Desirable Specification of Vetiver Grass Roofing Making Machine

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Abstract
This research objective was to study the appropriate mechanism and powertrain of the machine for the reducing of handwork process and time in grass roofing material manufacture. The SolidWorks 2016 Software was used to design and determine the limitation of mechanisms by use the Motion Studies function of the software. The analyzed data were calculated to determine the size of actuator and power required for the driving of machine. The result found that the designed machine required a 6 bars of air supply pressure and could has 5 mainly components such as (1) Grass sheet folding mechanism driven by the 63 mm diameter of pneumatic cylinder with the 28.08 liters/min air supply. (2) Grass sheet pressing mechanism powered by a couple of 40 mm diameter of pneumatic cylinder with the air supply 15.06 liters/min. (3) The wood rod frame griping mechanism driven by the 12 mm diameter of pneumatic cylinder with the air supply 0.66 liters/min. (4) The grass sheet feeding mechanism for the sewing process used the 50 Watts electric gear motor and (5) Electric sewing machine model GK26-1A to seam the grass sheet with the wood rod frame.

Keywords: Vetiver grass, Grass roofing, Semi-automatic machine

Introduction

Vetiver is a Thai local grass that grows easily in all regions of the country. Thai people knew the usefulness of vetiver for a long time such as, the using of vetiver leaves in a soil mulching to maintain the moisture for planting, the using of vetiver leaves as a material in handicrafts. Currently, they are many innovations about the usefulness of vetiver leaves for example, the planting materials, decomposing plant pots, the insulator from vetiver leaves for construction materials and the multipurpose particleboard etc. Another important of vetiver leaves usefulness is a roofing material (called vetiver roof in Fig.1) because it is a locally available material. If the vetiver roof was produced by the proper method the roof has been durable and can prevent the leakage of rainwater very well and it is an excellent material in thermal protection.

Figure 1. Vetiver roofing.

Today, the demand of vetiver roof in the house building and decorating business is very high especially hotel and restaurant decoration. However, all the vetiver roof producing are the handicraft activities. It found that there was a limitation in labor skill because there are complicated and time consumed work. The concisely process of vetiver roofing material manufacturing by operator was shown in Fig. 2. It has an attempt to design the semi-automatic machine or equipment to assist the vetiver roof manufacture. An assisted equipment prototype by Saisang K., Treeamnuk K. and Treeamnuk T. in vetiver roofing material production was reported that it is a folding plate to fold a grass sheet (prepared by sorting a stalk grass on the plate to a grass sheet layer form) with a wood rod. The grass bunch lacing by hand was replaced by sewing the grass sheet by a needle and mechanism. The prototype can help an operator to reduce the fatigue in working and able to increase the productivity. It can reduce a 3 minute/vetiver panel in producing time. But, the sewing by needle mechanism also takes a long time and has the tangled thread problem so, the electric sewing machine GK26-1A is replaced use in this study (Fig. 3).

(a) Grass drying (b) Lace a grass bunch

(c) bunches tied on wood rod (d) vetiver grass panel

Figure 2. The process of vetiver roofing material manufacturing

(a) Sewing machine (b) Seam stitched on the grass panel

Figure 3. Sewing machine and its seam stitched

For the development of the vetiver roofing making machine, Ján Vavro, Jr., Ján Vavro, Petra Kováčiková and Radka Bezdedová reported the using of SolidWorks in motion study in kinetic and dynamic of continuous mechanism. The using results are significant reliability and it is an effective method to monitor all kinetic parameters of mechanism and can also identify loads for any power drive in the system. Therefore, it is effective way to use the motion studies function from SolidWorks software to determine the limitation of movement in terms of kinematics and specify their necessary powertrain too.

This research proposes to determine the limitation of mechanism and powertrain of the vetiver roofing making machine. The intention of this article is to apply this results study with the prototype machine that will be fabricate in the next project research.

Mechanism and Powertrain studies

1) Mechanism and Powertrain Studies

1.1) Prototype and operation

The components and concept operation of machine prototype (Fig. 4) was described as a following.

1. The operation begins by operator feed the vetiver grass into machine tray (No. 6 in Fig. 4 and Fig. 5a) and sort it in form of grass sheet layer. After that, the operator inserts a wood rod frame on the vetiver grass sheet at position (No. 7 in Fig. 4 and Fig. 5b).

2. The wood rod frame griping mechanism (No. 3 in Fig. 4 and Fig. 5c) gripes the rod standing on the grass sheet by nails (Fig. 5b). Then, grass sheet folding mechanism (No. 1 in Fig. 4) folds and enfolds the wood rod frame by the grass sheet layer (Fig. 5d – 5e).

3. The grass sheet pressing mechanism (No. 2 in Fig. 4) is sliding down to press the folded grass sheet (Fig. 5e). After that, the tray just slides and carry the grass sheet feed into the electric sewing machine (No. 4 in Fig. 4) by the electric motor (No. 5 in Fig. 4)

4. The sewing machine just stitches the grass sheet layers seamed together (Fig. 5f). Then, the process is finished.

5. After that, all mechanism will move back to the begin position and wait for next operation starting.

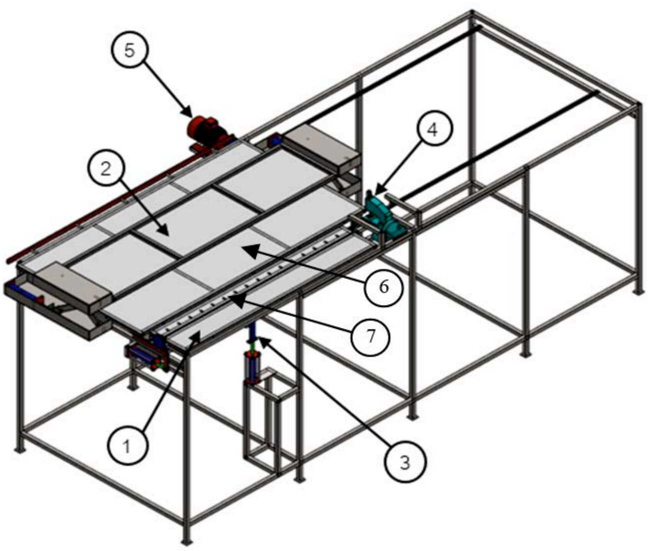


Figure 4. Component of prototype machine

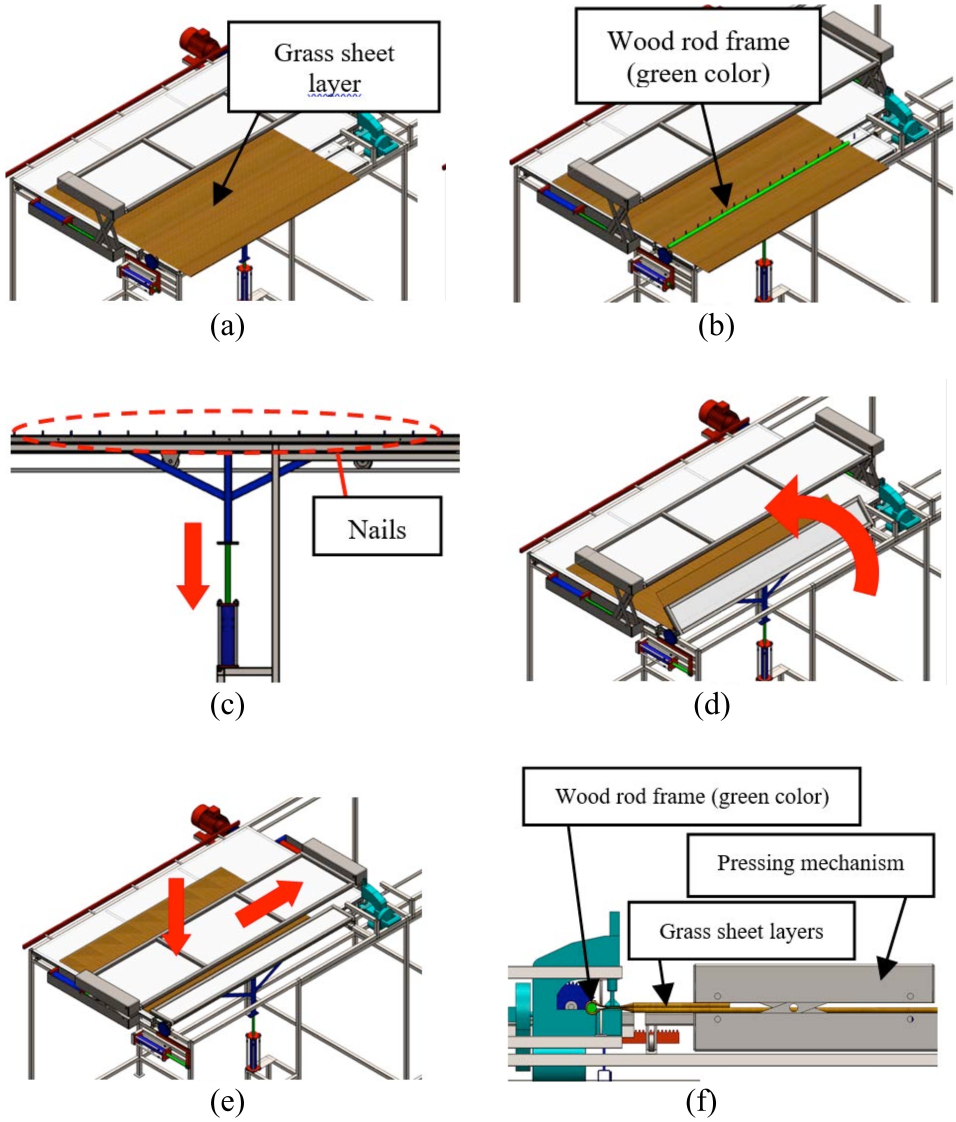


Figure 5. The operation of prototype machine

1.2) Mechanism

The motion and the power drive of mechanisms are:

1. Grass sheet folding mechanism was driven by pneumatic cylinder. It transforms a rectilinear motion to rotation motion by rack and pinion mechanism (Fig. 6a).

2. Grass sheet pressing mechanism was driven by the pneumatic cylinder. It transforms a horizontal sliding motion to vertical lifting motion by x-lift mechanism (Fig. 6b)

3. Wood rod frame griping mechanism was driven by pneumatic cylinder to lift the nails bar up and lay down to gripe the wood rod (Fig. 5c)

4. Sewing mechanism, this mechanism uses an electric sewing machine model GK26-1A.

5. Grass sheet feeding mechanism was driven by electric motor and the rectilinear motion of the machine tray was transmitted thru pinion and rack mechanism (Fig. 6c).

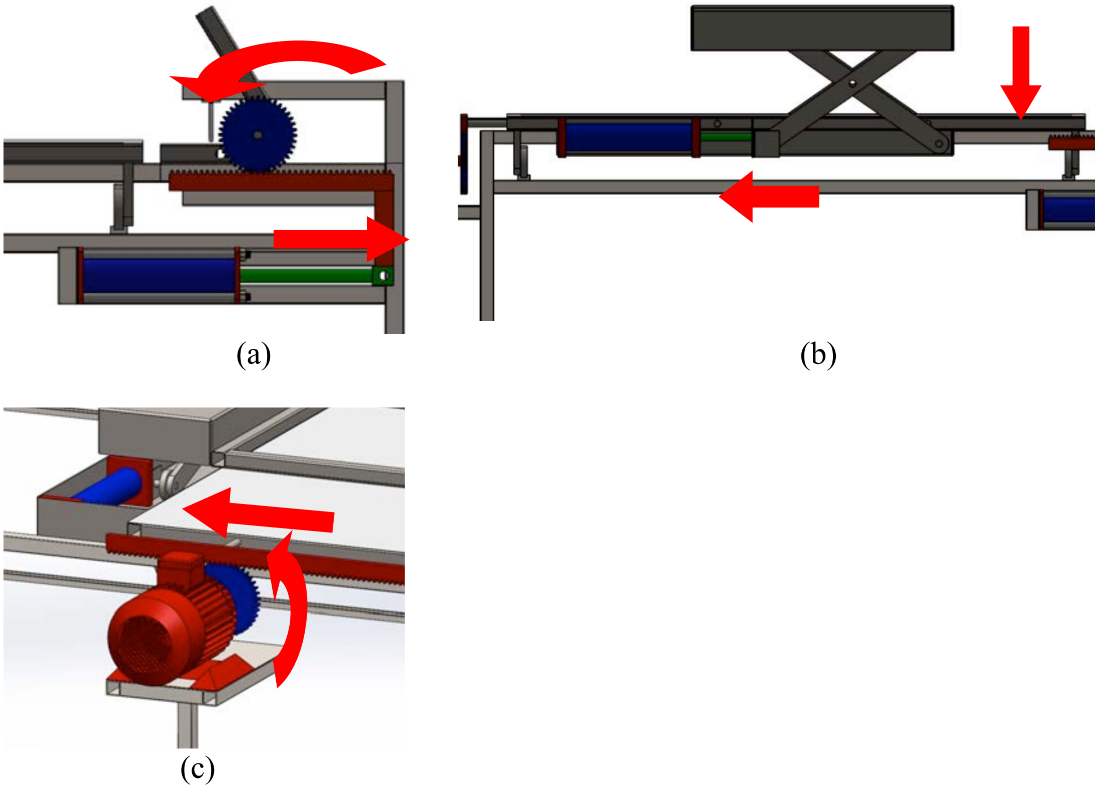


Figure 6. (a) Grass sheet folding mechanism (b) Grass sheet pressing mechanism and (c) Grass sheet feeding mechanism

1.3) Sequence of operation.

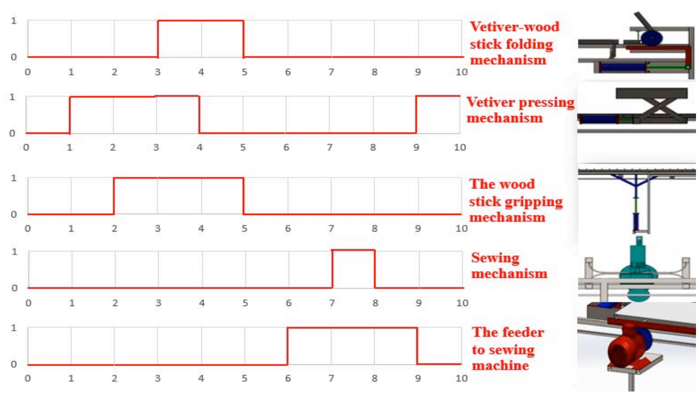


Figure 7. Sequence operation of the prototype machine

The components mechanism and sequence operation were described by the diagram in Fig. 7 where “0” and “1” on vertical axis are rest position and active position of an actuator respectively. Position “1” on horizontal axis is the start point of an operation and position “10” is the finish point. For the sequent order working, the feedback signals in each driver unit were used for control an operation of actuators and motor with Programmable Logic Control (PLC) module.

2) Mechanism and Powertrain Studies

2.1) Inertia force

The inertia force and inertia torque in mechanism was affected by an acceleration of machine motion described by (1) and (2) for rectilinear and rotating motion respectively.

$$F_o = ma \qquad (1)$$

Where F_o is Inertia force (N)
m is Mass of mechanism (kg)
a is Acceleration (m/s^2)

$$T_o = I\alpha \qquad (2)$$

Where T_o is Inertia torque (N·m)
I is Inertia of mechanism (kg·m^2)
α is Angular acceleration (rad/s^2)

2.2) X lift (Scissor lift)

X-lift or jaw mechanism is a lifting mechanism. The applied force on the leg when system is balance shown in (3).

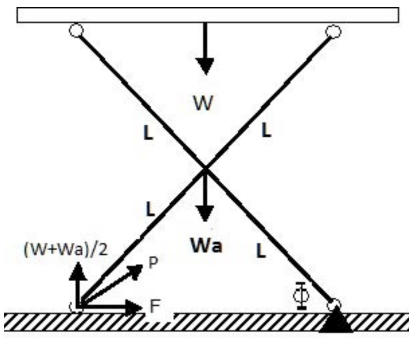


Figure 8. X-lift mechanism

$$F = \frac{(W + W_a)/2}{\tan\Phi} \qquad (3)$$

Where F is Applied force used (N)
W is Load weight (N)
W_a is Total arm frame weight (N)
ϕ is Angle between frame and arm (degree)

2.3) Electric motor power

A required motor power can determine by (4)

$$P = T\omega \qquad (4)$$

Where P is Power of motor (W)
T is Torque (N·m)
ω is Angular velocity (rad/s)

2.4) Pneumatic supply system

When supply the compressed air to a system, the force (F in N) required at the actuator can determine by the pressure of system (P in Pa) and the area of the piston (A in m^2) by (5).

$$A=\frac{F}{P} \qquad (5)$$

The air flow rate Q in liter/min can calculate by the displacement volume of cylinder (V in m^3) divided by the time (t in minute). The formula for flow rate is (6) [5].

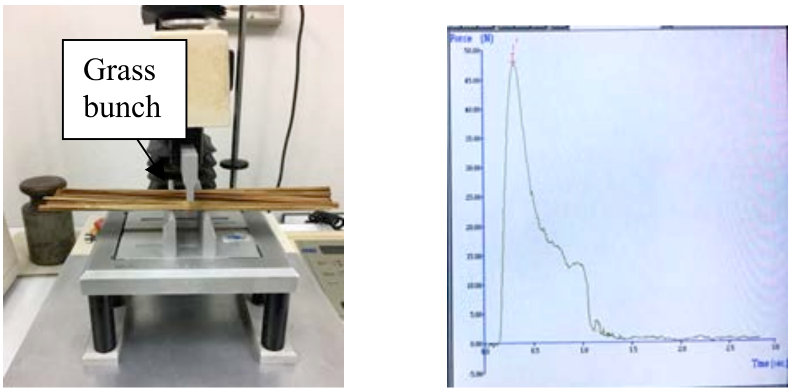
$$Q=\frac{V}{t} \qquad (6)$$

And displacement volume is the product of the piston area and the stroke (L in m) (7).

$$V=AL \qquad (7)$$

2.5) Motion studies in SolidWorks

1. Mechanical properties of vetiver grass was tested by use the vetiver grass specimen under the Universal Testing Machine (UTM) for evaluate bending force (Fig. 9). This bending force was used to calculate the necessary torque for grass sheet folding mechanism.



(a) Bending test on UTM (b) Bending force graph

Figure 9. Bending test of vetiver bunch

2. CAD files of the prototype (SLDASM file) designed from SolidWorks software was analyzed by the motion studies function to determine the magnitude of force of the driving element in each mechanism. The external force, gravity, material properties of every elements and limitation of element movement were specified in the function for calculation. This method take a less time in processing and provides

an appropriate calculation results that are equal to hand calculation with (1) to (3) for the value of interesting variables.

3. The calculated force magnitude results in each driver element from program were used to evaluate the limitation of powertrain in the machine by (4) to (7).

Results and Discussion

Based on the motion studies from SolidWorks when the range and time of motion is specified, the magnitude of force to overcome the inertia and gravity of motion are as follows.

(1) Vetiver grass sheet folding mechanism

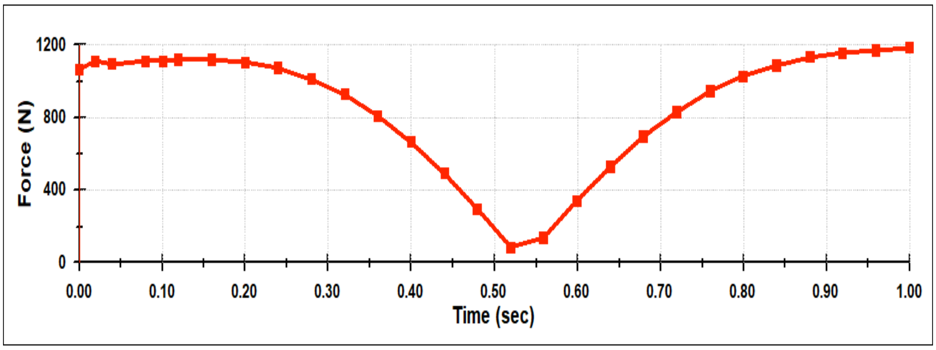


Figure 10. Relation between force change and time of grass sheet folding mechanism

From Fig. 10, the range of movement in this mechanism is 156 mm equaled to stroke of pneumatic power drive piston. At the motion times 1 s, the maximum force required for this mechanism was 1,200 N. At the time 0.55 s, an applied force is smallest because in this time the folding mechanism is in the perpendicular position with the line of piston motion and gives shortly radius of moment so, the moment is smallest too. For the air supply pressure 6 bars the necessary bore size of power drive pneumatic for this mechanism are 63 mm in diameter and it need an air supply rate 28.08 liters/min.

(2) Grass sheet pressing mechanism

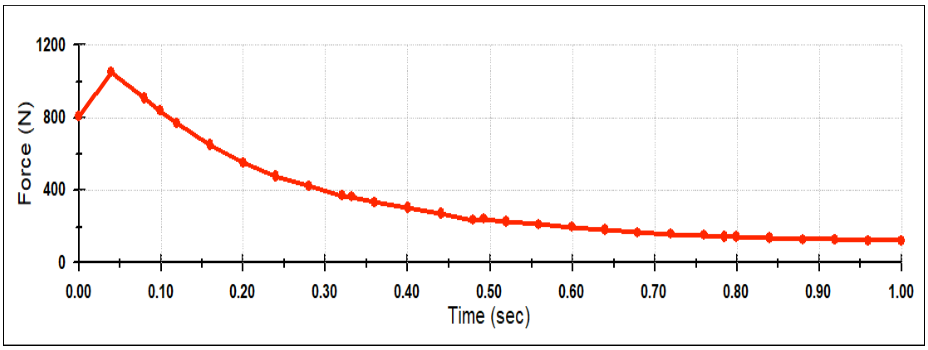


Figure 11. Relation between force change and time of grass pressing mechanism.

From Fig. 11, the result found that the maximum force required to lifting this mechanism is 1,100 N, and it have a decreasing trend when the time increases. The necessary bore side of pneumatic power drive is 40 mm in diameter and the supply air should be 15.06 liters/min when their supplied pressure is 6 bars.

(3) The wood stick gripping mechanism

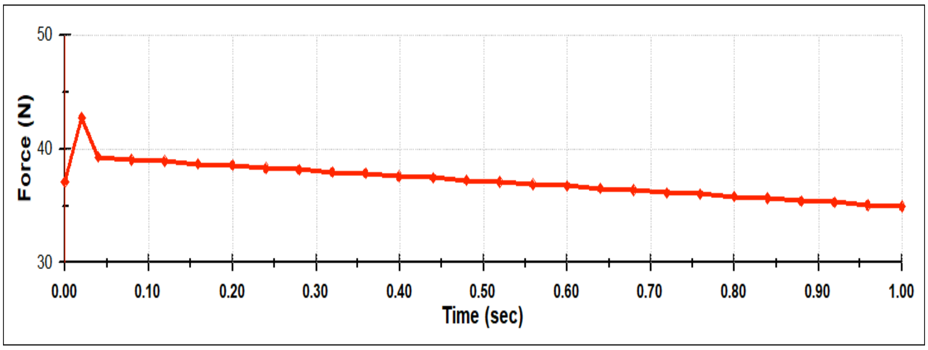


Figure 12. Relation between force change and time of the wood rod frame gripping mechanism.

In Fig. 12, the pneumatic a piston displacement is 100 mm and the moving time is 1 s in movement of the mechanism. It found that the maximum force required for this mechanism is 43 N at time 0.025 s. After that, the apply force will change with a constant rate of decreasing. The diameter of required pneumatic piston should be 12 mm with the air supply of 0.66 liters /min at 6 bars of air pressure.

(4) The grass sheet feeder mechanism

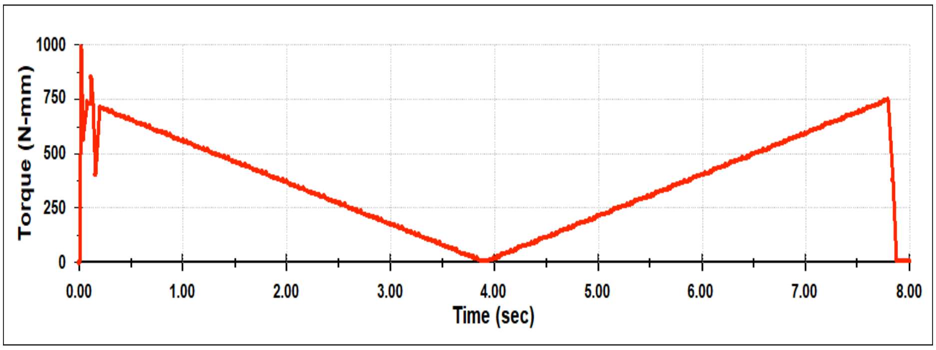


Figure 13. Torque changes by the time of feeder mechanism motion.

From Fig. 13, the driver pinion was specified 1,718.8 degrees of angular distance movement (equal to required 1.8 meters in rectilinear range of vetiver panel that will feed to the sewing machine). The pinion just rotates at 1,718.8 degrees in 7.82 s time (equal to Angular velocity 3.83 rad/s). Found that the maximum torque required for drive the pinion in this mechanism is 1,000 N • mm (1 N • m). On the first half of 8.00 s moving time, the pinion just starts rotating and need a maximum torque to turn all mechanism. After that, the last 4 s of moving time the system needs a maximum torque again to stop the rotating and rest in finally. The motor power calculation show that the system required a 50 Watts of power.

Conclusions

The using of SolidWorks 2016 Software to design and determine the limitation of mechanisms and powertrain by the Motion Studies function found that the designed machine required a 6 bars of air supply pressure and could has 5 mainly components as following (1) Grass sheet folding mechanism driven by the 63 mm diameter of pneumatic cylinder with the 28.08 liters/min air supply. (2) Grass sheet pressing mechanism powered by a couple of 40 mm diameter of pneumatic cylinder with the air supply 15.06 liters/min. (3) The wood rod frame griping mechanism driven by the 12 mm diameter of pneumatic cylinder with the air supply 0.66 liters/min. (4) The grass sheet feeding mechanism for the sewing process used the 50 Watts electric gear motor and (5) Electric sewing machine model GK26-1A to seam the grass sheet with the wood rod frame.

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