IJSTE - International Journal of Science Technology & Engineering | Volume 2 | Issue 4 | October 2015
ISSN (online): 2349-784X

Design and Development of A Torch Head Mechanism for A CNC Plasma Cutting Machine

Mr. M. E. Shinde
PG Student
Department of Mechanical Engineering
Pimpri Chinchwad College of Engineering, Pune, India

Dr. S. S. Lakade
Professor
Department of Mechanical Engineering
Pimpri Chinchwad College of Engineering, Pune, India

Abstract

One of the most important non conventional cutting methods is Plasma Arc cutting. It is highly accurate, good surface finish, and having ability to cut any hard materials. Plasma cutting can be used to cut all electrically conductive materials, such as structural steels, high-alloy steels; nonferrous metals i.e. aluminium and copper. By using plasma cutting technology, sheet metal between 0.5 mm and 180 mm thickness can be cut. For cutting of sheet metal, plasma cutting machine is used. In plasma cutting machine, three pairs of rack and pinion gear are used to obtain motion in the X and Y direction. In this system, torch to work distance is manually adjusted. In this conventional system, Bevel cutting of metal is not possible. Setting of angular motion of torch is not possible in conventional cutting method. In this study, special mechanism is designed for vertical and angular motion of torch, i.e. oblique to the cutting surface of torch for bevel cutting. Model of this mechanism is developed using CATIA. Bevel cutting up to 50 degree is achieved by using this mechanism. The results are validated experimentally on a torch head Mechanism model manufactured. Stress analysis of mechanism is carried out by using suitable CAE software.
Keywords: Bevel Cutting, Bevel Head Mechanism, Plasma Arc Cutting, Tapper Cutting, And Torch Head Mechanism

I. INTRODUCTION

Plasma cutting is a process that is used to cut steel and other metals using a plasma torch. In this process, an inert gas is blown at high speed out of a nozzle and at the same time an electrical arc is formed through that gas from the nozzle to the surface being cut, turning some of that gas to plasma. The plasma is sufficiently hot to melt the metal being cut and moves sufficiently fast to blow molten metal away from the cut. Plasma cutting can be used to cut all electrically conductive materials, such as structural steels, high-alloy steels. Various Equipments are used in the plasma cutting machine. First equipment is power source. Second equipment is plasma burner electrode and nozzle. Third equipment is work piece. The work piece is a part of an electric circuit. The ground of the connected work piece must be designed to permit a continuous flow of current. Forth equipment is coolant circulation system. Due to high thermal loads, plasma cutting requires effective cooling. Last equipment is cutting bench and exhaust system cutting. Benches serve as a stable device for positioning metal sheet to be cut.

Fig. 1: CNC Plasma Cutting Machine

In conventional plasma cutting system, Taper cutting of metal is not possible. We cannot set torch angle. Angular motion of torch is not possible. Objective of this project is to Design a mechanism for up and down motion i.e. vertical motion of torch. Design a mechanism for angular motion i.e. oblique to the cutting surface of torch for taper cutting. Stress analysis of this mechanism and to reduce the production cost of the torch head. Problem statement for this project is to design a torch head mechanism for vertical motion of torch head and angular motion for bevel cutting in plasma cutting machine and analysis of these mechanisms for minimum stress.

II. METHODOLOGY

Modeling methodology consist of five major component illustrated in figure. They are (1) Study of problem in which When problem was found out, we studied the problem for various consideration (2) Developing the mechanism for the torch movement in this component actual working model is created for required motion and mode is made in modelling software (3) Numerical analysis of mechanism in this parts model made in CAD software is analysed in ANSYS software (4) manufacturing and testing, in this part model is manufacture and assembled and testing is taken on plasma cutting machine using 5 axial control system (5) Result and validation, in this part result obtained from testing are compared with existing result of cutting.

III. DESIGN AND ANALYSIS

A. Design of the Driving Mechanism for Vertical Arm:

1) Selection of Ball bearing-1:
Shaft bearing will be subjected to purely medium radial loads; hence we shall use ball bearings for our application. AXIAL load = 590 N. $P = X F_r + Y F_A$, For our application $F_R = 0$, $P = Y F_A$ As; $F_A < e \Rightarrow X = 1, P = F_A$, Max AXIAL load = F_r =590 N., P= 590 N, dynamic load capacity of bearing $L = (C / P)^p$, where p= 3 for ball bearings, Assuming: L_H = 8000hr But; $L = (60\, n\, L_H)/10^6$, L=240 mrev, C= 3666.53 N. As the required dynamic capacity of bearing is less than the rated dynamic capacity of bearing; selecting; Single Row deep groove ball bearing as follows

Table – 1
Bearing Selection-1

IsI No	*Bearing design No (SKF)*	*d*	*D1*	*D*	*D_2*	*B*	*Basic capacity*	
50AC02	*6204*	*20*	*25*	*47*	*42*	*14*	*12700*	*6200*

2) Selection of Motor:
Assuming that the maximum weight of mechanism with all parts is not to exceed 60 kg . The net load on base plate thus the load on shaft = 590N approx. Assuming that the maximum bearing diameter on shaft not to exceed 50 mm. Coefficient of friction of steel to steel = 0.15 in lubricated condition. Friction force = 0.15 x 590 =88.5N. Maximum radius of the ball cage for 6010 bearing= 23.5 mm. Thus frictional torque to be overcome by motor = 88.5 x 0.0235 =2.07975 N-m. Traction torque is given by T= Cr x F x r ---Where , Cr- Coefficient of rolling resistance -= 0.15 for steel on steel, F= μ Rn =590 x 0. 15 =88.5 N, Factor of safety = 2 , Torque required by motor to rotate the shaft against the rolling resistance is given by T= 4.1595 N-m:

3) Design of Shaft -1:
According to ASME code permissible values of shear stress may be calculated from various relations. ($\tau_{max} = 0.18\, \tau_{ut}$) = 144 N/mm^2, OR ($\tau_{max} = 0.3\, \tau_{yt}$) =180 N/mm^2, Considering minimum of the above values τ_{max} = 144N/mm^2 . Shaft is provided with key way; this will reduce its strength. Hence reducing above value by 25%, τ_{max} = 108 N/mm^2. T design = 4.1595 Nm . Check for torsional shear failure of shaft. Assuming minimum section diameter on input shaft = 20 mm ---TO hold the shaft of the motor which is 12.7 mm diameter d =20mm, $Td = \Pi/16 \times \tau_{act} \times d^3$, $\tau_{act} = (16 \times Td)/ \Pi \times d^3$, τ_{act} = 0.71 N/mm^2,

- Analysis of shaft-1

In Analysis of shaft first CATIA geometry is taken on which meshing is done in ANSYS software. One side shaft is fixed as shown in figure. Then moment is applied on the shaft. Final part is static structural analysis is carried out on this shaft. Result shows the von mises stress on the shaft is 8.801 *105 Pa which is below the allowable stresses.

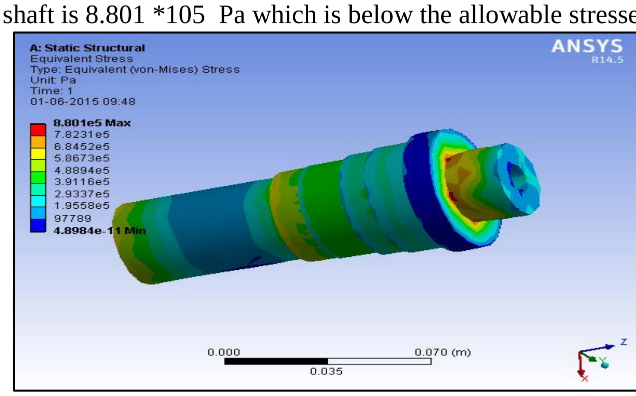

Fig. 2: Von-Mises Stress on the Shaft-1

B. Design of Driving Mechanism for Torch Arm:

1) Design of Vertical Arm:

The Vertical arm is a link that is subjected to direct tensile load in the form of pull = 590 N due to weight of system. Material is M.S. For calculating the stresses in the vertical arm, consider two areas of vertical arm. Consider the case plate with hole for calculating stress. First neutral axis is found out. $\bar{y} = \frac{A_1y_1+A_2y_2}{A_1+A_2}$ $\bar{y} = 261.363$. Then moment of inertia is calculated bout this axis $I = I_G + Ah^2 I = 544374366.8$, $\sigma = \frac{my}{I} \sigma = 10.203$. Analysis of vertical arm…..Result shows the von mises stress on the vertical arm is 1.19 *10^9 Pa which is below the allowable stresses.

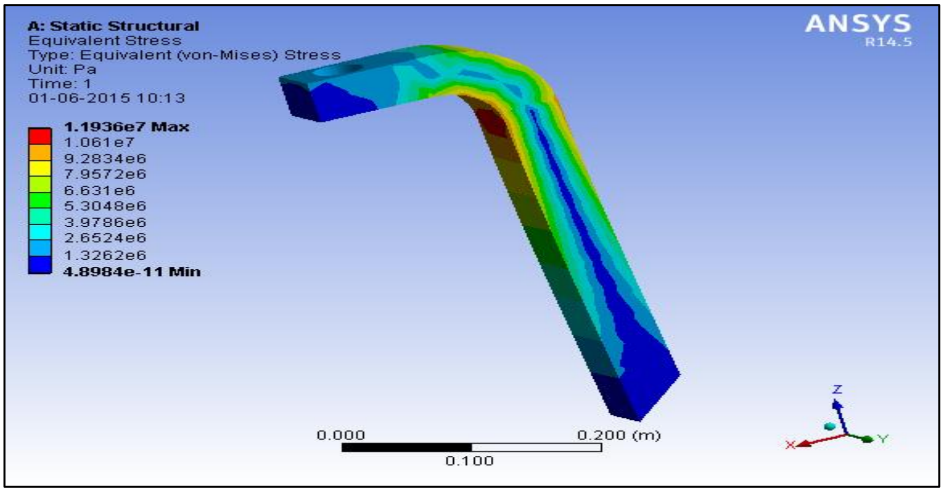

Fig. 3: Von-Mises Stress On The Vertical Arm

2) Design of Torch Arm Bracket:

On the torch arm bracket load = 196 N. Considering the weight of mechanism no to exceed 20 kg. Material is M.S. For calculating the stresses in the torch arm bracket, consider two areas of arm bracket. Consider the case plate with hole for calculating stress. First neutral axis is found out. $\bar{y} = \frac{A_1y_1-A_2y_2}{A_1-A_2}$ $\bar{y} = 59.49$ Then moment of inertia is calculated bout this axis is $I = I_{xx1} - I_{xx2}$, $I_{xx1} = \frac{bd^3}{12} + A_1(y_1 - \bar{y})^2$, $I = 7706708$ Also bending moment is calculated as $M = \frac{wL^2}{2}$, $M = 50700$, $\sigma = \frac{my}{I}$, $\sigma = 0.46$ N/mm^2 . Analysis of torch arm bracket…….Result shows the von mises stress on the torch arm bracket is 7.52 *10^5 Pa which is below the allowable stresses.

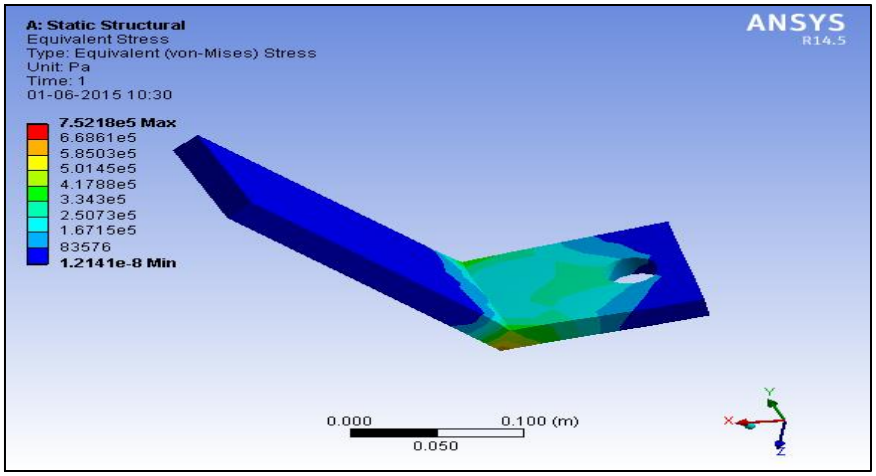

Fig. 4: Von-Mises Stress on the Torch Arm Bracket

IV. MANUFACTURING AND TESTING

Model designed is manufactured. For the manufacturing of this model mild steel material is used. Various process involved in the manufacturing are cutting, drilling, grinding, welding, milling. Various parts to be manufactured are base plate, support rib, vertical arm, shaft, holder bracket. Five axial control systems are used for the testing of model in which motors used are controlled by this system. So that we can get torch movement in any direction and angular cutting is also possible.rib is used to support the structure. Bearing is press fitted into the plate. Motors are connected to shaft through coupling.

Fig. 5: Front View of Assembly of Manufactured Model

A. Testing:

Test setup for this mechanism include CNC control system, CNC cutting machine, torch head mechanism, plasma torch, sheet metal plate, bevel angle measurement, surface roughness measurement

1) Test Procedure:

In Testing of this mechanism, using this mechanism cutting of sheet metal is done. For that CNC control system is used for testing. In this test whole assembly is mounted on the CNC cutting machine. Then this mechanism is fitted on this machine. Plasma torch is attached to system. Then input parameters are set. Cutting of sheet metal is done. In this test bevel at 30^0, 45^0 are cut. Also sample straight bevel is cut which is shown in figure.

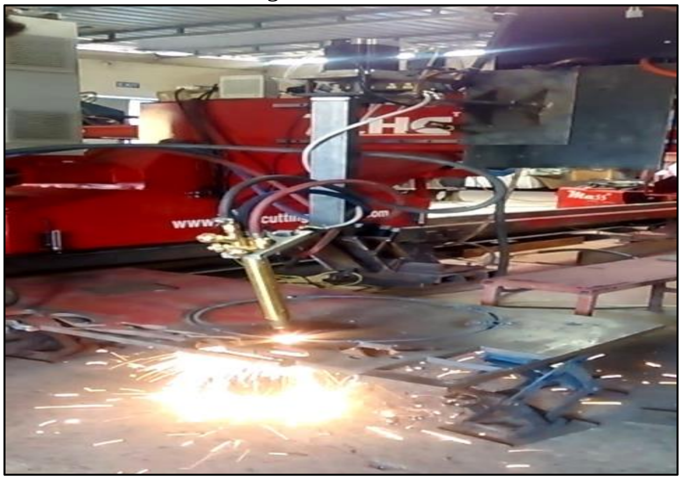

Fig. 6: Testing Of Mechanism

Fig. 7: Cutting Sample Of Thickness 16 Mm

Test Results Sample straight bevel is cut which is shown in figure (7)

2) Surface Roughness Measurement Test:

Measured roughness value of surface is in RA

Table – 2
Measured Roughness Values of Plate 1,

surface	*roughness value (μm)*
Cutting surface 1	*6.66*
Cutting surface 2	*7.82*
Cutting surface 3	*9.47*
Cutting surface 4	*7.21*
Cutting surface 5	*8.07*

Table – 3
Measured Roughness Values Of Plate 2

surface	*roughness value (μm)*
Cutting surface 1	*9.36*
Cutting surface 2	*7.13*
Cutting surface 3	*9.29*
Cutting surface 4	*6.78*
Cutting surface 5	*7.51*

Table – 4
Average Roughness Values

Sample plate	*Average roughness value*
plate 1	*7.846*
plate 2	*8.014*

As discussed from the table average roughness values of the cutting surface plates are 7.846, 8.014. By using conventional machine, roughness values are in between 6.3 to 12.5 up. These values are in acceptable region.

3) Angle Measurement Test:

In this test bevel cutting is done for 30^0 and 45^0. Then cutting angle is measured by using angle measurement.

V. RESULTS AND DISCUSSION

By using torch head mechanism straight cutting is done within acceptable tolerance of 1.5 mm. Stresses in the various components are calculated using ANSYS software. Stresses in the shaft, vertical arm, torch arm bracket, support rib are 0.88, 11.9, 0.7521, and 1.21 N/mm2. Bevel cutting at 30^0 and 45^0 is done. And angle is measure using angle measurement which shows same angle which is given for cutting. As discussed from the table (4) average roughness values of the cutting surface plates are 7.846, 8.014. By using conventional cutting machine, roughness values are in between 6.3 to 12.5 µm. These values are in acceptable region. Average roughness values obtained from test on plate 1 and 2 are shown in table (4)

VI. CONCLUSION

Manufacturing of torch head mechanism is easy and less costly. For manufacturing of torch head mechanism, components such as type of bearing and motor required are simple and easily available. Material used is mild steel.

Stresses induced in various components are calculated theoretically as well as by using ANSYS software. Results were compared which shows approximately same results. Stresses in the shaft by using ANSYS Software are 0.88 N/mm2 and numerically calculated is 0.71 N/mm2. Stress in the shaft is maximum where keyway presents. Stresses in the vertical arm by using ANSYS software are 11.9 N/mm2 and numerically calculated is 10.203 N/mm2. Stress in the vertical arm is maximum where curvature of arm is presents. Stresses in the torch arm bracket by using ANSYS software are 0.7521 N/mm2 and numerically calculated is 0.46 N/mm2. Stress in the torch arm bracket is maximum where torch is mounted on the bracket. Stresses in the support rib by using ANSYS software are 1.21 N/mm2 and numerically calculated is 0.923 N/mm2. Stress in the support rib is maximum where middle part of rib. Hence stresses induced in the component are within the acceptable value.

By using torch head mechanism bevel cutting at various angles is possible. Bevel cutting of sheet metal at angle 30^0 and 45^0 is performed. Maximum 50^0 bevel cutting is obtained using this mechanism. In this mechanism use of plasma as well as oxi-gas cutting torch is possible.

Average surface finish measured on sample cutting plate 1 and 2 are 7.846 and 8.014 which is within the acceptable region.

ACKNOWLEDGEMENT

I wish to express sincere thanks to my project guide Dr. S. S. Lakade (Head of Mechanical Department) for his valuable guidance and encouragement throughout the course of the work.

I am also grateful to Mr. Bankar sir (General Manager of Gautami Engineering Works) for direct or indirect help in completion of this project also thankful to Mr. Sagar, Mr. Ashwin and Mr. Ansar sir for help in completion of this project.

Last but not the least this acknowledgement would be incomplete without rendering gratitude to all those have helped in completion of this project.

REFERENCES

[1] Robert T. Flaig, Holland, NY (US); Garick J. Tischler, LakevieW, Bevel head attachment for plasma And oxy fuel cutting machines US patent 2011/0109022 United States A1 May 12, 2011
[2] Robert T. Flaig, Holland, NY (US); Garick J. Tischler, LakevieW, NY bevel head attachment for plasma and oxy fuel cutting machines US patent 8,378,250 B2 United States Feb. 19, 2013
[3] Yoichi Maruyama, Chiba_ken; Takashi Kawaguchi, IchikaWa, both of (JP) US patent 6,201,207 B1 Mar. 13, 2001 torch angle setting apparatus
[4] Murray Forlong, Auckland apparatus and methods for control of a material processing device US patent 2003/0000928 A1 Jan. 2, 2003
[5] Matthew Fagan, Middle Park bevel head for controlling a cutting torch to cut plate with weld preparation US patent 2012/0242015 A1 Sep. 27, 2012
[6] John H. Olsen, Vashon, apparatus that holds and tilts a tool US patent 7,074,112 B2 Jul. 11, 2006
[7] Zhipeng Lu, Hanover; John Sobr,Lebanon; Norm LeBlanc, Claremont; L. Peterson, Lebanon, plasma arc torch position control US patent 5,866,872 Feb. 2, 1999
[8] Seamus Gordon 1, Michael T. Hillery Development of high-speed CNC cutting machine using linear motors Journal of Materials Processing Technology 166 (2005) 321–329
[9] Neil sclater nicholas, p chironis Mechanism and mechanical devices source book
[10] V B Bhandhari design of machine element mcgraw hill education pvt ltd third edition.