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SIMULATION WORK ON AUTO-FEEDER BY SCISSOR LIFTER CONCEPT FOR DOOR PANELS PRODUCTION

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ABSTRACT

This paper describes a mechanical design and analysis of a simple auto-feeder using scissor lifter concept. The design has been proposed to replace current manual feeding of door panels in a factory by automatic system. The main instruments and tools are compressors, pneumatic cylinders and mechanical structure. A piston of part no. P1D-S125MS-500 is used for pneumatic cylinder at 10 bar and P1D-S032MS-100 at 5 bar. The mechanism of pneumatic cylinder is calculated to lift the load of 1000 Kg including the frame weight structure with payload of door panels. The material used for beam is S30400 stainless steel, with density is 8000 Kg/m^3. The air pressure needed to lift the frame and the load has been calculated to be 9.8 bar, and the angle of inclination is set to be optimum at 17 degrees. Calculations of the structure capacity has been carried out in relation with strength of the material and capacity of the piston. Design and analysis of the model by SolidWork software shows displacements and stress of the frames and top platform are compared with manually calculated results and they are in agreement. For the automation controlling system, Programmable Logic Controller (PLC) has been used where ladder diagrams are programmed.

Keywords: automation, mechanism, scissor lifter.

INTRODUCTION

Manpower in factories is an essential factor to be considered because of their capabilities and abilities to manage and to work within their working environment. However, slowly and surely the roles of human has been undertaken by automation process especially in fabrication of raw materials to finished products. This phenomenon is more likely to be a second revolution of industry, where computers have been extensively applied in most industries. Automation is a type of computerized system which has followed the trends of changing not only because of speed and accuracy, but also security and cleanliness in operations. This research has been undertaken to design an automatic door panel feeding system into a polishing machine since manual operation still being used in the factory and th recent target of this factory is to increase its capacity so as to meet its increasing overseas market demands.

The concept is to design an auto-feeding machine using simple equipment to lift 50 to 100 pieces of unpolished door panels without human intervention. Its mechanical system must be analyzed carefully, as well as calculations of mechanical load, stress and deformation of the feeding machine. Moreover, the materials is considered perfect in order to achieve the best performance in terms of durability and accuracy.

Contribution of software programs has been analyzed to design a 3-dimension drawings and accomplished simulations. Required instruments and tools have to be selected carefully with reference to appropriate standards and calculations.

The idea of the research is to design a scissor lifter system to fully function as the auto-feeder. The use of this concept helps to extend or locate raw material on a platform to facilitate the feeding of door panel into the machine. The term "scissor" comes from mechanical point of view with support in cross "X" pattern [4] and [5]. Air pressure force from compressor is transferred to a pneumatic actuator applied to lift up the scissor lifter where the platform has also been lifted up together with the material on the top. The other pneumatic functions to push the door panel layer by layer of each mechanical movement by a piston that moving forwards and backwards. In other words, there are two types of pistons being used, namely lifting-up piston and pushing-retracting piston.

CX-Programmer is a software being used for Programmable Logic Controller where ladder diagrams are programmed according to the sequence of movements, and Automation Studio is another software used for simulation tests [2] and [9].

Mechanical parameters such as buckling stress, hoop stress, longitudinal stress, displacement and bending moment, are analyzed and generated from SolidWork and being compared with manual calculations and material physical behavior to achieve best performance. By using the automation feeding, the factory creates an ergonomic environment. It will reduce the likelihood of accidents in production field and can eliminate human exposure to the toxic chemical, dust, etc which could save human lives. Moreover, by the application of autofeeder, employers can save overhead cost of industry including operators' salary, human management and training programs which is fairly costly. In long term, the use of this machine increases more profits and benefits to this industry [6].

To conclude, automation helps manufacturing facility to gain complete control of its manufacturing process, achieving consistency in manufacturing, improving quality and accuracy, not needing workers to work in difficult or hazardous environments and increase productivity as well.

MANUAL OPERATION

So far, the process of feeding is done by operators as shown in the following Figure-1 and -2. Observations and interviews have been carried out during visits to the door panel factory. Based on these information and data, the steps and procedure of the manual operations have been identified. The time sequence of each sheet of door panes is recorded to define the cycle time. These data is important for comparison with automation system later. Normally, the manual operations require 5 to 6 people to handle the feeding into the machine. This manual system not only inefficient and inaccurate but also unsafe and an unlearned working condition. Therefore, it also degrades the product quality of each door panel produced.

Figure-1. Manual operation.

Figure-2. The bulking stack of door panels.

The above Figure-2 shows a bulk of door panels which consists of 50 sheets and weigh about 700 Kg that are ready to be fed into a polishing machine by operators. The bulk is handled by operators one by one starting from lifting, placing, positioning and pushing movement. This sequence or cycle time of each product consumes around 50 seconds or approximately 1 minute per sheet. Hence it typically requires 50 minutes per bulk to be finished without resting time, or 12000 pieces/month, on the other hand, the market demand is 20,000-30,000 pieces/month.

SCISSOR LIFTER CONCEPTUAL MODEL

Scissor lifter is a type of platform moves in vertical manner. The concept of the scissor is a mechanical function with the use of linked, folding and support in a cross ‘X’ pattern, known as pantograph [1]. Pressure is to be applied to move the platform in upward motion, elongating the crossing pattern, and propelling the work platform vertically upwards [4].

Contraction of the scissor can be pneumatic, hydraulic or mechanical via a lead screw or rack or pinion system. Depending on power system employed on the lift, it may require no power during retracting motion rather than simply releasing the pressure [5]. This is the main reason why these method is preferred for lifting. Pneumatic linear actuators are used to convert stored energy of compressed air into linear mechanical force and motion. Although the actuator is in linear motion, a variety of mechanical linkages and devices may be added to it in order to produce final output rotation, semi-rotation or a combination of linear motion and rotation. Lever and linkages may also be applied to achieve force multiplication or force reduction as well as an increase or decrease of motion speed.

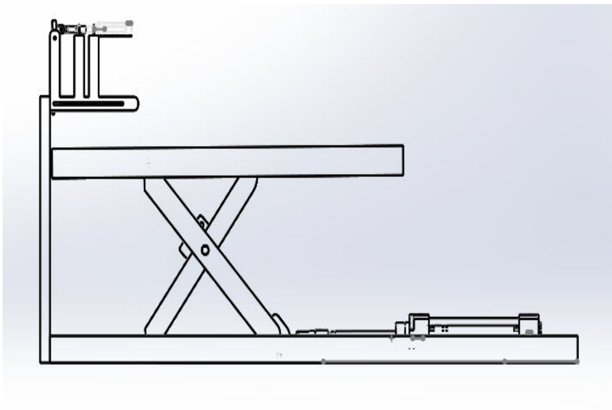

Figure-3. Scissor lifter diagram.

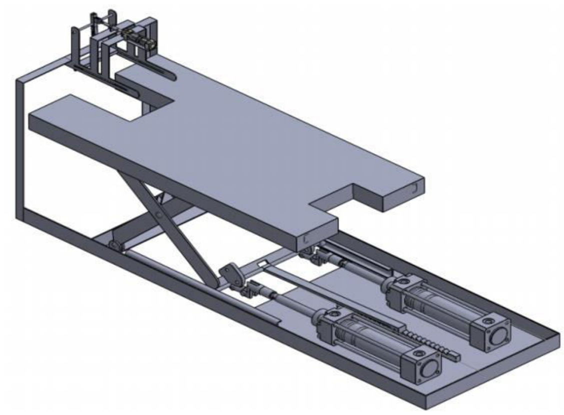

Figure-4. Scissor lifter design concept.

Single acting actuator is an actuator which produces pneumatic force in a single direction only. Therefore, these actuators may be mounted in a vertical direction, when the load is applied to the actuators, it will go back to its home position after lift or movement are done. When there is no load applied after movement or lifting, the piston can return to its home position by adding springs to cause retraction or return of the piston.

The simplest type of pneumatic actuator is the single acting cylinder. It consists of a piston which attach to a cylinder rod and moves inside a cylindrical housing(stroke). There is a port at the end of the cylinder which provides passage for air. A typical single acting cylinder can apply a force only in extension. Gravity or a spring provides the force necessary for retraction. [2]

LIFTING FORCE

The lifting force depends on mass and inclination angle which the mass is lifted. The force is calculated as

$$F_L = m \times g \times \sin\alpha \quad (1)$$

m : mass of load

α : inclined angle

g : gravitational force

BUCKLING IN CYLINDER

In the selection of cylinders, two primary concerns were noted:

a) The strength of the rod. i.e. its ability to support a specified load without experiencing excessive stresses.
b) The ability of the piston to support a specified load without undergoing deformations.

Bulking load Pb is

$$Pb = \pi^2 E I / L^2 \quad (2)$$

where,

E :Young Modulus of Elasticity
I : Moment of Inertia
L : Unsupported Length

To avoid buckling (bending) of the strut, the compressive stress σ_E must not exceed the yield stress σ_Y ($\sigma_E < \sigma_Y$). Because of the large deflection caused by buckling, the least moment of inertia I can be expressed as

$$I = AK^2 \quad (3)$$

Where,

A : Cross sectional area
K : Radius of gyration

Note: The smallest radius of gyration of the column, i.e. the least moment of inertia I must be taken in order to find the critical stress, buckling stress, or crippling stress.

The bulking stress,

$$\sigma_b = Pb / A \quad (4)$$

Substituting equation (2) into (4) gives

$$\sigma_b = (\pi^2 E) / (L/K)^2 \quad (5)$$

σ_b must not exceed the yield stress σ_y of the material $\sigma_b < \sigma_y$.

L/K is called slenderness ratio. It is a measure of column's flexibility.

STRESSES IN CYLINDERS

When cylinders are subjected to internal fluid pressure, the following types of stresses are developed. Hoop stress is produced as a result of forces applied from within the cylindrical pipe pushing against the pipe circumferential cylinder walls. On the other hand, longitudinal stress is produced by forces pushing against the top ends of a cylinder.

The pressure needed by the cylinder is calculated based on parameters of cylinder and the the load of platform plus weight of frame. It is found that the optimum pressure is 9.8 bar of each piston cylinder. Buckling stress, for one end fixed and the other end's pin jointed,substituting equation (3) into (5), buckling stress (σ_b) is given by:

$$\sigma_b = 2\pi E I / AL^2 \quad (6)$$

where
E : the Young's Modulus of Elasticity
I : Moment of inertia
A : Cross section area of cylinder
L : Length of cylinder

Hoop Stress is

$$\sigma_h = P d / 2t \quad (7)$$

where
P : Air pressure to the cylinder
d : Internal diameter of cylinder
t : Thickness of cylinder

The hoop stress must be less than tensile stress of the cylinder piston.

The longitudinal stress is

$$\sigma_L = P d / 4t \quad (8)$$

And the bursting force is

$$Fb = P d L \quad (9)$$

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In this calculation, pressure needs to be applied from the cylinder are determined. Weight of scissor structure and also the top platform which need to be supported by the cylinder is also calculated. By computing the volume of both parts and inserting it in the density formula, mass of the beam can then be determined.

Force equation which is defined from the structure is applied with incline angle of 17°. Pressure is then determined as 9.8 bar after pressure equation is applied. As conclusion, a pneumatic cylinder can only support up to 10 bar, hence two cylinders are needed. The bending moment is also calculated based on the calculated results of each inclination angle.

Table-1. Bending moment varies with inclination angles.

No. of door panel	Payload N	Scissor angle,θ	Bending moment, Nm
35	6867	17°	3226
30	5886	21.71°	2529.44
25	4905	26.425°	2043.84
20	3924	31.14°	1576.42
15	2943	35.855°	1135.84
10	1962	40.57°	730.04
5	981	45.285°	366.36

DESIGN BY SOLID WORKS

The experiment with Solid Works where the material is set on the model as cast stainless steel, with linear elastic isotropic as model type. It has a mass density of 8000.5 kg/m^3 and elastic modulus of 1.9x10^{11} N/m^2. It also has Poisson's ratio of 0.26 with thermal expansion of 1.5x10^{-5} K. Based on the loads and fixtures table, it states that there are 5 faces entities applied with fixed hinge, which is in front of the beam. Then, a gravitational force of -9.81 m/s^2 is applied into the centre of the beam. Another force of 3433.5 N is also applied in front of the beam, which is considered as the force applied by weight of load. According to mesh information, this analysis has been conducted using solid mesh as standard mesh. Automatic transition and mesh auto loops is turned off. There are 4 Jacobian points applied. The element size is 1.70321cm with tolerance of ±0.0851604cm as well as quality being set as high. In particular, the total nodes is 17828 while the total elements is 8373. Its maximum aspect ratio is 15.801%. For an aspect ratio of less than 3, the percentage of elements is 92.7%. However, for an aspect ratio of higher than 10, the elements is 0.0717%.

The distortion element (Jacobian) is 0%. The time for a complete mesh takes only 2 seconds. The results show a resultant displacement plot for mode shape with load factor of 2709.04. The highest resultant displacement is only at one side of middle section of the beam, which is 41.4974mm that involves 6597 nodes. For minimum resultant displacement, it is at almost the entire section of the beam with 1.64099x10^{-8}mm that involves 17311 nodes.

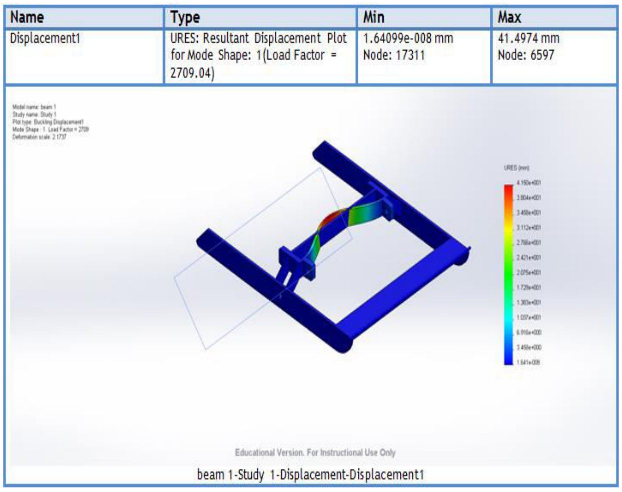

Figure-5. Beam 1 displacement analyses.

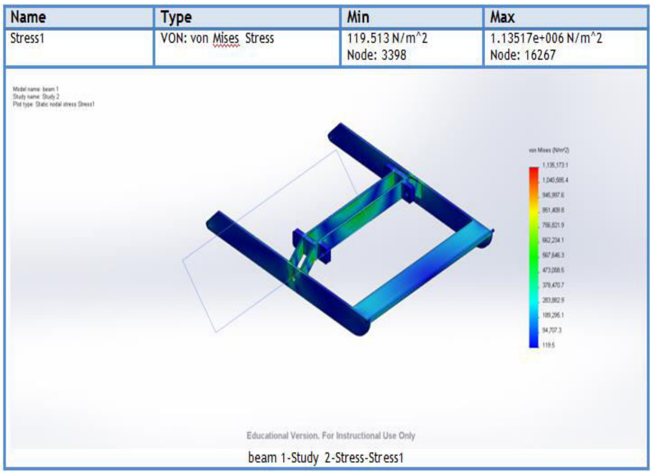

Figure-6. Beam 1 stress analyses.

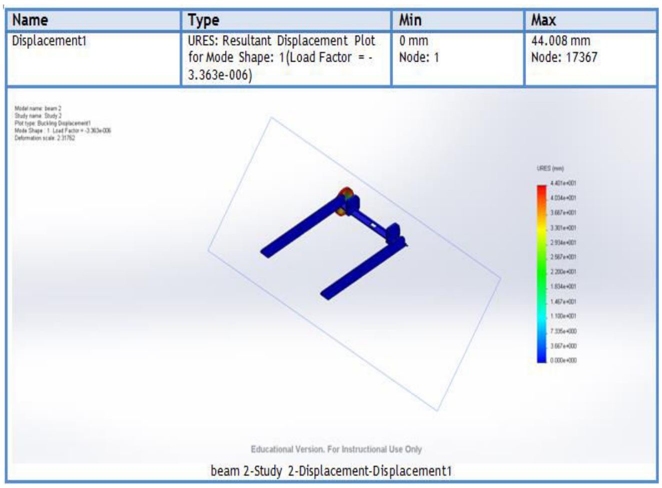

Figure-7. Beam 2 displacement analyses.

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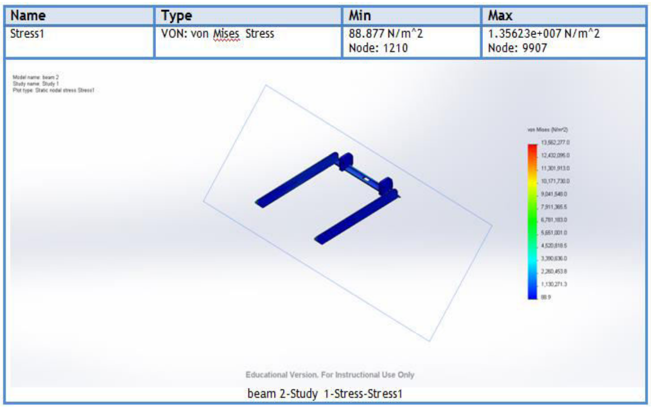

Figure-8. Beam 2 stress analyses.

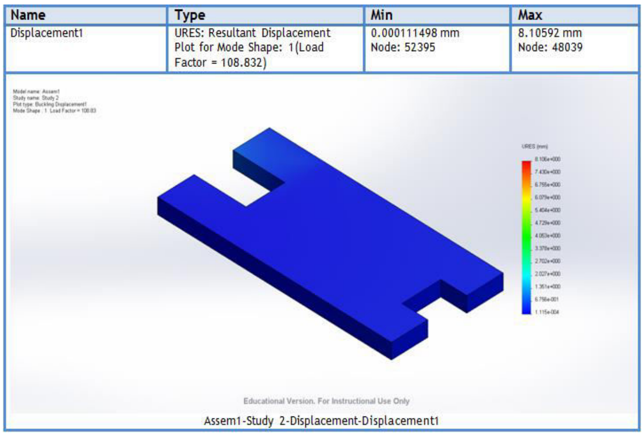

Figure-9. Platform displacement analyses.

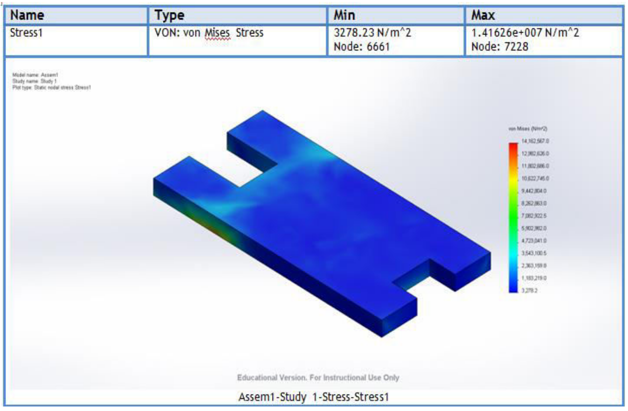

Figure-10. Platform stress analyses.

Table-2. Displacement and stress of scissors parts by solid-works.

Parts	Displacement (mm)		Stress (N/m^2)	
	min	max	min	max
Beam1	0.0000	41.4947	119.5	1.1352x 10^6
Beam2	0.0000	44.008	88.88	13.5620x 10^6
Top Platform	0.0001	8.1059	3278.23	14.1620x 10^6

CONCLUSIONS

This research concludes that the model of auto-feeder has been completed by development of scissor table, which consist of top platform, inner and outer beams, base platform and feeder. Two pneumatic pistons for supporting auto-feeder structure and another for feeding the door panel have been used. This model is expected to carry maximum load of 1000kg of panel doors. The natural has been selected as stainless steel S30400 for the frame. Two pneumatic cylinder pressure for supporting structure model is 5 bar and 10 bar for feeding the door panel. Calculation of the structure capacity has been carried out in relation with strength of the material and the capacity of piston. The Solid Work 2013 has been used in this project to model the movements of the auto-feeder.

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