Development of Semi-Autonomous Sheet Bending Machine

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Abstract - *Sheet metal is widely used in the manufacturing of several components. It plays a very important role in various industries. Sheet bending is a common process associated with sheet metal. Industries now are being driven by automation. Automation has spread its roots in all kinds of industries. Automation has several advantages like increased productivity minimized errors but these systems are expensive. The newer industries with low or moderate productivity find implementing automatic types of machinery expensive. In this paper, we have proposed one semi-autonomous machine for the sheet bending operation. The machine can perform sheet bending tasks with minimum human interference as compared to manual machinery.*

***Key Words*: Sheet metal, Sheet bending, Fluid power, Automation, Pneumatic circuits, Finite element analysis**

1. INTRODUCTION

Sheet metal bending plays an important role in the metal manufacturing world. Sheet metal is used to make a variety of items, including tools, hinges, and automobiles. Automation is playing an important role in the manufacturing industry. Industries prefer to use autonomous machinery in their plants than performing a particular task manually. Autonomous systems are intelligent devices that can-do high-level activities without the need for detailed programming or human supervision.

Though automation is becoming an integral part of the industries the cost of the machinery is not affordable for small-scale or rising companies (Industries), which is one of the drawbacks of automatic machinery. The industries with moderate production capacity find the modern automatic machinery costlier.

Semi-automatic types of machinery are types of machinery that eliminate manual work to a certain extent while still being more affordable than automatic ones. These machines still require some type of manual assistance to complete the assigned task but, certainly, these are more productive than the completely manual machines.

In this paper, we have tried to develop one semi-autonomous machine to perform the task of sheet bending. We have implemented the concept of fluid power systems for the bending of sheet metal, for doing so pneumatic actuators are used. The machine is designed to be robust under influence of different forces and environmental conditions with the help of analysis software like ANSYS. The machine is designed to operate in the industrial environment.

2. LITERATURE REVIEW

We have referred to [1] to determine the different parameters in designing the pneumatic actuator. Also, we went through one more research paper talking about the Industry requirements and working to understand the requirement of the market. We went through several websites and online platforms where such sheet bending machines are on sale. We observed different machines of different manufacturers in the range of ₹15k for getting a brief idea of the market. After research, we concluded that machines are available in the range of ₹15k are manual only. Some of the machines have the advantage that they have high power bending so can bend sheets of more thickness than that of our machine but it can easily be tackled. Manual machines require multiple workers to perform work and our machine is semi-autonomous which will require only one person. The work performed by the worker is also negligible so the manager or owner won't have to spend much money on labor charges.

3. METHODOLOGY

The machine utilizes a simple mechanism for bending sheet metal. The mechanism consists of pneumatic actuators to provide the required force for bending operation. The machine is designed considering the maximum thickness of the Aluminum sheet as 3mm, bending length as 200mm, inner and outer bending radius of 5 and 8mm respectively.

3.1) Calculations

Assumed aluminum metal sheet.

Thickness = 3mm

Bending Length(L) = 200mm

Inner Bending radius(r1) = 5mm

Outer Bending radius(r2) = 8mm

Tensile Strength (TS) = $90N/mm^2$

Bending Force (F) = $\frac{T^2 * L * TS}{6000 * (T * r1 * r2)}$

From the calculations, the computed bending force is 14587.53N while the factor of safety is considered as 1.5

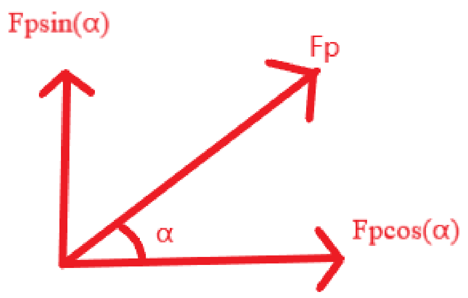

Fig -1: Forces in sheet bending.

From fig 1. The sin component of force is responsible for the bending operation. Sin(α) increases from 0°-90°, but with an increase in α the stroke length of actuator is also observed to increase hence, the α is chosen as 60°. The mechanism utilizes 4 pneumatic actuators inclined at an angle of 60°.

$$4F_p \sin 60 = 14578.53 \; newtons$$

$$F_p = \frac{14578.53}{4 \sin 60} \; newtons$$

$$F_p = 4211.1 \; newtons$$

Pneumatic actuators needed to be supplied with compressed air in order to provide the required output force. The machine consists of an air compressor of 400 psi which is about 2.75N/mm^2. This data is further utilized to calculate the bore diameter of the linear actuator.

$$Pressure = {Force}/{Area}$$

$$Area = {Force}/{Pressure}$$

$$\pi r^2 = \frac{4211.1}{2.75}$$

$$r^2 = \frac{4211.1}{2.75\pi}$$

$$r = 22$$

From the calculations for bending an aluminum sheet of the assumed parameters using a 400-psi air compressor, the mechanism needs 4 linear pneumatic actuators of bore diameter 44mm [2][3].

3.2) Designing of Mechanism

The pneumatic system plays a very important role in this mechanism. Pneumatic actuators use air pressure for performing linear work. Working with pneumatics requires a storage tank for compressed air and also a high-pressure compressor. [4] The pneumatic system will be supplied with pressurized air using a 400psi air compressor and the compressed air will be stored in a container that will act as a reservoir.

Every machine requires a frame called chassis for mounting the required mechanisms on it. We have designed such chassis for our machine on SolidWorks software. The chassis is designed by using 60 x 60 x 4 mm Aluminum alloy square hollow tubes. We are using hollow tubes because hollow tubes have a better strength-to-weight ratio than solid ones.

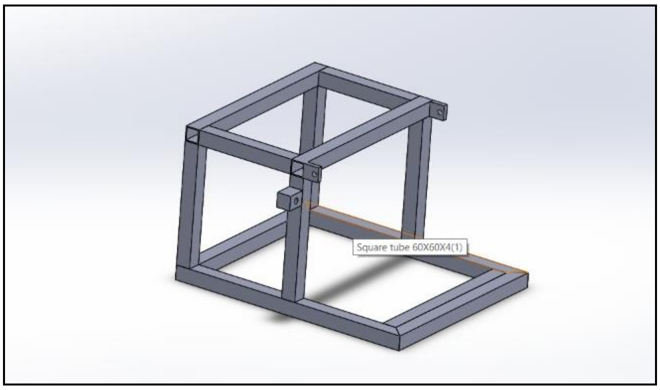

Fig -2: Chassis Design

Working with pneumatic actuators also requires a pneumatic circuit. A pneumatic circuit is similar to an electric circuit. An electric circuit carries current while a pneumatic circuit carries high-pressure air from a storage tank to the actuator. For our project, we will be using a 12mm x 8mm hose. In this project there are four double-acting pneumatic actuators hence, we are using a 5/2 hand lever direction control valve.

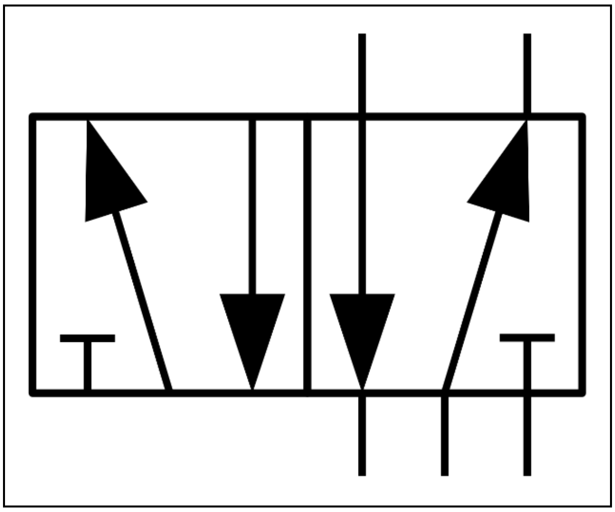

Fig -3: 5/2 DCV

The compressed air stored in bottles will be transported to one 4:1 connector which will connect all bottles and they will act as a single source.

Fig -4: 1:4 Valve

To prevent backward flow one check valve is connected to the reservoir.

Fig -5: Check Valve

The 4:1 connector is connected to a 5/2 DC valve via the hose. The two different 1:4 connectors are connected to a 5/2 valve one is for two different inlets.

1:4 valve is used to split the single compressed air supply into 4 hoses for both sides of actuation. After actuation of lever 5/2 valve will allow air to pass through either one of the 1:4 connectors which will result in final actuation of pneumatic actuator

Fig -6: 5/2 Lever actuated DCV

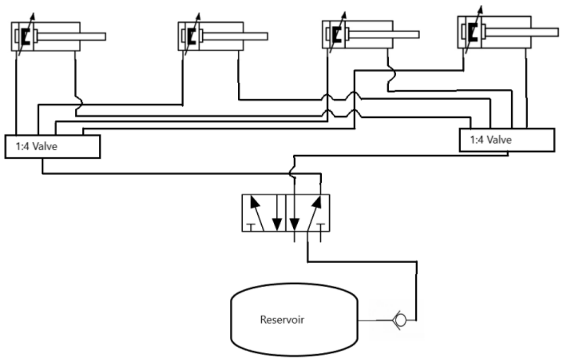

Fig -7: Pneumatic Circuit

3.3) Analysis of machine components

FEA i.e., Finite Element Analysis of actuator stroke and chassis is done with the help of an Ansys solver. Ansys is a product design, testing, and operating simulation software for Multiphysics engineering. The analysis consisted of stress and deformation analysis. Actuator stroke needed to be analyzed as it is the starting point of all the force used to bend the sheet metal.

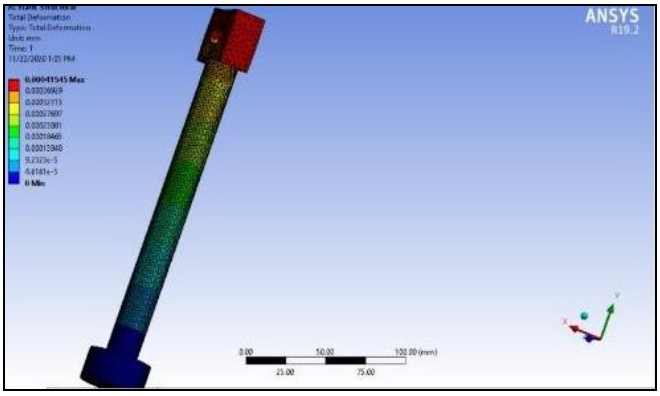

Fig -8: Deformation of Stroke

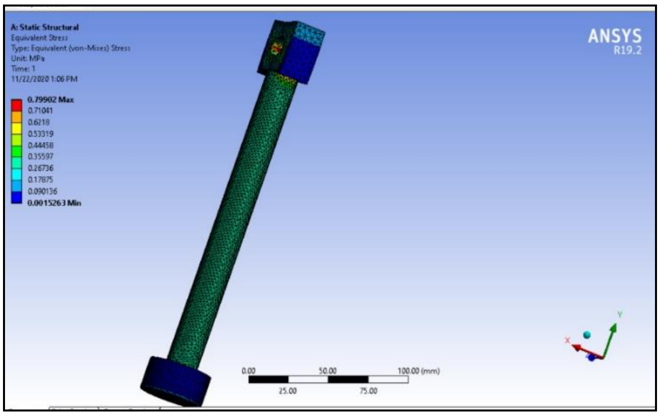

Fig -9: Stress-induced in stroke

The stress analysis of the chassis is also done to determine the stress and deformation induced in the chassis.

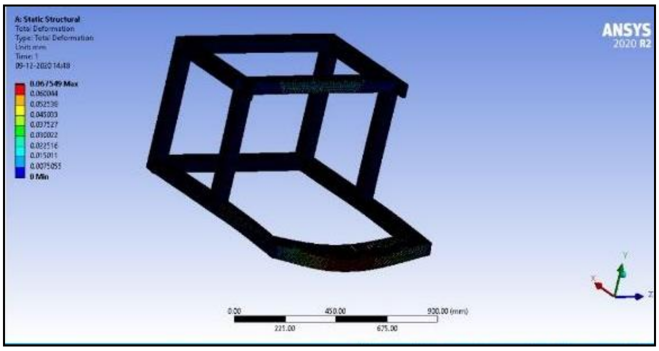

Fig -10: Deformation induced in chassis

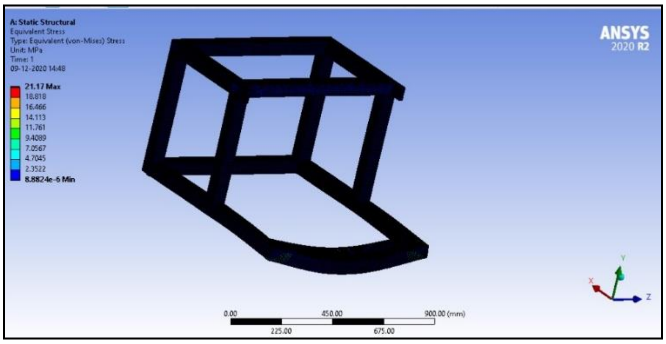

Fig -11: Stress-induced in chassis

The analysis revealed the maximum induced deformation and stress in the actuator stroke is 0.0005mm and 0.79902MPa which is permissible. Similarly, the deformation and stress-induced in the chassis are 0.06mm and 21.7MPa which is also permissible representing the design can bear the loads associated with it.

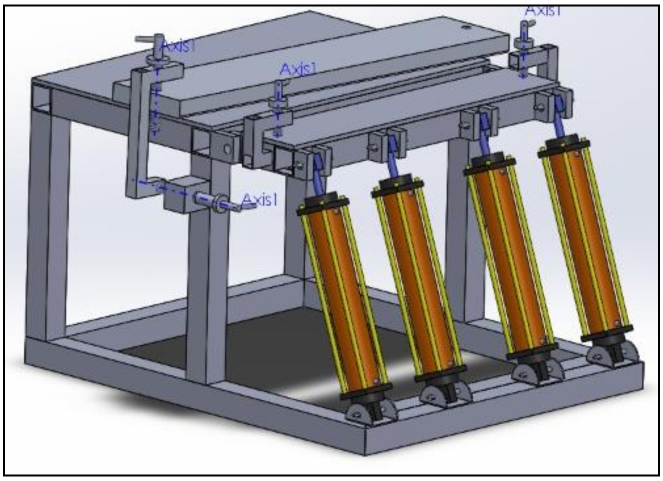

Fig -10: Assembly of mechanism(Machine)

4. CONCLUSIONS

A semi-autonomous machine was developed for the sheet bending operation. The machine lies between the manual and fully automated machine making it suitable for newer industries that can't afford fully automatic types of machinery. Increased productivity in comparison to manual machines can be obtained with the help of the proposed machine. The user without any skill can also operate the machine with absolute ease making it more valuable. The compact nature of machines can be useful for industries with space constraints. The analysis results represented the robust nature of the machine making it suitable for harsh environments.

5. REFERENCES

[1] P. S. Thakare, C. C. Handa, A. V. Vanalkar, and P. G. Mehar, "PRODUCTIVITY ANALYSIS OF MANUALLY OPERATED AND POWER OPERATED SHEET BENDING MACHINE: A COMPARATIVE STUDY," International Journal of Engineering Research and Applications, vol. 2, no. 2, 2012.

[2] "Bending (metalworking)," Wikipedia, 24-Nov-2020. [Online]. Available: https://en.wikipedia.org/wiki/Bending(metalworking). [Accessed: 07-Nov-2020].

[3] M. A. Farsi and B. Arezoo, "Bending force and spring-back in v-die-bending of perforated sheet-metal components," Journal of the Brazilian Society of Mechanical Sciences and Engineering, vol. 33, no. 1, 2011 [4] H. I. Ali, M. H. Marhaban, S. M. Bashi, and S. B. B. Mohd, "A Review of Pneumatic Actuators (Modeling and Control)," Australian Journal of Basic and Applied Sciences, vol. 3, no. 2, 2009.

[4] C. Gonzales, "What's the Difference Between Pneumatic, Hydraulic, and Electrical Actuators?," Machine Design. [Online].Available:"https://www.machinedesign.com/mechanical-motion-systems/linear-motion/article/21832047/whats-the-difference-between-pneumatic-hydraulic-and-electrical-actuators." [Accessed: 04-Dec-2020].

[5] Rosen, R., von Wichert, G., Lo, G., & Bettenhausen, K. D. (2015). About The Importance of Autonomy and Digital Twins for the Future of Manufacturing. IFAC-PapersOnLine, 48(3), 567–572.