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Design of 90 Degree Overturning Mechanism for H-beam Handling

#1Akshay N. Gade, #2Narendra K. Chhapkhane, #3Ganesh B. Thakare

[1]akshayngade@gmail.com
[2]narendra.chhapkhane@ritindia.edu
[3]ganeshthakare@adorians.com

#1Student,Department of Mechanical Engineering,Rajarambapu Institute of Technology, Rajaramnagar, Islampur, Maharashtra, India.

#2Associate Professor, Department of Mechanical Engineering,Rajarambapu Institute of Technology, Rajaramnagar, Islampur, Maharashtra, India.

#3Deputy Manager,Welding Automation & Product System, Ador Welding Ltd., Pune

ABSTRACT

In today's competitive world, the customer expects better products within least time than the existing one. To meet this, there is need to adopt fast, responsive, adaptive and innovative pre-processing or product development processes. The aim of this paper is to design the robust mechanism for handling heavy H-beam while production. This paper concentrates on automation in H-beam welding process. This paper presents 90 degree overturning mechanism used at first work station in fully automated H-beam production line. Except assembly machine and straightening machine that should be equipped with travelling crane, other transportation of work piece can be realized with overturning rack, conveyor. This paper introduces the right equipment for heavy duty H-beam with high automation and high efficiency.

Keywords:H-beam; Overturning;

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I. INTRODUCTION

H-beam is the type of wide flange beams and it looks similar to I-beam. H-beam and I-beam look similar enough to the untrained eye to easily confuse the two. Basically both beams are different from application point of view; both are suitable for heavy structural applications in mechanical as well as civil construction industries. H-beams are used in construction support beams for factory shops, steel buildings, factory platforms, bridges, frames for truck bed, machinery etc. The H-beam production line consist of CNC cutting machine, H-beam welding machine, H-beam flange straightening machine, H-beam shot blasting machine etc. The H-beam is the assembly of web and two flanges. The first step of fabrication process consists of joining of web and flanges by means of tacking by arc welding to hold flange with web. To achieve welding seams at the joining portions of web and flange whole assembly is required to overturn to desired welding position. Various methods are used for achieving welding such as V-blocks, where the beam is lifted by using crane and placed in V-block. In this process the transportation of work piece is carried out by using crane, which is harmful to the peoples working on the shop floor.

Difference between H-beam and I-Beam

1) H-beam weighs more and is more load resistant. I-beam weighs less and is less load resistant.
2) Flanges of H-beam are tapered. Flanges of I-beam are not tapered.
3) H-beam can build up to any size. I-beam builds up as much as manufacturers milling machine permits.
4) H-beams can use for spans up to 330 feet. I-beam can use for spans between 33-100 feet.
5) H-beams are made up of three different pieces attached together, resembling an uppercase "H".
6) I-beams are one piece of steel, resembling an uppercase "H".
7) H-beams are ideal for use in construction of bridges, large platforms, and machine base.
8) I-beams are ideal for supporting frames and columns for trolley ways and lifts.

H-beam production process

1) At very first sheet cutting is carried out to the required size of web and flange i.e. lay-off.

2) H-beam assembly (Tack welding at certain positions with equal distance to hold flange with web).
3) Welding of welding seam - I.
4) Turning the whole assembly to next welding position and welding of welding seam II.
5) Similarly by turning welding of welding seam - III and welding seam - IV completed.
6) Straightening of plate i.e. flange I and flange II.
7) Convey to shot blasting (for cleaning the beam surface).

Proposed layout of H-beam production process

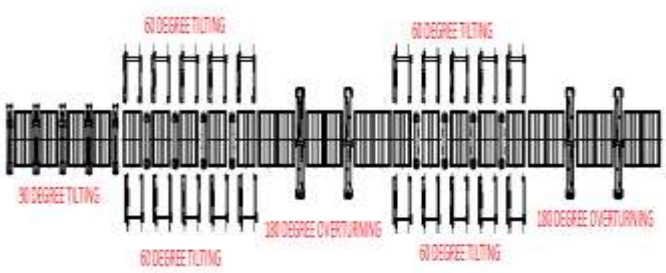

Figure 1: Proposed layout of H-beam production process

H-beam Specification

Table 1: H-beam Specifications

	Web	*Flange*
Length (l) (mm)	*15000*	*15000*
Width (b) (mm)	*200 - 300*	*200 - 1000*
Thickness (t) (mm)	*16 - 50*	*20 - 80*

- *H-beam material = Steel.*
- Density of steel = $7.85X10^{-6}$ kg/mm³.
- *To find minimum weight of H-beam*
- *Number of flange = 2 Nos.*
- *Number of Web = 1 Nos.*

Minimum weight of H – Beam = 2 X (Minimum weight of flange) + Minimum weight of Web

Weight = Volume X Density.

Similarly we can calculate maximum weight of H-beam.

90º Overturning Mechanism

The production line consist of CNC cutting machine, H-beam automatic welding machine, H- beam automatic gantry machine, H- beam flange straightening machine, H-beam shot blasting machine etc.

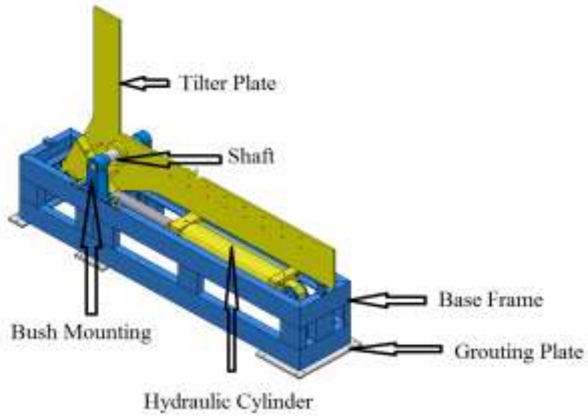

Figure 2: 90º Overturning Mechanism

First the cutting of sheet is carried out, and then secondly T-beam assembly of web and one flange is carried out, after that I-beam assembly is carried out. Both T-beam and I-beam assembly is carried out by using tack welding. Tack welding is carried for holding web and flange together. 90º overturning mechanism is used after I-beam assembling to carry out the overturning of beam so that it resembles like "H".

Design of Tilter Plate

Consider the case when the plate will be just lifted, at 0º it will be the case of propped cantilever beam and it is quite difficult to calculate the dimensions of the tilter plate.

No. of Mechanisms = 5 Nos.

For IS 2062 grade, S_{ut}=410 N/mm^2.

Bending Stress = Allowable bending stress = S_{ut} / f.o.s.

= 410/3 =136.7 N/mm²

Thickness of tilter plate = b = 20 mm.

Total Load of Beam = 310 KN.

Load on each tilter = 310/5 = 62 KN.

The load 62 KN will be equally distributed over the tilter at the point of contact of each flange and tilter plate (i.e. point A and Point B) as shown in Figure 3 below

Figure 3: Free Body Diagram for Horizontal Tilter Plate

Moment at point B = WXL

= (31X10^3) X 2140

= 66.34X10^6 N-mm.

I = bXd³ / 12, y = d / 2.

Z= Section Modulus = I/y = $bX\frac{\frac{d^3}{12}}{\frac{d}{2}}$ = bXd² / 6

We have Bending Equation,

$$\frac{M}{I} = \frac{\sigma}{y}$$

σ = M / Z
Z = M / σ
Z = (66.34X10^6) /136.7
Z = 485.3X10^3 mm³.
But, Z = bXd² / 6
=485.3X10^3 = (20Xd²) / 6

d = 381.56 mm~ 385 mm.

Checking for Bending Stress:

I = bXd³ / 12
= (20X385³) / 12
= 95.111X10^6 mm^4
y = d/2 = 385 / 2 = 192.5 mm.

$$\frac{M}{I} = \frac{\sigma}{y}$$

σ_b = Induced Bending stress

$$= \frac{M}{I} Xy$$

$$= \frac{(66.34X10^6)X192.5}{(95.111X10^6)}$$

= 134.27 N/mm².

Bending Stress < Allowable Bending stress

Design of horizontal tilter plate is safe.

At extreme position i.e. 90° assume whole load will act as uniform distributed load (udl) over the vertical tilter plate.

Assume, thickness of plate = 20 mm.
Similarly, by using Bending equation we calculate value of d.

Hydraulic Cylinder Selection

- Find the load required to lift.
- By using leverage formula calculate the effort required.
- By using Pressure vs Force table find the pressure corresponding to effort required.

Using Hydraulic cylinder product catalogue select the appropriate cylinder corresponding to presuure and effort required.

Table 2: Pressure vs Force

Pressure (bar)	Force F_e (KN)	
	Extension stroke	Retraction Stroke
100	314.2	250.5
120	377	300.6
140	439.8	350.8
160	502.7	400.9
180	565.5	451
190	597	476
200	628.3	501.1
210	659.7	526.1

For above Table 2
Assumed Cylinder,
Eaton IHM series for heavy duty applications cylinder
Working pressure range = up to 210 bar.
Type = CE (Cap fixed plain eye mount)
Assume, From Eaton IHM heavy duty cylinders (Cap fixed plain eye mount)
Bore size = D = 200 mm
Piston Rod = d = 90 mm
Area of Extension stroke = A_e

$$A_e = \frac{\pi d^2}{4} = \frac{\pi X 200^2}{4} = 31.42X10^{\wedge}3 mm^2.$$

Area of retraction stroke = A_r

$$A_r = \pi X \frac{(D^2 - d^2)}{4} = \pi X \frac{(200^2 - 90^2)}{4}$$

= 25.05X10^3 mm².

Force (F_e) = Pressure X Area = P X A N.
Sample Calculation for force:
Pressure (P) = 100 bar = 100X10^5 N/m² = 100X10^5 X 10^-6 N/mm² = 10 N/mm².
For Extension Stroke,
F_e = PXA = 10 X (31.42X10^3) = 314.2X10^3 N = 314.2 KN.
For Retraction Stroke,
F_e = PXA = 10 X (25.05X10^3) = 250.5X10^3 N = 250.5 KN.

Shaft Design

For the case in this paper shaft designed is based on ASME code.
ASME code established in 1927, defines certain rulings on the design of shaft, the important criterion defined by the code are:
1. The permissible shear stress of the material will be given by the smaller of the following two values
$\tau_{perm} = 0.30\, S_{yt}$ and $\tau_{perm} = 0.18\, S_{ut}$.
2. If shafts have keyways, or stress concentration due to shoulder fillet, than the permissible stress is reduced by 25%.

$$\tau_{perm} = \left[\frac{16}{\pi X d^3}\right] X\{(KB\,XMB\,X\,K1)^2 + (KT\,XMT\,X\,K2)^2\}^{\wedge}\tfrac{1}{2}$$

Assume,
D = 1.5 X d mm.
ASME bending factor, K_B= 1.5,
Stress concentration factor in bending, K_1= 1.5.
By using permissible shear stress formula diameter of shaft can be calculated.
For the Shaft in this paper loading diagram is as follows,

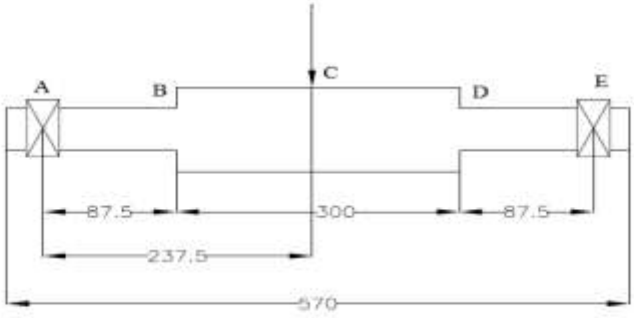

Figure 4: Shaft loading diagram

Taking moment at point A,

$\Sigma M_A = 0$
$R_e X475 = 64.1X237.5$
$R_e = 32.05$ KN.
$\Sigma V = 0$
$R_a - 64.1+32.05 = 0.$
$R_a = 32.05$ KN.
Now at point C bending moment is maximum.
$M_C = (32.05X10^{\wedge}3)$ X 237.5 = 7.6119X1010ˆ6 N-mm.
Now at point C shaft diameter is 1.5 times more than smallest diameter. Also the effect of stress concentration due to change in section would increase the stress at point B & D.
M_B = Bending moment at point B.
$M_B = (32.05X10^{\wedge}3)$ X 87.5 = 2.8044X1010ˆ6 N-mm.
M_D = Bending moment at point D.
$M_D = (32.05X10^{\wedge}3)$ X 87.5 = 2.8044X1010ˆ6 N-mm.
At point B and D the bending moment is smaller; the weakest section will be at point B and D. At these points the diameter d should be determined. As per ASME,

$$\tau\, perm = \left[\frac{16}{\pi X d^3}\right] X\{(KB\,XMB\,X\,K1)^2 + (KT\,XMT\,X\,K2)^2\}^{\wedge}\,½$$

As there is no twisting moment, $M_T = 0$ N-mm.

Therefore,

$$\tau\, perm = \left[\frac{16}{\pi X d^3}\right] X(KB\,XMB\,X\,K1)$$

$$126 = \left[\frac{16}{\pi X d^3}\right] X(1.5X2.8044X10^{\wedge}6\,X\,1.5)$$

$d^3 = 255.0481X10^{\wedge}3$
d = 63.42 mm ~ 70 mm.
Now, D = 1.5d = 1.5X 70 = 105 mm.

Bush Selection

b= width of bush = 75 mm.

d = bore diameter of shaft = 70 mm.

Load acting on bush = 32.05 KN.

Factor of Safety (F.O.S.) = 3

Net load acting on bush =F = Load acting on bush X F.O.S.

= 32.05X3 = 96.15 KN

p = Specific bearing load of Crushing stress in N/mm^2.

Now specific bearing load is given by,

$$p = \left[\frac{\text{load acting on bush}}{\text{projected area}}\right]$$

$$p = \left[\frac{F}{dXb}\right]$$

$$p = \left[\frac{96.15X10^{\wedge}3}{70X75}\right]$$

p = 18.31 N/mm^2.

The sliding velocity can be calculated using,

$$v = \left[\frac{(n\,X\pi\,X\,d)}{60\,X\,1000}\right]$$

Where,
v = Sliding velocity in m/s.
n = rotational speed in rpm.
d = bore diameter of bush in mm.
Ass1ume, n = 20 rpm.

$$v = \left[\frac{(20\,X\pi\,X\,70)}{60\,X\,1000}\right]$$

v = 0.073 m/s.
Now from SKF bushings, thrust washers and strips Catalogue,
Solid Bronze bush having,
Permissible bearing load = p = 45 N/mm^2. …(For static loading).
Permissible sliding velocity = v = 0.5 m/s.
We select **PBM708590M161** bush with
d = 70 mm, D=85 mm, b = 90 mm.

II. CONCLUSION

The proposed design in this paper is robust mechanism for handling H-beam. The mechanism is easy to operate. It will reduce the handling of H-beam during fabrication. The use of gantry crane will reduce by implementation of such mechanism, which incorporates with conveyor and lift for conveying H-beam from one station to other station for welding operation.

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