molding and extrusion process. In their experimental studies compares the machinability of the wood-based plastic by different machining methods such as water jet and AWJ. The proposed experimental setup of the model is gives a better surface finish of the sample. Ramu et al. [XI]
predicting and comparing the final diameter which is obtained from AWJ machining with the FEM model, while machining of stainless steel. In that, the impact angle of the abrasive jet as a major factor for predicting the kerf geometry and it is essential to analyze the final diameter of ductile and brittle material. The sine function of the kerf geometry provides better surface quality than the cosine and exponential function. Kartal et al. [XII] performed the AWJ machining of (CU-Cr-Zr) alloy and analyzing the surface roughness of the material for various inputs such as nozzle feed, nozzle distance, and abrasive flow rate. Whenever the nozzle feed and stand of distances get increased leads to increase surface roughness. The average surface roughness decreases based on the increment and decrement of spindle speed and abrasive flow rate. In another study by Kartal et al. [XIII], MRR and surface finish of the low-density polyethylene material improved by using AWJ turning for the optimum condition which is obtained from the experimental design method. The lower feed rate associated with a higher level of flow rate and spindle speed to increases the MRR with the acceptable surface roughness.

Xu et al. [XIV] performed the machinability of the study of 1060 aluminum alloy material is done by the AWJ machine. Conventional machining of aluminum induces the heat which predominantly affects the surface property of the material. Surprisingly, AWJ machining improves the surface quality along with greater volume of MRR due to the heat-free cutting zone. The researcher also stated that the higher level of spindle speed and pressure improve the surface finish. In the meantime, a higher level of transverse speed increases the surface roughness value of the sample material. Balamurugan et al. [XV] has been conducted the AWJ machining on LaPO4/Y2O3 material for various levels of Feed, abrasive water jet pressure, abrasive discharge and concludes depth of cut is affected with respect to feeding and water jet pressure. The efficient cutting is done by a normal jet impact angle with a higher surface speed. Depth of cut majorly equalizing out whenever the abrasive flow rates get increased. In another machining study by, Balamurugan et al. [XVI] conducting turning operation on M2HSS material, by using AWJ and concludes that, the fundamentals of inducing residual stress into the sample surface to enhance the surface hardness of the materials that increased the life of the materials. Bhasha et al. [XVII] claimed that, while machining of aluminum composites generates the higher cutting temperature in the cutting zone. Arunkarthikeyan et al. [XVIII] reported that higher temperature increases the tool wear and Ra.

The main objective of the current study is to modify the existing worktable with proper chuck and motor assembly of the AWJ machine to get maximum MRR with the acceptable surface finish. For that purpose new chuck and motor assembly designed and implemented on an existing abrasive water jet machine.

II. Experimental Methods and Materials

It is designed with a new fixture which could be an integrated part in the AWJM. A chuck powered by an electrical motor, mechanical power transmission by means of links or by a belt from the motor. This assembly is placed the available bed area in AWJM. The flexibility of this arrangement will permit us to cut the samples
both in completely submerged and in the open environment. Also, the machining cylindrical workpiece is possible in AWJM. The fixture is prepared for motor chuck assembly. Here using a belt for power transmission the slip can be reduced in case usage of V-Belt and stepped belt. The speed control device is used to control the speed of the motor and to change the direction (Clockwise and Counterclockwise). Normal lathe operations like (turning, facing, slotting, drilling, threat cutting) can be on AWJM by using this type of assembly. The modified AWJM is shown in Figure 1.

![Proposed design chuck and motor assembly](image1.jpg)

**Fig. 1:** Proposed design chuck and motor assembly

![Proposed design of work table](image2.jpg)

**Fig. 2:** Proposed design of work table

The mixture of abrasive particle and the high velocity water mixed in the flow chamber and it’s shown in Figure 2. AISI D2 steel is the workpiece material has excellent hardness, toughness and wear resistance and it is used in high-speed cutting. Table 1 shows the chemical composition of AISI D2 tool steel. The current experimental study follows the Taguchi’s L4 orthogonal array (OA) for 3 factors and 2 levels design matrix was performed with the Kartal et al [XIII] design. The machining input parameters and their levels are displayed in Table 2. Three machining parameters, such as abrasive flow rate (AFR), standoff distance (SOD) and transverse speed (TS), are considered for investigation purpose. The parameter
selection based on low and high level and the output responses (MRR and Ra) are observed for all experiments.

Table 1: Chemical compositional percentage of the AISI D2 steel

| C    | Mn  | Si  | Cr | Ni | W  | V  | P  | S  | Cu | Fe |
|------|-----|-----|----|----|----|----|----|----|----|----|
| 1.60 | 0.55| 0.60| 12 | 0.2| 1.0| 1.10| 0.03| 0.03| 0.25| 82.64|

The L4 array turning experiments were performed for the cylindrical workpiece for the length and diameter are 100 mm, 50 mm respectively. The surface profile roughness (Ra) of the workpiece is measured by the Talyurf SJ-201P surface measuring device.

Table 2: Machining parameters and their levels

| S.No. | Input variables       | Level-I | Level-II | Units |
|-------|-----------------------|---------|----------|-------|
| 1.    | Abrasive mass flow rate| 250     | 400      | g/min |
| 2.    | Standoff distance     | 1       | 2        | mm    |
| 3.    | Traverse speed        | 80      | 120      | mm/min|

III. Results and Discussion

AWJ machining is carried out on the AISI D2 tool steel using Taguchi’s L4 OA experimental design matrix. MRR and Ra are observed and compared for the both design of AWJM is tabulated in Table 3.

Fig. 3: Variation in MRR (Kartal et al [XIII] design Vs proposed design)

Variation in MRR for Kartal et al [XIII] design and proposed design of AWJM is shown in Figure 3. Proposed design gives the maximum MRR for all experimental trails. The ‘3’ experimental trail shows the maximum value of MRR. The higher value of AFR and minimal SOD increases the MRR. The abrasive particles have
removed from the material at a higher level. The MRR improvement of proposed design lies between 4.6 to 14.7%. The maximum MRR improvement observed for experimental trail 4. Variation in Ra for Kartal et al [XIII] design and proposed design of the AWJ machine is shown in Figure 4. The proposed AWJM shows better results for all combinations of cutting conditions. The highest Ra improvement is obtained for the new design during machining of the AISI D2 steel for various cutting conditions. Ra improvement percentage lies between 2.7 to 14.4%. The maximum improvement is observed for ‘1’ experimental trail, Compared to the Kartal et al [XIII] design Ra value. The lower level of AFR, SOD, and TS enhances the better surface finish. The reason for the improvement of proposed design is, the vibration was controlled effectively.

![Fig. 4: Variation in Ra (Kartal et al [XIII] design Vs proposed design)](image)

### Table 3: Machining parameters and their levels

| S.NO | AFR (g/min) | SOD (mm) | TS (mm/min) | Proposed design | Kartal et al [XIII] design | Improvement |
|------|-------------|----------|-------------|----------------|----------------------------|-------------|
|      | MRR (mg/min) | Ra (µm) | MRR (mg/min) | Ra (µm) | MRR (%) | Ra (%) |
| 1    | 250         | 1        | 80          | 22.4 | 2.523 | 19.5 | 2.886 | 12.9 | 14.4 |
| 2    | 250         | 2        | 120         | 27.3 | 3.967 | 25.3 | 4.096 | 7.3  | 3.3  |
| 3    | 400         | 1        | 120         | 28.1 | 3.826 | 26.8 | 3.991 | 4.6  | 4.3  |
| 4    | 400         | 2        | 80          | 21.8 | 4.120 | 18.6 | 4.230 | 14.7 | 2.7  |

### V. Conclusion

- AWJ machine was designed with new chuck and motor assembly and the machining was conducted as per the Taguchi’s L4 OA on AISI D2 tool steel, to verify the performance of the machine.
Proposed AWJ machine exhibits better machinability characteristics compared to the existing AWJ machine. TS has the greatest influence on the surface roughness. TS variation influences the Ra. AFR is the predominant factor while considering the MRR followed by SOD.

TS is not affect the output responses individually. The interaction of AFR and SOD plays important role in MRR.

Proposed AWJ improves the MRR and Ra, the percentage is lies between 4.6 to 12.9%, 2.7 to 14.4% respectively.

The proposed AWJ machine is suitable for machining the AISI D2 steel than the Kartal et al [XIII] design used AWJ machine

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