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DESIGN AND FABRICATION OF MULTIPURPOSE SHEET METAL PROCESSING MACHINE

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ABSTRACT:
Nowadays the majority of traditional machinery is replaced with the newest, fastest, most technologically advanced machinery that provides an industrial setting that is easy to use. Building a separate machine for every task is not a good idea. Alternatively, a single, multifunctional machine that can carry out a variety of tasks may be created. Multipurpose Machine for the Sheet Metal Process is a versatile machine capable of performing multiple sheet metal operations, including punching, bending, cutting, hammering, and blanking. The machine's primary power sources are compressed air and a pneumatic cylinder, making it a cost-effective and efficient choice for small and medium-sized businesses. The presence of various tooling alternatives enables the handling of diverse sheet metal processing activities. This study makes a substantial contribution to the domain of sheet metal fabrication technology by presenting a compact, dependable, and cost-effective solution that is applicable across various sectors. These include the manufacturing of automotive body parts and chassis, the development of metal enclosures for electronic devices, the production of metal roofing, and the fabrication of aircraft components, such as panels and ducts.

Keywords: sheet metal processing, pneumatic, punching, bending, cutting, hammering, blanking.

I.INTRODUCTION:

The transformation of flat sheets into various shapes and components through sheet metal processing is crucial across numerous manufacturing industries. While conventional techniques are often successful, they typically necessitate a multitude of specialized machines for distinct operations, potentially resulting in inefficiencies, higher expenses, and added complexity. To address these issues, this paper presents the design and construction of a multipurpose sheet metal processing machine. This cutting-edge machine is capable of executing a range of operations, such as punching, bending, cutting, hammering, and blanking. The creation of this integrated machine meets the rising demand for efficient and adaptable manufacturing solutions. By combining multiple functions into a single platform, manufacturers can optimize their production workflows, decrease setup times, and enhance overall productivity. Furthermore, this strategy provides considerable cost reductions by lessening the reliance on individual machines and the related maintenance costs.

The aim of this advanced equipment is to improve the flexibility and efficiency of manufacturing processes. It raises the benchmarks for design and functionality by utilizing state-of-the-art technologies, including computer-aided design (CAD) and computer-aided manufacturing (CAM), ensuring precision, accuracy, and adaptability. The expected integration of artificial intelligence control systems is anticipated to enable real-time monitoring, data analysis, and swift adjustments to

processes, thereby substantially enhancing quality and efficiency. In the following sections, we will examine the complex design considerations, manufacturing methods, and testing associated with this adaptable sheet metal processing equipment. Furthermore, we will elaborate its operational mechanisms and assess the possible benefits and limitations of this novel approach to sheet metal management.

1.1 Working Principle of the Multipurpose Sheet Metal Processing Machine:

The multipurpose sheet metal processing machine operates on a modular design concept, incorporating Replaceable tooling, and adaptable mechanical structure, the versatile sheet metal processing machine can serve a variety of tasks. The main elements and their corresponding roles consist of:

1. **Mechanical Frame:** This sturdy frame acts as the machine's base, offering rigidity and stability during operation. It encompasses all the diverse components and systems necessary for a range of tasks.
2. **Tooling System:** The adaptable tooling system facilitates swift and straightforward transitions between various operations. It includes interchangeable tools such as punches, dies, shearing blades, and V tools, which are securely attached for specific applications.
3. **Pneumatic Power Unit (PPU):** The Pneumatic Power Unit (PPU) plays a crucial role in producing the compressed air necessary for the operation of the machine's actuators and components. By supplying pressurized air to the cylinders, it facilitates the efficient movement of tools and work pieces, thereby ensuring uninterrupted functionality during the entire operation.
4. **Work piece Clamping Mechanism**: This durable clamping system is engineered to hold work pieces securely during processing. Its adjustable configuration enables it to fit a wide range of shapes and sizes, guaranteeing that each piece is firmly held in position for precise and dependable machining.

1.2 Operation Sequence:

1. **Tool Selection:** Depending on the item, size and available materials of work piece operator select tools. This freezes the selected tools to take part in your machine's tooling system.
2. **Work piece Loading:** This step involves placing the work piece on a supported table of machine and get tightened so that it will not move further. The Control system to ensure the correct alignment of work piece.
3. **Process Initiation:** The process is started by the operator, who manually pulls a lever. This causes the pneumatic cylinders to actuate and moves both tooling as well as work piece.
4. **Operation Execution**: The pneumatic cylinders have tooling able to be moved as the press operator manually activates a lever. For instance, in punching the movement of the lever would make it hits into work piece which results as cutting off work piece from its desired shape. When bending, the lever moves to trigger a pneumatic cylinder that positions, the V tool at the work piece and applies force for material bending.
5. **Operation Completion:** When the operation is completed the operator lets go the lever. The clamping fixture no more will be lost except when the work piece is removed by the operator. Tools are changed to process the work piece again if necessary.

The adjustable design and the sequential operation of the machine give a possibility to ensure multipurpose sheet metal processing with the machine enabling it to accomplish various tasks by changing the design in accordance with the production requirements.

II. Literature Survey:

Generally, a review of literature will give an insight into factors that influence the performance of the multifunctional sheet metal machines. From the research findings, one discovers that earlier single-purpose systems are replaced with flexible systems, like punching, bending, and cutting machines. For SMEs, pneumatic power is a preferred form of power, since it is economical, with a minimal maintenance rate. It has also been applied in the automotive and aerospace industries where productivity, accuracy, and versatility count. This compact multipurpose solution minimizes specialized equipment needs, therefore making this practical for sharp production environments.

The pneumatic systems for sheet metal fabrication found in the literature declare that they are cost-effective and applicable to small or medium-scale industries, as opposed to other more expensive alternatives based on hydraulic sources. Madhu Kumar et al.(2016) , their study on Pneumatic Sheet Metal Cutting and Bending Machine . Pneumatic systems are practical for operations necessary to cutting and bending according the work of operator. This machine has most of the process automated with a double-acting pneumatic cylinder, which is operated through solenoid valves and IC timer circuit improving productivity, repeatability as well as accuracy while reducing cycle time and labour costs. Its small and portable design to provide flexibility that makes it best for aluminium and other lightweight body material industries such as automotive, packaging with secure carrying options. The authors detail that enhancing cutting and bending thickness capacities using a high-pressure compressor from which it is more affordable to be collected ready for use and the utilization of hardened blades would broaden potential applications, consequently strengthening competitively by keeping reduced cost solutions also suitable in terms of resources used much around.

The advantages of pneumatic systems are being very accurate, economical and easy to maintain hence fitted with semi-skilled operators. The literature on competition answers where they have started their journey in manufacturing industry. For example, Aditya Polapragada and K. Sri Varsha (2012) implemented a Pneumatic Auto Feed Punching and Riveting Machine which shows its effectiveness at low pressure operation of 6 bar for moving punches as well as rivets that the article makes energy-efficient machine applicable to other materials also. Being able to interchange punch and die setups allows you the flexibility of choosing from a wide variety of product designs using these pneumatic machines. The research indicates future automation improvements, even with automatic material handling, stay in alignment of the industry trend towards more streamlined and automated production.

Literature survey based on published literatures showed that multifunctional sheet metal processing machines play a significant role in terms of productivity and economy but the emphasis was more for small scale industries only and used extensively over these years. Alie Wube Dametew (2017) in his Study on Design and Analysis of a Multipurpose Machine for Sheet Metal Processing designs and analysed rolling, bending grooving beading machine. The design includes three rotating rollers, a bending portion and a torsional feature that should upgrade the efficiency of manufacturing, increase production speed as well as movement capacity at low cost. His calculations take into account sheet metal parameters (type and thickness), induced forces, deflection analysis, wear-resistance performance as well thermal effects where it can be established that power-driven multipurpose machine increases the overall rate of productivity in relation to manually driven machines maximizing its all-time availability. The study reveals that the machines are cost-effective, successful and approachable to workers with limited technical background thereby collaborate financial as well as functional proficiency in sheet metal manufacturing domain.

The literature on multi-functionality of manufacture machinery has been growing as it helps in optimal space utilization, reduction in cost and time in general, yet the most vital understanding of this multipurpose functionality is required in small scale industries. Devan et al. (2024) of the Design and Fabrication of a Multi-purpose Metal Cutting Machine note that integration of several operations such as grinding, drilling and shaping in one machine helps to reduce the area of coverage and power consumption of the shop floor. This design done in Solidworks 2017 integrates various mechanical components such as gears, belt drives, shafts and cutting tools which allows production processes on small work pieces to be done concurrently. Such versatility of the machine is of great importance for small industries and even home repairs. It can also be economical in providing a way of addressing a number of machining requirements in a small space. Further similar applications may be possible by adding more shafts for other operations to enhance efficiency and suitability in most manufacturing environments.

The multi-industrial machinery pneumatic system literature always points out to their flexibility and efficiency for operations targeted for different functions in sheet metal processing. Mishra (2019) Design and Fabrication of an Automatic and Multifunctional Pneumatic Machine is one where the

machine features bending, cutting, punching, and hammering capabilities. This compressed air-driven pneumatic cylinder machine makes U-shaped clamps and circle besides straight cuts. Mishra also points out the merits of simple pneumatic machines against hydraulic ones, which bring in complexity and higher costs. Hydraulic machines are not suitable for small-scale sheet metal industries based on simplicity and ease of maintenance. The shearing process of this description illustrates the process in which localized plastic deformation, achieved by small clearances between punch and die, creates controlled fractures in the metal. Conclusion: this all-purpose pneumatic machine is a cost- and labour-saving idea that provides a space-saving, very reliable solution for sheet metal operations.

Evidently, the literature on motorized multifunctional machines suggests importance in the actualization of productivity and cost-cutting within manufacturing sites. An article Design and Fabrication of Motorized Multi-Purpose Mechanical Machine by Muruganantham et al. (2021) describes a system whereby all drilling, cutting, and grinding are carried out using a single electric motor by means of a bevel gear mechanism. This design has the efficiency to operate at work centers concurrently, hence saving electricity while reducing cost production. Further, through the implementation of a mechanism known as a scotch yoke, the versatility of this machine in both metallic thin sheets and wood makes it appropriate for use in industries and small-scale workshops. The important consideration of such machines is saving a floor space and labor movement along with an energy usage reduction that, in its overall sense, provides them valuable resources to output-based production sectors, mainly focused on achieving high outputs coupled with low operating costs.

Literature about pneumatic sheet cutting machines shows that such machines are the most efficient and versatile cutting machines available in modern manufacturing processes. In their review, Pandita et al. (2018) have discussed several aspects of pneumatic sheet metal cutting and bending. They highlighted significant advantages offered by such machines as compared to manual techniques, especially providing a high surface finish and flexibility to create various shapes that the industries require. As this paper indicates, the performance and reliability of pneumatic cutting machines conclude by promoting energy efficiency as one of the chief aspects of sustainable production. The authors also study the fact that the pressure in pneumatic cylinders could be optimized for the energy losses to be minimized besides general enhancement of machines' efficiency. The conclusion in the research was that the cutting machines are especially valuable for the small sheet metal industries with their compact design and ability to adapt; hence ensuring their reliability in production improvement while reducing costs during the operation.

Parihar et al. (2017) discussed the optimisation of process involving sheet metal blanking, showing a critical interaction between the punch-die clearance and punch geometry, as well as sheet thickness. The authors also mentioned that more clearances result in burrs and the worst quality product and lower clearances impact the tool life adversely and poor edge quality. This study systematically investigates various important parameters affecting the blanking process with an intention to increase productivity and tooling for high-volume production. Analyzing the vital relationship of such factors, authors therefore give valuable information related to optimum conditions regarding the production of sheet metal parts that indirectly leads to higher quality and efficient production. The study's findings suggest that to achieve maximum productivity and quality for the product, careful management between tool life and burr height, relating to the material properties and thickness, has to be done.

Suryawanshi et al. (2019) proposed a design and development study of a pneumatic punching machine. Its superiority over hydraulic systems comes in terms of cost and in terms of suitability for producing large quantities. The pressure needed for punching operations by the machine is generated with compressed air, and then it controls airflow with the help of a solenoid valve. This would encompass knowledge of the system mechanics, such as the transfer of pressure by the polyurethane tubes and also the mechanism of plastic deformation in punching. The project is a prime example showing that indeed, it is possible for a machine to punch holes in sheet metal with a high level of efficiency without wasting much space and not making work laborious for its users. The study gives

grounds for further modifications and applications of the pneumatic punching machine, while underlining its relevance to small-scale manufacturing settings such as education centers.

The literature on pneumatic hole punching machines is of tremendous importance in the manufacturing aspect of aluminium products in car and food packaging industries; Sharma (2015), for instance, discussed, designed, and implemented a pneumatic automatic hole punch machine, discussing the positive aspects of using pneumatic systems over hydraulic machines-which are often more expansive and require higher maintenance and upkeep. This has been made possible through the use of software known as Solid Works, thus showing that technology in modern times plays an important role in efficient solutions for manufacturing. It was proved that small-scale industries can utilize the use of solar power as an alternate source for this pneumatic machine, thus reducing this consumption of electricity and corresponding costs by a huge deal. This approach goes in line with sustainability and takes the advanced manufacturing technique to even small enterprise.

III.Tool Design Calculations:

Material Selection for the Machine Frame:

- **Mild Steel:** The most commonly used material for the machine frame because of its abundant availability, low cost and good mechanical properties. This material has moderate strength with good machining characteristics and thread rolling, For further information see Injection moulding Design Guide
- **Galvanized Iron (GI) steel:** It is a great metallic type for making sheet-metal work pieces in various applications, largely due to its Corrosion Resistance, Strength & Durability, Cost-Effectiveness and last but not least Wide Availability.

3.1 Specifications of sheet metal work:

- **Length of cut (L):** 25mm
- **Thickness (t):** 0.3mm
- **Max shear strength of GI sheet metal (τ):** 160Mpa
- **Ultimate tensile strength of GI sheet metal (σ_t):** 500Mpa
- **Die opening Factor for V bending (K) =** 1.33
- **Width of Die opening at K is 1.33 (w) =** 16t
- **Area of Pneumatic cylinder (A) =** 0.0019635 m^2

i. Force and Pressure calculation for cutting operation:

Force required to cut the sheet (Fc) = $L \times t \times \tau$

$= 25 \times 0.3 \times 160$

$=1200$ N

The force needed to cut the sheet metal is higher than the initial calculation, with a margin of 10% to 20%.

Therefore the maximum force required to cut the sheet (Fc) = 1440N

Pressure from air compressor required to cut the sheet metal (Pc) = Force (Fc) / Area (A)

$= 1440/0.0019635$

$= 733384.2628$ Pa

$= 7.333842628$ bar ≈ 7.3 bar

ii.Force and Pressure calculation for bending operation:

Force required to bend the sheet (Fb) = $(L \times t \times \sigma_t \times K)/w$

$=(25 \times 0.3 \times 500 \times 1.33)/(16 \times 0.3)$

$= 1040$ N

The force needed to bend the sheet metal is higher than the initial calculation, with a margin of 10% to 20%.

Therefore the maximum force required to bend the sheet (Fb) = 1248N

Pressure from air compressor required to bend the sheet metal (Pb) = Force (Fb) / Area (A)

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= 1248/0.0019635
= 635600 Pa ≈ 6.3 bar

iii. Force and Pressure calculations for Punching operation:

- **Sheet Thickness (t):** 0.3 mm
- **Punch Tail Diameter (d):** 6 mm
- **Die Hole Diameter (D):** 14 mm
- **Penetration Depth (p):** 15 mm
- **Shear Area (A):** $\pi \times d \times t = \pi \times 6 \times 0.3 = 5.65$ mm²

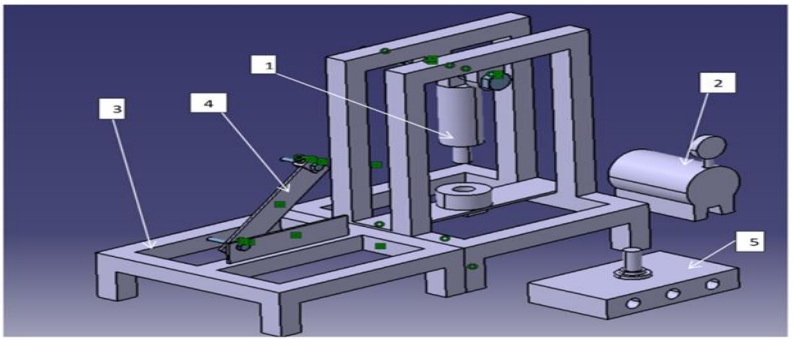
Force Calculation:

Force (Fp) = $\tau \times A = 160 \times 5.65 = 904$ N

Pressure from air compressor required to punch the sheet metal (Pp) = 904/0.0019635
= 460402.3 Pa ≈ 4.6 bar

For this we had taken Air compressor of having maximum pressure supply of 8bar to perform cutting, bending, hammering and punching operations.

3.2 Design and Drafting of a Multipurpose Sheet Metal Processing Machine using CATIA 3D Software:



PART NUMBER	PART NAME
1	Double Acting Mini Pneumatic Air Cylinder
2	Air Compressor
3	Frame
4	Shearing blades
5	Hand lever Operated by Compressed Air

Fig 3.2.1: CATIA Modeling of Multipurpose Sheet Metal Processing Machine

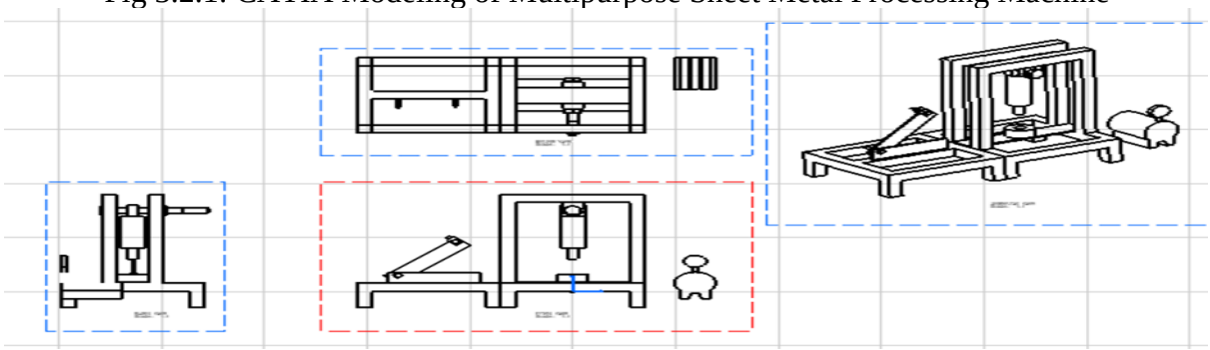


Fig 3.2.2: CATIA Drafting of Multipurpose Sheet Metal Processing Machine

3.3 Working Model of Multipurpose Sheet Metal Processing Machine:

Fig 3.3: Working model of Multipurpose Sheet Metal Processing Machine

3.4 Components of Multipurpose Sheet Metal Processing Machine:

a) Air Compressor:

This multipurpose sheet metal processing machine is powered by an air compressor. It will create compressed air, which is followed by the pneumatic cylinder and other movements to carry out different operations. This force and control is supplied by the compressed air for various applications like punching, bending cutting, hammering blanking etc. The different jobs require air pressure and flow rates need to be met by the compressor. Compressors have an intake filter which pulls in air from the environment. This mechanism overall, compresses the air which in turn increases its pressure. This cooler is generally known as the after cooler and its purpose of cooling by this, we reduce temperature with full compress air dry. The air now cooled and dried, is collected in the air tank. Whenever it is required, the air pressure will be supplied from that suction accumulator and provided to an actuator located in this particular machinery.

Fig 3.4.1 Air compressor

b) Pneumatic air cylinder:

Double-acting pneumatic cylinders Double-acting is just about the most standard model of cylinder which functions from both sidesorizontal shaft impact crushers on two distinct directions. The sealing system is composed of a pound body, two pieces orseals and its piston. The piston moves in the direction of forward and backward. It is connected to a compressed air source through the cylinder. There are also piston-style drive cylinders where compressed air is provided to one side of the piston which causes it to move in a direction and extends the cylinder rod. The direction of compressed air supply is subsequently reversed and the piston moves back in direction opposite to that it was during extension, thereby retracting cylinder rod.

Fig 3.4.2 Pneumatic air cylinder

c) Dies and Punches:

Dies and punches are essential tools in sheet metal processing such as blanking, punching, and hammering. These can be used for shaping or cutting sheet metal to the desired mounted part.

Blanking and punching Dies and Punches: used for cutting out designed shapes in sheet metal. Punch are provided with a extension at the opposite end, about the penalty of thickness we can obtained

and die has cavity in it, wedged punch along into blanked out material is pushed through drawing pin opening to form desired shape.

Fig 3.4.3: Blanking and Punching dies and punches

Punches and Dies for Hammering Operations: In the sheet metal hammering operation these are used as a basic tool to shape or form material. The punch itself is the contacting feature that has contact with the work part, and die provides both a supporting surface to counteract material flow as well as it guides the path of movement for correct positioning. Flat Surfaces on Punch and Die.

Fig 3.4.4: Punches and dies for Hammering operation

d) V-Tool for bending:

V-tool — A bending tool for sheet metal working used to make V-shaped bends. These include two V-shaped jaws which are connected at one end to create a V-opening. The V-tool Using the necessary bending force (usually a pneumatic cylinder) along with of the Our typical set upauxillary tool mounted to. Select cast iron plates of the right thickness and shape to make V. Machine the plates to size & shape with proper alignment of V-notch in accurate position. Either weld the two plates together or anything that will allow a rigid connection. Dress the V-tool to remove any burrs or blemishes.

Fig 3.4.5: V-Tool for Bending

e) Snips for cutting:

Shears, which are referred to snips in Australia and New Zealand. These metal cutting tools rely on hand pressers for shearing functions as they operate with additional force compared to other blades used together or separate. They have usually constructed with steel and consists pair of jaws one on

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the joining ends. These jaws are designed to cut through sheet metal quickly and cleanly. However, the snips are powered by air cylinders. It is welded to the metal frame and attach it with pneumatic cylinder & control hand lever. And sheet metal is placed between the jaws of snips and required cutting action is done to it.

Fig 3.4.6: Snips for cutting

f) Pneumatic Solenoid Valve:

This project uses the RIH 5 Way 2 Position Air Hand Lever Operated Valve Pneumatic Solenoid Manual Control Push Pull Valves (4H210-08) (1/4" NPT), pneumatic valve to control flow regulation for this process. The valve is five-ported and two-position apparent in the nature. Used for controlling the flow of compressed air to and from various pneumatic components etc. The changeover also requires a manual actuation, performed by depressing or releasing the push-pull lever. The Solenoid valve specified can work within a pressure range of 25 to116 PSI (1.7-8 bar).

Fig 3.4.7: Pneumatic solenoid valve

3.5 Methodology:

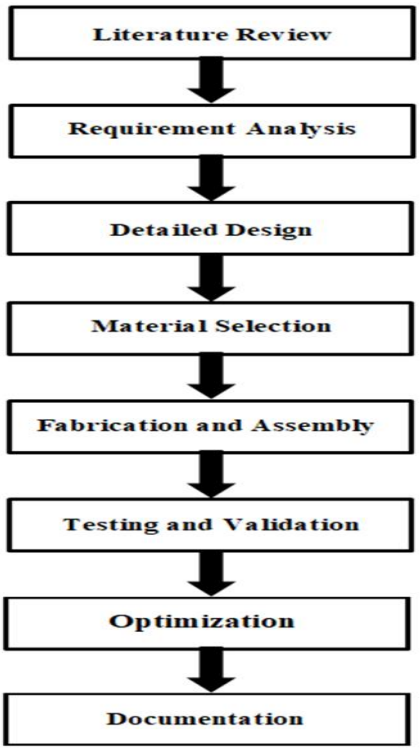

Fig 3.5: Methodology flowchart

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The designing, manufacturing, and validation of a multifunction sheet-metal processing machine was the main approach done throughout this project. This is first undertaken by a broad literature review where existing research designs and techniques on similar machines would be found out. Following that, this review assisted in defining innovation areas. The initial conceptual design of the machine was developed after analyzing the requirements of the overall structure, components, and mechanisms of the machine. The designs were evaluated on the basis of their feasibility against defined requirements and cost considerations.

Therefore, a relevant selection of materials for each machine component was completed on the basis of strength/durability, corrosion resistance, and availability of cost-effective options. The techniques applied for fabrication of the machine components varied from cutting, forming, welding, and machining. The assembly of the various components into a complete machine was then undertaken with care to maintain alignment and performance. Proper testing was carried out to verify the performance, accuracy, and safety of the machine. It was put through all the various operations under test for a variety of materials. Efficacy, productivity, and ease-of-use were evaluated. The necessary modifications were made to redesign the machine or improve its operations depending on the results. The drawings, assembly instructions, and complete documents were prepared. A report describing the methods, findings, and conclusions of the project was prepared.

3.6 Stress Analysis at different Pressures:

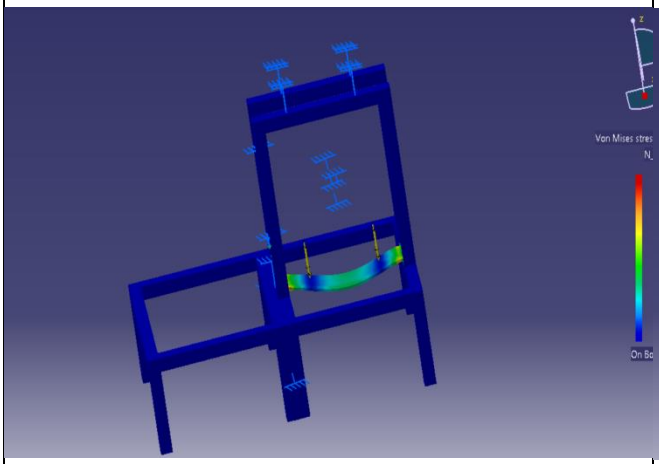

Fig 4.1) 8 bar

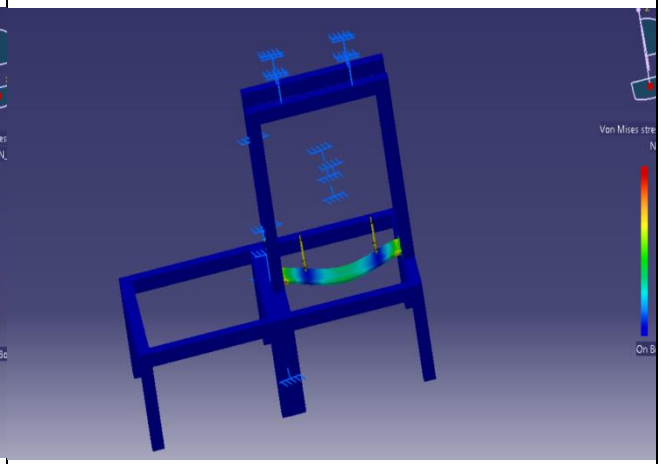

Fig 4.2) 6 bar

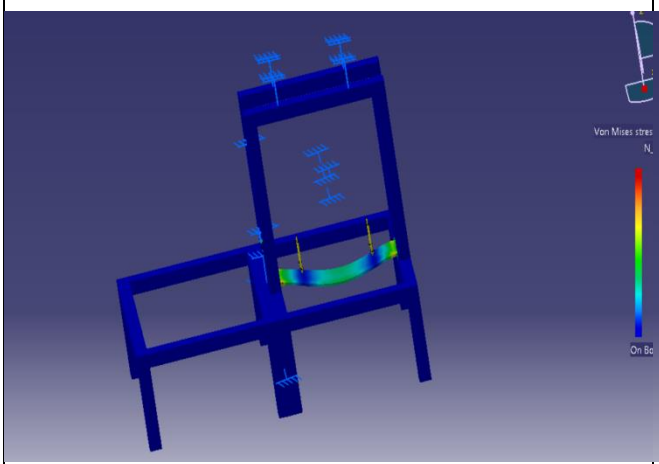

Fig 4.3) 4 bar

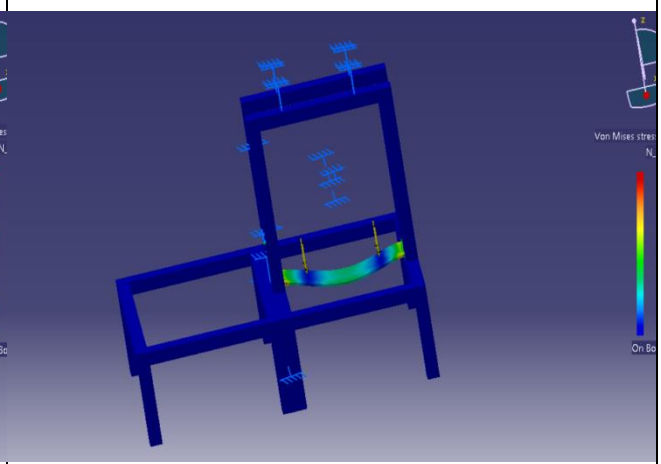

Fig 4.4) 2 bar

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Table 1 Pressure applied vs Stress Induced

Pressure applied (bar)	Stress Induced (Mpa)
8	408
6	306
4	204
2	102

The maximum Shear Stress value of Cast Iron is 528 Mpa and we got 408 Mpa Stress induced value for our air compressor limit (8bar), so the Design of the Model is under safe condition.

3.7 Displacement Analysis at different Pressures:

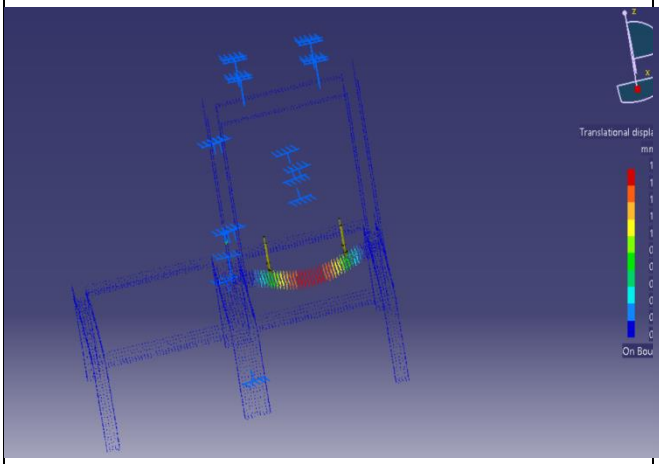

Fig 5.1) 8 bar

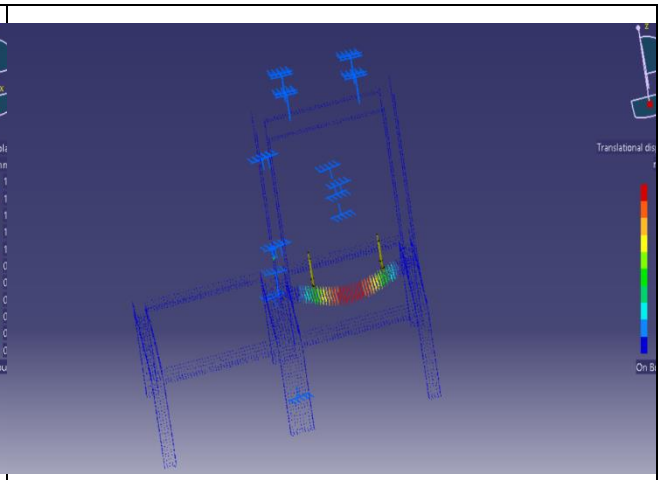

Fig 5.2) 6 bar

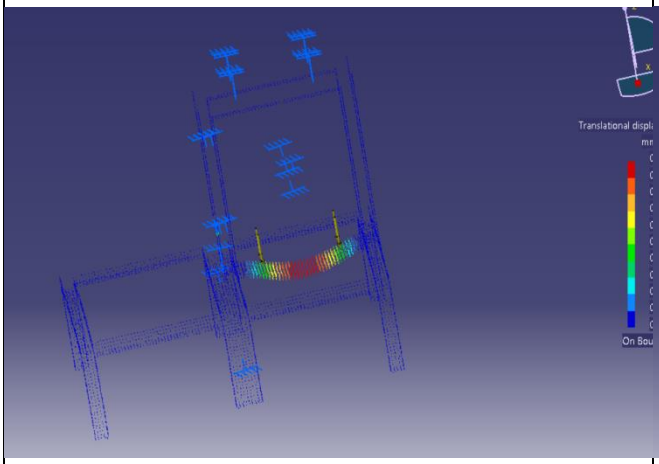

Fig 5.3) 4 bar

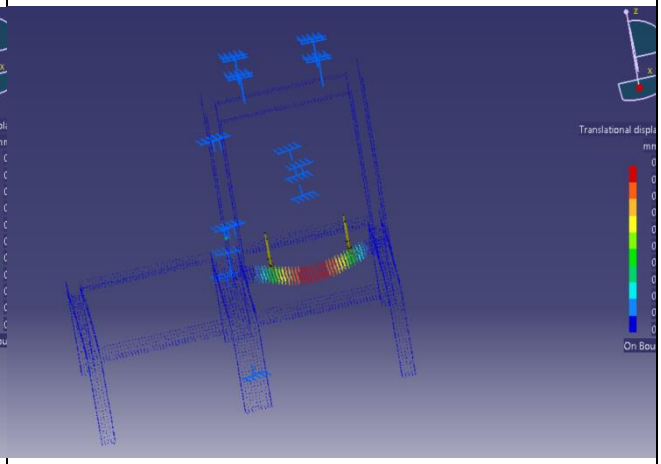

Fig 5.4) 2 bar

Table 2 Pressure applied vs Displacement

Pressure applied (bar)	Displacement (mm)
8	1.85
6	1.39
4	0.926
2	0.463

3.8 Advantages:

Enhanced Efficiency and Productivity: Combining several operations in a single machine can save setup times, material handling time as well production time.

Versatile and Flexible: The main characteristic of the CNC machine it can perform number of operations which beneficial in manufacturing processes.

Financial Benefit: Purchasing of a single machine which can perform different types of machining operation in one setup saves the huge amount as compared to purchasing 7-8 specialized machines.

Compactness: So we have a idea to save space of this machine to makes that more compact.

Efficiency: With a machine, it is capable of performing different tasks efficiently which help in increasing the productivity.

3.9 Disadvantages:

Complexity: Designing and fabricating a multifunctional machine can be more complex than designing individual machine.

Capital Investment: The up-front price of producing and establishing the appliance may be greater than that for purchasing separate machines.

Noise: Compressor will make the more Marble Noise when working on Machine.

Limited to the dimensions of sheet: Large length sheets are hard to machine.

3.10 Applications:

Automotive Industry: Manufacturing car body panels, bonnet and other metal components.

Small and medium-scale industries: Providing a cost-effective and efficient solution for sheet metal processing.

Electronics Industry: It can be used in manufacturing the metal housings of electronic devices.

Construction: Manufacturing of metal roofing, and any other type of metal creations.

Aerospace: Aircraft component manufacturing (panels, ducts).

IV. Conclusion:

This paper introduced a new multi-functional sheet metal processing machine, which provides an effective way to enhance both the efficiency and versatility of sheet metal fabrication. The more processes that can be completed by a single machine, the lower costs and higher productivity, with improved product quality. Pneumatic systems has quicker response time, it is also good for accurate and repetitive applications such as punching or bending. They also need less maintenance and are considered to be generally safer because of using air as the working fluid. In addition, pneumatic systems are generally more economical than hydraulic systems due to lower operating costs. The tool is of utmost use to small sheet metal cutting and bending industries that need manoeuvres out from hydraulic machines due to their cost.

V.References:

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