International Journal of Futuristic Trends in Engineering and Technology
ISSN: 2348-5264 (Print), ISSN: 2348-4071 (Online)
Vol. 3 (05), 2016

Design of a Guiding Mechanism for Welding over given Circular Profile

(Paper ID: 35ET3004201614)

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***Abstract*:** In MAG welding, quality of a welded joint is directly influenced by the welding input. The lists of problem identified during the process are: Poor weld quality, larger cycle time, Continuous human body exposure to UV-radiation, Process not as per welding procedure specification, Welding parameters decided on the basis of welder’s experience, etc. Thus, a guiding mechanism can be proposed to do MAG welding on a circular profile with required parameters at lower cost compared to Industrial welding robots. Hence, a generic design of welding robot arm with estimated geometrical specifications is proposed in the research paper and same are verified on the basis of strength criterion.

Keywords: Metal Active Gas Welding (MAG), Arduino microcontroller, lead screw

I. INTRODUCTION

Welding is one of the most common methods used for joining metals. It is at the same time described as a dusty and dangerous process. It involves such phenomena as: splinters, slag, gases and radiation. Due to the fact that joint production is time-consuming and it often requires the necessity to work in a limited area, the welder’s body is exposed to long-term harmful influence of UV radiation and toxic fumes. [1].

In order to reduce the hazardous effect of the above mentioned factors along with the industrial development and particularly with the implementation of advanced electronics in machines, new welding technologies as well as devices fully or partially automating the welding process have been developed. [1].

While welding of circular profile, it is not easy to maintain all the required parameters. Also, the process is time consuming and tedious. The weld bead is irregular and discontinuous.

Thus, it is not possible to control all the parameters manually. Hence, this study incorporates the design of an Arduino controlled manipulator that helps the welding of circular profile.

II. MAG WELDING PROCESS

MAG welding process is based on the principle of developing weld by melting faying surfaces of the base metal using heat produced by a welding arc established between bases metal and a consumable electrode.

Metal inert gas process uses the automatically fed consumable electrode. Therefore it offers high deposition rate and so it suits for good quality welded joints required for industrial fabrication. Consumable electrode is fed automatically while torch is controlled either manual or automatically.

Parameters affecting MAG Welding Process:

Current, Voltage, Travel Speed, Stick Out, Electrode Extension, Electrode Inclination, Electrode Size, Shielding Gas & Flow Rate, Welding position, etc. [2],[3],[4],[5].

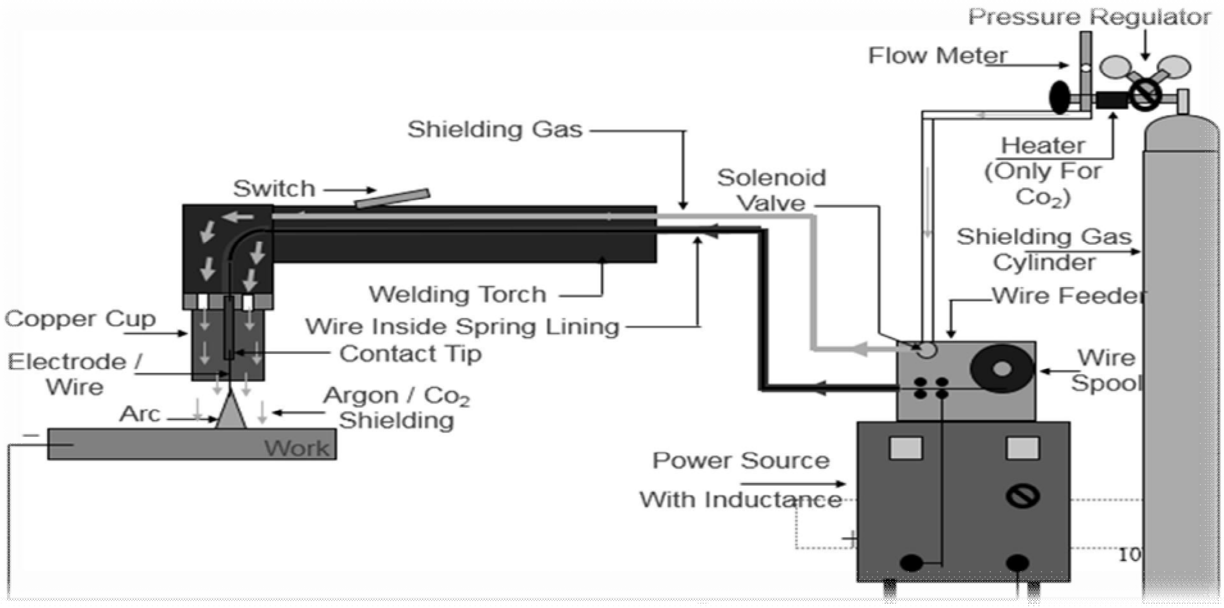

Fig. 1. MAG welding schematic

III. III Design of Mechanism

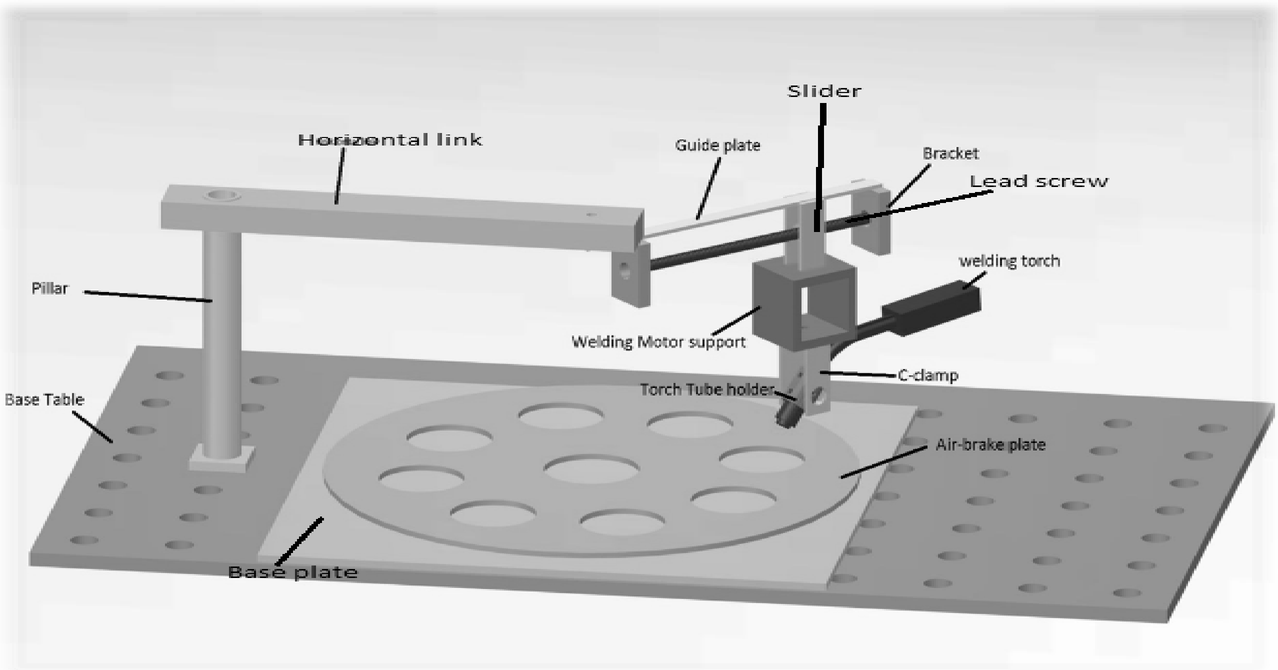

Fig. 2. 3D Model of Mechanism.

A generic design of mechanism for circular welding and various parts involved in mechanism as shown in fig. 2 are:

- Torch Holder Tube
- C Clamp
- Clamp
- Slider
- Guide Plate
- Acme Lead Screw
- Bracket
- Horizontal Link
- Pillar
- Nut

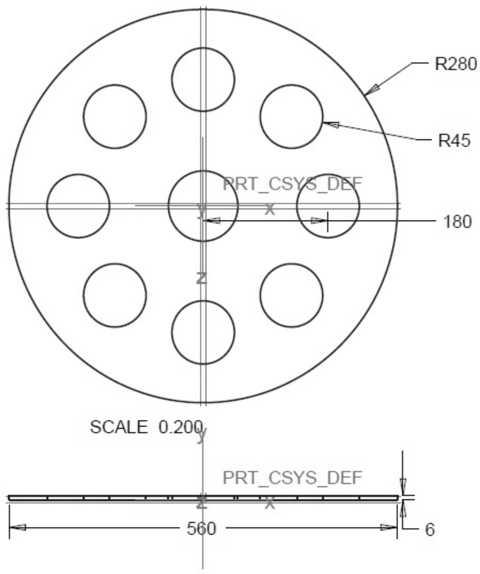

Fig. 3. Circular plate to be welded.

Various parts of the mechanism are designed keeping in mind the Circular plate with annular holes as shown in fig. 3 as the part to be welded.

The plate, on its outer periphery has to be welded with a base plate and all the annular holes have to be welded with the same baseplate on their inner peripheries.

Here, due to geometrical constraints, first we have selected dimensions of various parts and then have checked for strength.

Most of the parts are designed using simple strength relationships such as shear, bending or tensile strength under given load.

Design of some of the main parts of the mechanism is as follows:

A. *Design of torch holder tube:*

From known properties of materials and geometrical data,

Material of tube be medium carbon steel with maximum shear strength = 40 MPa

Based upon common information available from market, weight of MAG Welding torch = 2.0 kg

And as shown in fig. 4:

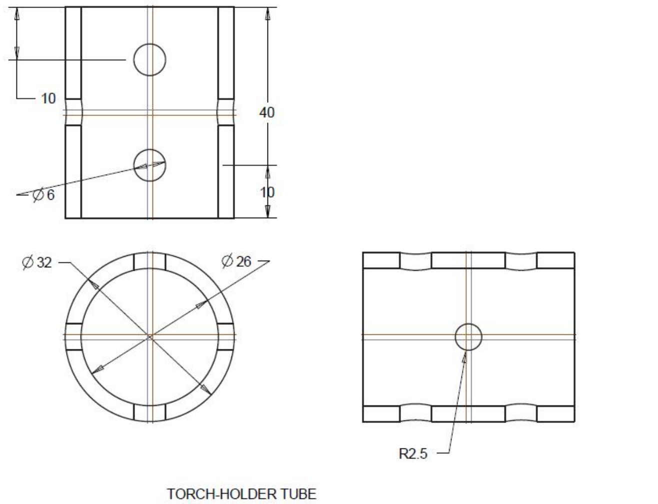

Fig. 4. Design of torch holding tube.

Outer diameter of tube d_o = 32 mm,

Inner diameter of tube d_i = 26 mm, l = 40 mm,

Diameter of hole d_{hole} = d = 6 mm

Shear stress $f_s = (2\times P)/((d_o-d_i)\times d)$

$= (2\times 2.0\times 9.81)/((32-26)\times 6)$

$= 1.09 MPa < 40 MPa$

Thus, design is safe.

B. *Design of horizontal link:*

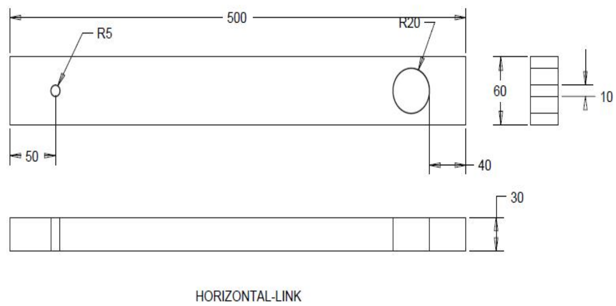

Fig. 5. Design of horizontal link.

From known properties of materials and geometrical data, Weight of the components supported by horizontal link as shown in fig.2 is 7.324 kg.

Also, from fig. 6:
Length L = 500 mm, width b = 60 mm, thickness t = 30 mm,
Large hole diameter d*1* = 40 mm,
Small hole diameter d*2* =10 mm.

Load acting P = 7.324 kg = 7.324 × 9.81 = 71.85 N.
Let, P = 75 N.

Moment at large hole:
Moment M = P × l = 140 × 875
=122500 N-mm
Moment of inertia I = $(60 \times 40^3)/12 - (\pi \times 40^4)/64$
= 194336.29 mm^4
Section modulus z = I/y = (194336.29)/20
= 9716.82 mm^3

Bending stress σ_b = M/z = 122500/ (9716.82)
= 12.61 MPa < 80 MPa

Shear stress σ_s = P/ ((b-d*2*) ×t) = 140/ (20 × 30)
= 0.233 MPa < 40 MPa
Thus, design is safe.

C. *Design of Pillar:*

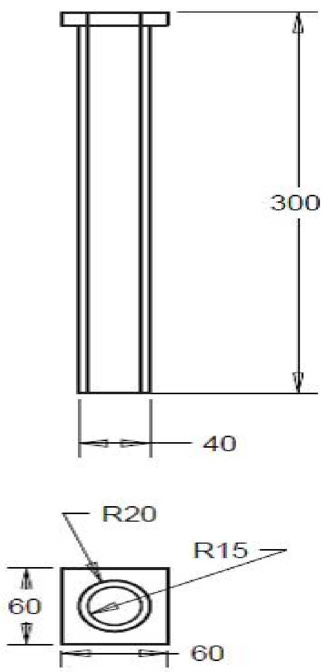

Fig. 6. Design of Pillar.

From known properties of materials and geometrical data, weight of the components supported by as shown in fig.2 is 8.5 kg.

Load acting P = 8.5 × 9.81 = 83.385 N

Here, as shown in fig. 7,
Outer diameter of pillar d_o = 40 mm
Inner diameter of pillar d_i = 30 mm
Height of pillar H = 40 mm

Now, moment acting at pillar M = P × H
M = 41692.5 N-mm

Section modulus z = $\pi/32 \times ((d_o^4 - d_i^4))/d_o$
= 4295.15 mm^3

Bending stress σ_b = M/z = (41692.5)/ (4295.15)
= 9.71 MPa < 80 MPa

Compressive stress $\sigma_c = P/A_c = P/(\pi/4 \times (d_o^2 - d_i^2))$
= $83.385/(\pi/4 \times (40^2 - 30^2))$ = 0.1517 MPa

Total stress σ = 9.71 + 0.1517 = 9.862 MPa < 80 MPa.
Thus, design is safe.

D. *Design of Lead screw:*

The crucial part of the mechanism is Lead Screw.
Various loads acting on different parts of the mechanism are taken by estimating some initial data such as weight of welding torch, length of the lead screw and horizontal link, etc. as shown in fig. 2.

Let, material of lead screw and nut be medium carbon steel as generally available combination in market.

From known properties of materials and geometrical data,
Weight of the components supported by horizontal link as shown in fig.2 is:

W = 5 kg × 9.81 m/s^2 = 49.05 N
By assuming factor of safety = 2

Hence, load F = 49.05 × 2 = 98.1 ≈100 N

The load acting on the lead screw can be assumed as point load since it acts through nut only and hence, loading of lead screw can be analogous to simply supported beam with point load as shown in fig. 8.

As we know that in case of simply supported beam with point load, maximum deflection and bending moment occurs at the

Centre, the shear force and bending moment with point load at the Centre are shown in fig. 8.
Thus, taking moments about A and equating the same:
$R_B \times 0.3 = 100 \times 0.15$
$\therefore R_B = 50$ N

Also, $R_A + R_B = 100$.
$\therefore R_A = 50$ N
From Bending Moment Diagram:
$M_A = 0$, $M_B = 0$ and
$M_C = F/2 \times l/2 = (F \times l)/4 = (100 \times 300)/4 = 7500$ N-mm (Plus due to sagging).
Now, for screw material:
Let, permissible stress in tension $\sigma_t = 70$ MPa,
Permissible stress in compression $\sigma_c = 70$ MPa,
Permissible stress in shear $\tau = 50$ MPa

Here, due to geometrical constraints, first we have selected dimensions of various parts and then have checked for strength as follows:
We have,
Length of lead screw l = 300 mm
Core diameter of screw = $d_c = 10.67$ mm
Outer diameter of screw = d = 12.7 mm = 0.5 inch
Pitch of lead screw p = 4 mm
$\therefore$ Core area of screw $Ac = \pi/4 \times (d_c^2)$
$= 89.42$ mm^2.
Now, $\tan \alpha = p/(\pi \times d) = 4/(\pi \times 12.7) = 0.1$

$\therefore$ Helix angle of screw thread $\alpha = \tan^{-1}(0.1) = 5.73°$

Now, Shear stress produced in screw:
$\tau = F_c/((\pi/4) \times d_c^2) = 50/((\pi/4) \times 10.67^2)$
$= 1.12$ MPa < 50 MPa
Now, shear modulus = $z = I/y = \pi/32 \times d_c^3$
$\therefore z = 119.26$ mm^3
Thus, Bending stress $\sigma_b = M_c/Z = 7500/119.26$
$= 62.89$ MPa < 70 MPa.
Using maximum shear stress theory,
Maximum shear stress in the screw
$\tau = 1/2 \times \sqrt{(\sigma_b^2 + 4 \times \tau^2)}$
$= 1/2 \times \sqrt{(62.89^2 + 4 \times 1.12^2)}$
$= 31.46$ MPa < 50 MPa
Thus, design is safe.
Using maximum principal stress theory,
Maximum principal stress in the screw
$\sigma = \sigma_b/2 + ½ \times \sqrt{(\sigma_b^2 + 4 \times \tau^2)}$
$= 62.89/2 + 1/2 \times \sqrt{(62.89^2 + 4 \times 1.12^2)}$
$= 62.9$ MPa < 70 MPa
Thus, design is safe.

E. Automation of mechanism

As per the requirement of welding procedure, Servo or Stepper motors can be employed at various stages of mechanism. [1]. the selection of the motor can be done by measuring the torque required at various stages or parts of the mechanism experimentally and then, controlling them using a microcontroller such as Arduino. Thus, welding parameters like welding speed, welding position, electrode inclination, etc. can be controlled. [4].

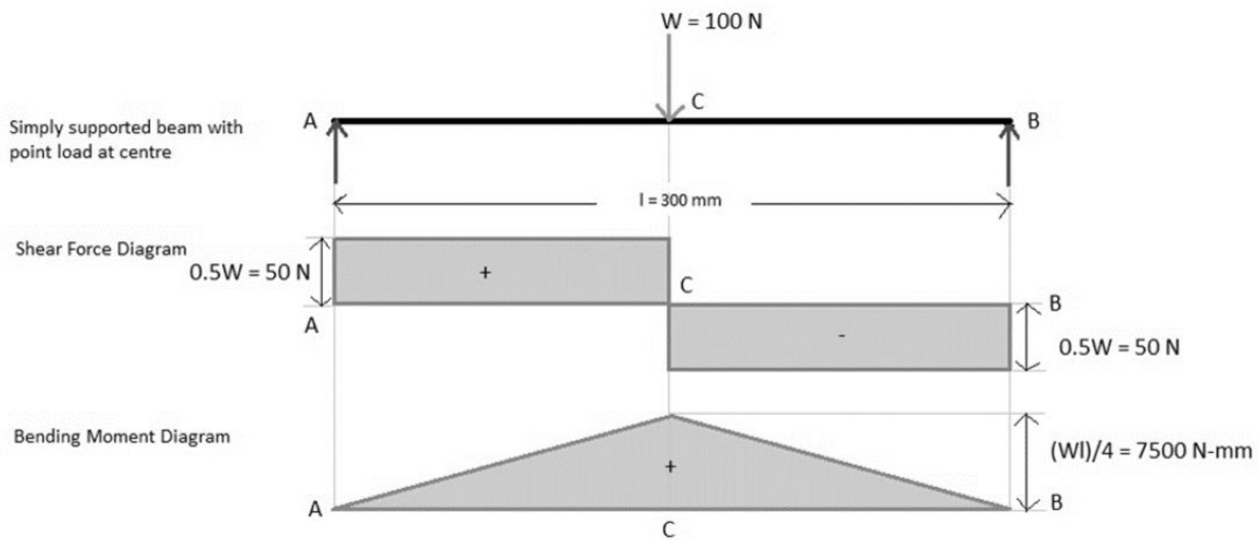

Fig. 7. Simply supported beam with point load at Centre.

IV. Conclusion

The aim of the study was to design a manipulator that can simplify the task of circular welding. A generic mechanism was proposed in this study to fulfil the foretold aim. An Arduino controlled guiding mechanism for circular welding may be suggested to improve quality of weld, eliminate need of proficient welder, reduction in cycle time and increase in productivity. It is a low cost solution and can be affordable to small scale industry also.

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