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Design of filler and compactor for oyster mushroom growing medium (baglog)

T Rizaldi[1], Raju[1] and M R Piliang[2]

[1]Department of Agricultural Engineering, Agriculture Faculty, Universitas Sumatera Utara, Indonesia
[2]Student of Agricultural Engineering Department, Agriculture Faculty, Universitas Sumatera Utara, Indonesia

E-mail: taufik.rizaldi@usu.ac.id

Abstract. Oyster mushroom cultivation requires good quality growing medium (baglog). In addition to good baglog material, a suitable density level is needed for mushroom growth. Filling and compaction of baglog is often found use manual methods so it takes longer time. The objective of this study is to design a filler and compactor mechanical device for mushroom growing medium. The design obtained dimensions of length 150 cm, width 90 cm and height 153.06 cm. The device is operated by an electric motor of 1 Hp with rotation of 1450 rpm. The device capacity is 180 baglog/hour. The design test showed that the material for the main frame component consist of angle bar with size of 40 mm x 40 mm and thickness of 4 mm, was able to load the device with minimum safety factor of 3.58.

1. Introduction
Increasing demand for oyster mushroom (*Pleurotus ostreatus*) especially in North Sumatra is not comparable with mushroom production due to less mushroom farmers number. Mushroom cultivation that requires special growing medium is one of the reason community has low interest to cultivate it [3]. Raw material for mushroom growing medium is made from sawdust and added complementary ingredients such as corn, gypsum, lime, agricultural fertilizer and seeds which are put into a plastic bag then compacted and called baglog [6].

The procedures are still manual, using a device which is operated by human. These procedures spend more energy and time to produce a baglog, therefore making a device that can subtitute human is needed. The objective of this study is to design a prototype of filler and compactor mechanical device for mushroom growing medium by a graphic design, considering device design parameter including hopper, screw conveyor and retaining pipe.

2. Materials and Methods
Materials which is used in this study are mushroom growing medium (baglog) data in form of volume and mass and Solid Work 2014 software, while the tool is a set of computer.

2.1. Stages of research
This research is based on design principles with several stages, (1) literature study, (2) problem analysis, (3) design of apparatus concept, (4) evaluation and design of apparatus.

2.2. Functional design

1. Hopper
   Function as chamber of growing medium material that will be made as baglog with 45 kg of capacity.
2. Output pipe
   Function as output for material. The dimension is 10 cm of diameter and 30 cm of length.
3. *Screw conveyor*
   Function as material carrier toward plastic bag through output pipe. Screw diameter is 9.13 cm and 60 cm of length. Distance between 2 pitches is determined by equation below

   $$D = \sqrt[3]{\frac{4\,Q}{60\,\pi \times 0.8\, n\, \Psi\, \Upsilon\, C}} \qquad (1)$$

   Description:
   Q = needed capacity (kg/hr)
   n = shaft rotation (rpm)
   Ψ = *loading efficiency*
   Υ = density
   D = screw diameter [5]

   Determine pitch distance

   $$S = 0.8 \times D \qquad (2)$$

   Description:
   S = pitch diameter [4]

   Determine motor power requirement

   $$N_0 = \frac{Q\, L\, W0}{367} \qquad (3)$$

   Description:
   N = motor power (kw)
   Q = needed capacity
   L = screw length (m)
   W_0= friction factor [5]

4. Retaining pipe
   Pipe diameter is 10.3 cm and has function as barrier for growing medium material which is loaded so the material will be solid.

2.3. Structural Design

Baglog filler and compactor device has several structural components, namely:

1. Frame
   Provide support for several other device components, the dimension is 150 cm of length, 70 cm of height and 90 cm of width. Frame is made from angle bar, 40x40x4 mm of dimension.
2. Electric motor
   Function as power source to operate screw conveyor and gearbox. Motor specification is 1 Hp and 1450 rpm of rotation.

3. Pulley
   Function of pulley is to distribute power from electric motor to screw conveyor shaft and gearbox through v-belt. Pulley sizes are 2, 3 and 20 inch.
4. Gearbox
   Gearbox function is to reduce motor rotation. The ratio is 1:30.
5. Operator button
   Button function is to control device movement which gives back and forth rotation to electric motor, so the retaining pipe can move forward and backward.

2.4. Apparatus mechanism
Mixed baglog material growing medium is loaded to hopper then control button is pushed to operate electric motor. Electric motor power and rotation is distributed to screw conveyor shaft by v-belt so screw conveyor rotate and carry material which is filled to baglog plastic. Retaining pipe is operated by pulley which is rotated by gerabox through v-belt that give compressive force due to its slower shaft rotation. This action will make baglog material become solid and correspond to planned weight.

2.5. Testing
Test is done to determine design success by solidworks software simulation. There are two kind of simulations, static and motion simulation [1]. Static simulation aims to ensure whether type and thickness of device materials are able to hold whole accepted static load without experiencing plastic deformation. Motion simulation aims to ensure whether whole components motion support each other to achive the objective of device design as filler and compactor for mushroom growing medium material.

3. Results and Discussion

3.1. Device Main Part and Its Function
3.1.1. Frame. Main frame as whole device support was made by angle bar and had size 40 mm x 40 mm and 4 mm of thickness. Frame dimension was 150 cm of length, 90 cm of width and 70 cm of height. Figure 1 below showed frame design

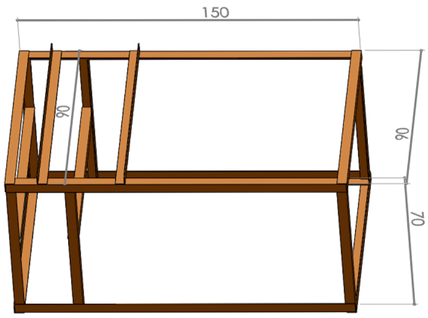

Figure 1. Main frame design

3.1.2. Hopper. Hopper was designed for growing medium material chamber and was able to load 45 kg material or was equal to 30 baglogs. The load amount was basic to design hopper volume which was 117647.06 cm^3. Dimension and design was showed on Figure 2 below

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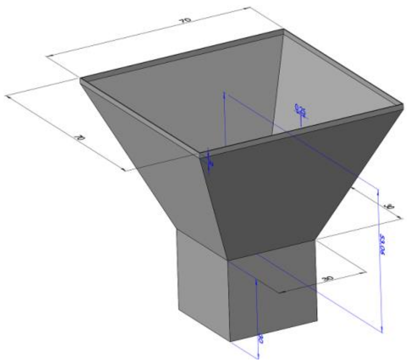


Figure 2. Hopper design

3.1.3 Screw conveyor. Screw conveyor was designed for growing medium material carier component which was located below the hopper as shown in Figure 3. Screw conveyor was installed on 2 cm of shaft diameter and 80 cm of length. Screw conveyor diamater was 9.13 cm, its pitch was 7.3 cm and its whole length was 58 cm.

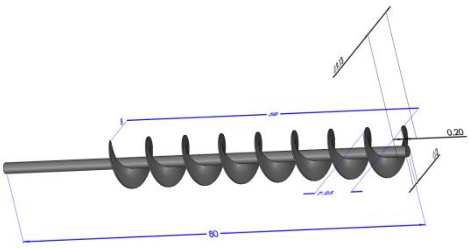
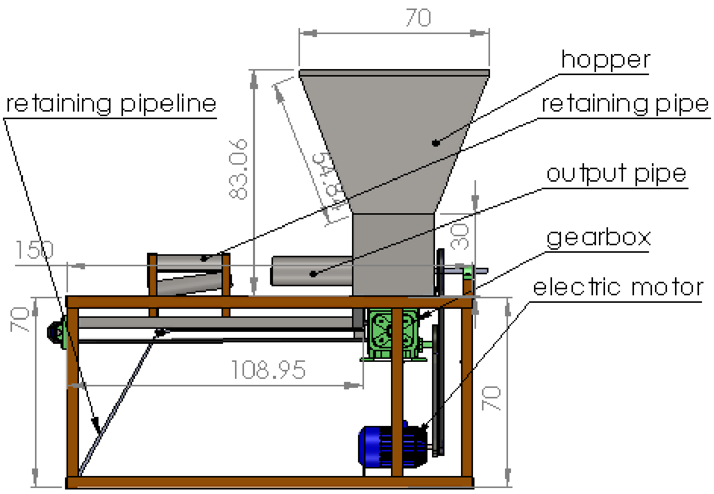


Figure 3. Screw conveyor design

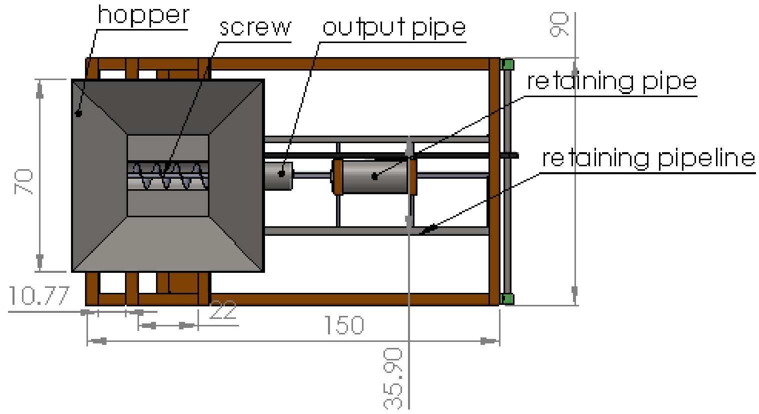
Shaft rotation designed to move screw conveyor was 135.33 rpm. By the rotation, screw conveyor was able to carry medium material up to 270 kg/hr.

3.2 Device Design Result

Device design is showed on Figure 4. Figure 4 describes whole device dimension 150 cm of length, 90 cm of width and 153.06 cm of height. Device is operated by 2.5 Hp electric motor with 1450 rpm of rotation. Electric motor power and rotation are distributed to move screw conveyor by pulley, 2 and 20 inch of diameter, respectively. While, to operate retaining pipe device uses 1:30 gearbox and 3 inch pulley. Screw conveyor shaft velocity, which is carrying growing material medium, is faster than retaining pipe velocity in order to give pressure when the material is loaded to the baglog.



(a)



(b)

Figure 4. Device design side view (a) and top view (b)

3.3. Design Test by Simulation

3.3.1. Device motion simulation. Test aimed to determine design success which was showed by compatibility of whole functional component motion. Figure 5 shows retaining pipe position while the device was operating.

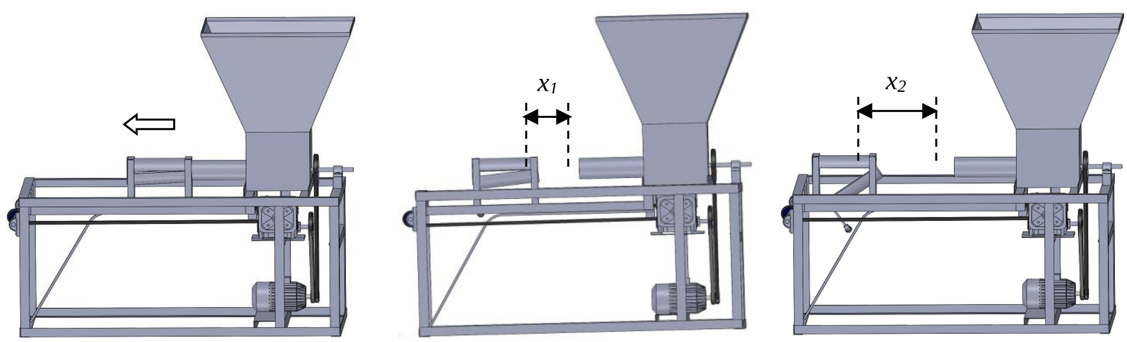


Figure 5. Retaining pipe motion

Retaining pipe would move backward slowly while plastic bag started to load growing medium material which was carried by screw conveyor. Part of retaining pipe started to open at 1.06 second while baglog mass was increasing and would be wide open if baglog was fully loaded. Baglog would slide down through output line at 3.5 second. Retaining pipe would back to its starting position after 20 seconds, so we could conclude that baglog loading and compacting capacity was 3 baglogs/minute.

3.3.2. Static load simulation. Test aimed to determine design success which was showed by plastic deformation absence on device especially to main frame when static load was given to the frame. Theoretically, total load for main frame was 60 kg (588 N).
3.3.2.1. Stress test. Load bearing ability determination on main frame was depended on color code which was resulted by simulation [1]. Simulation result showed that type and thickness of material had maximum 19794.758 N/mm^2 tensile stress (red color) and minimum 769.814 N/mm^2 (blue color), while calculation result showed that tensile stress which was occured about 710 N/mm^2. Calculation concluded that material type was able to accept tensile stress so plastic deformation would not be occured. Simulation result is showed on Figure 6 below

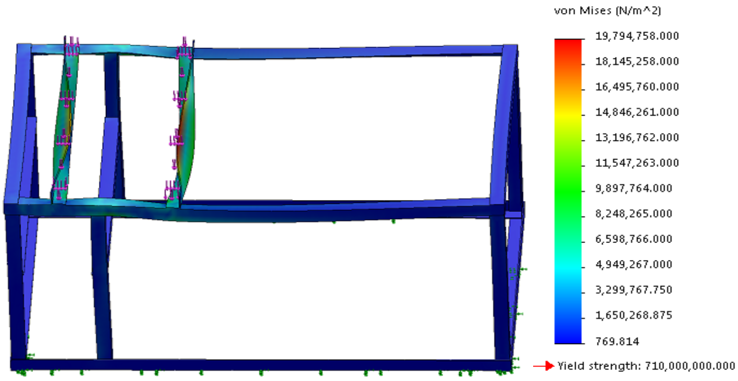


Figure 6. Main frame static stress test result

3.3.2.2 Factor of safety (FoS) test. Simulation is used to determine material ability to lift load based on factor of safety (FoS). Main frame design will be concluded safe if FoS value is higher than 2 (FoS > 2). Simulation result showed that main frame material FoS value must be minimum 3.58 to be able to lift the load. Simulation result is showed on Figure 7 below

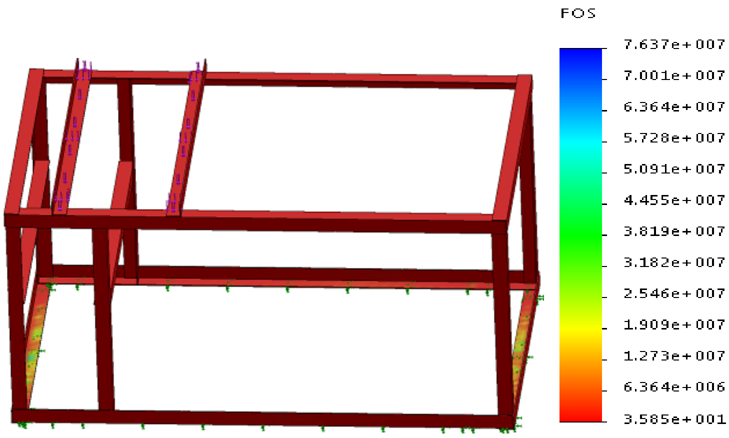


Figure 7. Main frame factor of safety test result

4. Conclusion

Design of filler and compactor device for mushroom growing medium had dimension 150 cm of length, 90 cm of width and 153.06 cm of height. Device was operated by 1 Hp and 1450 rpm electric motor. Device work capacity was 180 baglogs/hr. Design test result showed that main frame material component which was angle bar 40 mm x 40 mm and 4 mm of thickness was able to lift load while factor of safety was 3.58. Device whole components motion showed compatibility, so the design could be recommended to be manufactured.

5. References

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