Nigerian Research Journal of Engineering and Environmental Sciences 9(2) 2024 pp. 841-847
p ISSN: 2635-3342; e ISSN: 2635-3350

Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

Original Research Article

Development of Hydraulic Powered Helical Flight Bending Machine

***Aliemeke, B.N.G., Ehimuan, M., Olorioke, S.M. and John, J.P.**

Department of Mechanical Engineering, School of Engineering, Auchi Polytechnic, Nigeria
*aliemekebng@auchipoly.edu.ng

http://doi.org/10.5281/zenodo.14566276

ARTICLE INFORMATION

Article history:
Received 04 Nov. 2024
Revised 08 Dec. 2024
Accepted 11 Dec. 2024
Available online 30 Dec. 2024

Keywords:
Hydraulic
Bending machine
Helical flight
Conveyors
Efficiency

ABSTRACT

The development of a hydraulically powered helical flight bending machine has been successfully carried out in this study. This was done to carry out bending operation on ferrous and non-ferrous metals with ease. The study was aimed at developing a hydraulically powdered helical flight bending machine that finds practical expression in the manufacturing of industrial screw and bucket conveyors. The hydraulic powered device helps to eradicate the dependence of power supply from the National grid. The machine was developed using mathematical formulae and AutoCAD graphical modeling tools. This hydraulic powered bending machine was designed to have hydraulic cylinder area of 7855 mm^2 and a force of 9806 N per ton. The machine which was meant to develop an efficiency of 95.1 % for a required force of 147090 N overcame an exerted load of 140000 N. The 15 ton hydraulic device with a diameter of 100 mm exerted a pressure of 18.75 N/mm^2. The high efficiency of the machine is a testament of the effectiveness of the hydraulic powered bending machine.

1. INTRODUCTION

The technique involve in bending and shaping of metallic materials is key in the recent advancement of industrial manufacturing and product development (Gagnol and Morvan, 2014). Numerous applications are requisite of precise curves and bends starting from the steel materials in structural buildings to the more complex components produced in the various transportation sectors which include aviation, marine, railway and road (Ying and Hongji, 2021). However, some bottlenecks are often encountered when bending thicker materials as more force is applied in its shaping. The application of a hydraulic powered machine could be very critical at this stage in addressing this operation as it offers utmost precision, strength and the requisite versatility necessary for industrial manufacturing (Chen and Cao, 2019).

Bending as an operation has been a long term practice in ancient and modern engineering era. The traditional bending operation has always centered on the manual driven machines which are bedeviled by lack of force and proper directional control required for precise bending (Josephson, 2005). This archaic method is largely subject to inaccuracies, time consuming and labor intensive which often culminates in material waste and product quality compromise. These inadequacies becomes more pronounced when applied in screw conveyors which involves deployment of uniform spirals to convey materials along the track particularly in construction, agricultural and manufacturing industries (Gupta and Sharma, 2020). There is high demand of greater quality of helical screw bending operation to bring about machine concept that may perform very complex functions with low deployment of human strength (Chan and Yan, 2001).

Helical flights are major component of screw conveyors, which bring about movement or conveyance of granular materials from the conveyor base to mainly an elevated platform or storage via an inclined belt or bucket screw conveyor (Hunter, 2018). The production flights required some unique effort in attaining uniform pitch, bending angles and other shaping dimension. Crude method of manufacturing flights such as stamping and rolling creates limitations in component precision which may evolve uneven pitches and figure dimension leading to material handling inefficiencies and wear possibility (Yakovle and Sokolov, 2016).

The prevalent efficiency of hydraulic systems in their ability to sustain huge amount of force with relatively small application of force to combat heavy duty operations has contributed to the excess crave for its application in bending operation (Wang, Huang and Wang , 2017). A fluid powered system controlled bending machine utilizes the hydraulic strength to impact bending pressure, speed and bending angles on various metallic materials. The applied pressure offered by the hydraulic machine is required to shapen the ferrous and non-ferrous material correctly to the required dimension. This fluid determined operation is highly efficient, time saving and cost efficient (Yadav *et al*, 2015).

As good as this emerging technology in hydraulics can be, it is also worthy of note that some intricacies exist in the usage of the machine. Some screw flight bending machines find it difficult to produce flights pitch, angles and effective thickness required in the production of conveyors and various mixers (Wang et al, 2014). Also, it is important to note that the direction of engineering is fast tilting into nano-technology which rules out the bulky form of machine production. The need for a more user friendly and compact natured hydraulic screw flight bending concept is an all important area for engineering developmental strides (Zhang and Leung, 2014). In a bid to address the various industrial challenge encountered in bending operation, it led us into developing a fluid powered helical flight bending machine that can be precise, less application of energy, user friendly and inducing consistent bends as predicted by Thakare and Borse, (2021).

Fluid powered machines leverages on the hydraulic and pneumatic strength in fluid to bring about large amount of energy necessary to bend high strength ferrous and nonferrous material which ordinarily would have posed a huge challenge to bend if the crude or manual method of bending operation were to be employed (Smith and Jones, 2023). Bramah and Pascal′s principle in fluid dynamics portrays the application of very small force to produce large amount of output force buttressing the concept of high power-to-size ratio necessary in accomplishing heavy duty operation (Khraiseh and Aqrabami, 2021).

Hydraulic screw flight machines are prevalently reputed for applying significant force in cutting operation without been subjected to adverse mechanical effects like fatiguing and fracturing (Patel and Gupta, 2024).. This fluid system is effective for maintaining constant pressure throughout the bending operation while reducing perceived variation in pitch and bending angles. Hydraulic systems leverages on the ability to exert force in both directions to bend complex helical and spiral shapes needed for flight (Patel and Gupta, 2017). However, there exist some limitations in the use of hydraulic machines. This is evidenced in the slow operational speeds when compared with its electrical counterpart and leakage of fluid on the machine and the environment. Also, pressure irregularities had always been a bane on the smooth working mode of some hydraulic powered machine. This study is targeted at developing a hydraulic powered helical flight bending machine that may apply pressure for precise cutting.

2. MATERIALS AND METHODS

2.1. Materials

The hydraulic powered helical flight bending machine was developed using materials such as 9 mm sheet, 2 inches angle bar, tape rule, marking out tools, petroleum oil, 2 inches square pipes, bolt and nuts. The equipment deployed in the study are welding machine, grinding machine, Guillotine cutting machine, drilling machine, hammer, hydraulic jack.

2.2. Design Consideration

In developing the machine, some materials were properly considered so as to give the machine durability and strength required to withstand various contending stresses during operation. Mild steel was considered for its ductility and malleability as a material to construct the machine frame. The metal sheet and pipes used were mild steel to ensure for strength and rigidity. Also, the machine considered was meant main to be run by hydraulic power (Rajapakse and Fernando, 2010). The size of the machine was reduced to so as not to waste material and still achieve great machine efficiency.

2.3. Design Specifications

Some specifications were applied in calculating the various sizes of the components used.

i. Acceleration due to gravity=10 m/s^2
ii. Hydraulic cylinder capacity=15 tons
iii. Diameter of hydraulic cylinder=100 mm
iv. Allowable stress of steel=350 MPa

2.4. Calculation of Hydraulic Cylinder Area

The area of the hydraulic cylinder was determined by applying Equation (1) obtained from Khurmi and Gupta (2014).

$$A_c = \frac{\pi \times d^2}{4} \tag{1}$$

Where Ac=area of cylinder and d =diameter of cylinder

2.5. Calculation of the Required Hydraulic Force

The required force in the hydraulic system was calculated by using Equation (2) obtained from Khurmi and Gupta (2014).

$$F_h = Mg \tag{2}$$

Where F_h=Hydraulic force in N

M=mass of one ton take to be 980.6 kg

2.6. Calculation of Hydraulic Pressure

The hydraulic pressure of the machine was calculated by applying Pascal`s principle of fluid dynamics. It states that constant pressure flows in a closed hydraulic system. The graphical representation of the hydraulic principle is shown in Figure. 1.

In applying the Pascal`s principle as stated in Equation (3) obtained from Mokhtar *et al*, (2017)

$$P = \frac{F_1}{A_1} = \frac{F_2}{A_2} \tag{3}$$

Where P=Applied pressure, A_1= Area of first cylinder, A_2=Area of second cylinder, F_1=force applied in first cylinder, and F_2=force applied in second cylinder

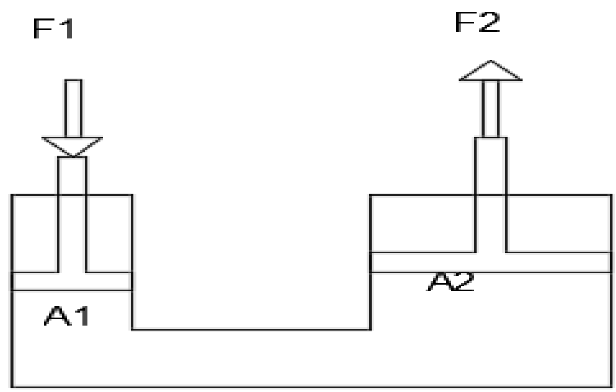

Figure 1: Pascal`s principle of fluid dynamics

2.7. Calculation of maximum hydraulic load

The maximum hydraulic load was calculated using Equation (4)

$$L_h = A_s \times \delta \tag{4}$$

Where L_h =hydraulic load

δ= Allowable stress taken to be 350 Mpa

As=area of steel material

2.8. Determination of Load Difference

The load difference was determined by obtaining a difference between the maximum load on the hydraulic system from the maximum force exerted by the hydraulic jack as given in Equation (5)

$$D = F_h - L_h \tag{5}$$

2.9. Determination of Hydraulic System Efficiency

The hydraulic system efficiency was determined by applying Equation (6). It is the ratio of the work output (i.e the load exerted on the hydraulic jack) to the work input in the system

$$Efficiency = \frac{work\ output}{work\ input} \times 100\% \tag{6}$$

3. RESULTS AND DISCUSSION

3.1. Summary of Values Calculated for machine components

The hydraulic area and required force were determined to be 7855 mm^2 and 9806 N per ton respectively (147090 N for 15 tons).

$$A_c = \frac{\pi \times 100^2}{4} = 7855\ mm^2$$

$$F_h = 980.6 \times 10 = 9806\ N$$

The pressure exerted by the hydraulic jack and efficiency were calculated to be 18.73 N/mm^2 and 95.18 % respectively.

$$P = \frac{147090}{7855} = 18.73 \frac{N}{mm^2}$$

For 20mm×20mm steel material the maximum load was calculated to be 140000 N by applying Equation (4) while the difference in load was determined to be 7090 N.

$$Efficiency = \frac{140000}{147090} \times 100\% = 95.18\%$$

The various values calculated for the helical flight bending machine are shown in Table 1. The designed values were found to be in agreement with that obtained in Mokhtar et al. (2017).

Table 1: Summary of values calculated for machine components

Parameters	Numerical values
Cylinder area	7855 mm^2
Required force	147090 N
pressure exerted	18.73 N/mm^2
maximum load	140000 N
Difference in Load	7090 N
Efficiency	95.18%

3.2. Graphical Modeling of the Machine

The hydraulic powered helical flight bending machine was modeled using AutoCAD software. The isometric and Third Angle Orthographic projection drawing of the bending machine are shown in Figures 2 and 3 respectively.

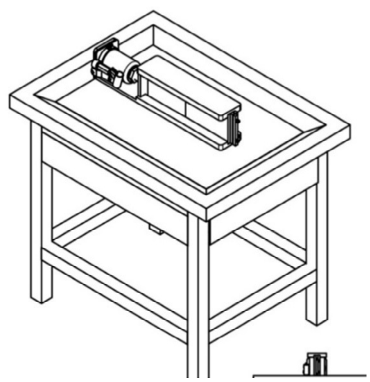

Figure 2: Isometric drawing of the bending machine

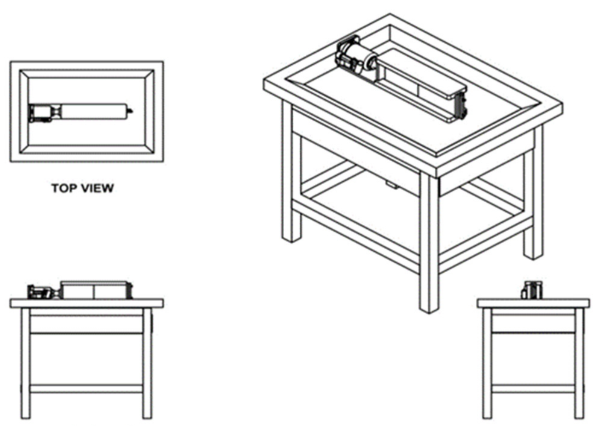

Figure 3: Third angle orthographic projection

3.3. Machine Fabrication

The various materials and equipment necessary for the fabrication were properly assembled with the marking out carried out using tape rule, square steel rule and metal marker. Hacksaw was used to cut the various 2-inch pipes and angle bar. The metal sheet was cut using Guillotine cutting machine. The tabular assembly was properly squared and joined using arc welding joining process (Zhang and Wang, 2022). The hydraulic jack was placed horizontally to provide the requisite force needed for the bending operation. The fabricated work was washed properly using emery cloth before the application of paint for final finishing. The developed machine shown in Figure 4 was fabricated in Auchi Polytechnic, Nigeria.

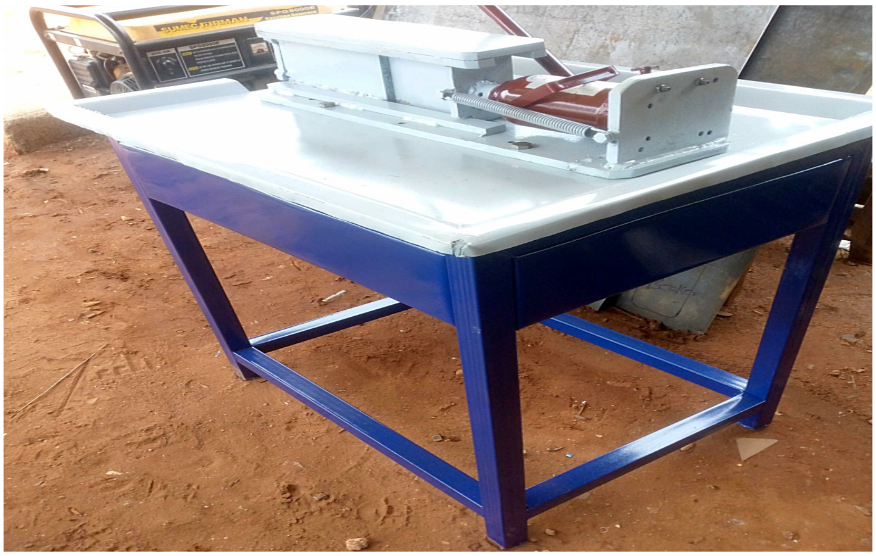

Figure 4: The developed machine

4. CONCLUSION

The development of a hydraulically powered helical flight bending machine was successfully done so as to achieve exact bending geometry of metallic material. The machine was conceived and designed to cut metallic material needed for manufacturing industrial conveyors. It was designed to be powered by hydraulic means. This rules out the need to wait endlessly for the dependence of power supply from the National grid. This particular machine was designed to have hydraulic cylinder area of 7855 mm^2 and a force of 9806 N per ton. The machine developed an efficiency of 95.1% for a required force of 147090 N that accomplished a load of 140000 N. The 15 ton hydraulic device exerted a pressure of 18.75 N/mm^2. The high efficiency of the machine underscores the effectiveness of the choice hydraulic means of powering the bending system. The aim of the study was adequately achieved for a directed focus on performance and practical usage.

5. ACKNOWLEDGMENT

The authors wish to appreciate the management of Auchi Polytechnic, Auchi for giving out their laboratory and workshop for this study

6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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