Force Evaluation Of Integrated Bamboo Processing Machine And Performance Of Dies

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Abstract—Bamboos are a unique group of giant arborescent grasses in which the woody culms arise from underground rhizomes. They are shrubs and have tree-like habit. Their culms are erect and sometimes climbing. It is the fastest growing plant on this planet. Bamboos are characterized by woody, mostly hollow culms with internodes and branches at the culms nodes. India is the second richest country in terms of Bamboo genetic diversity with a total of 136 species under 75 genera. It encompasses about 8.96 million hectares of forest area, which is equivalent to 12.8 per cent of the total forest cover of the country.

Generally different types of machines are use in different industries like bamboo cross cutting machine, bamboo splitting machine, knot removing machine, bamboo slicing machine, bamboo stick making machine, bamboo stick sizing machine, bamboo stick policing machine.

Initial treatment to raw bamboo before ready for actual work is called bamboo processing which includes Cross-Cutting, Splitting, External and Internal Knot Removing, stick length setting etc.

Presently for all processing of bamboo, individual machines are available. The main theme involved in this work is to Design & Fabricate a machine with specialty of multiple operations of bamboo processing in a single unit. Hence, integrated bamboo processing machine is fabricated and tested for all successful runs. The design evolves a new concept of bamboo processing machine with multiple operations with help of multipurpose die, which eliminated the disadvantages offered by the present processing machines, which are for single operation only.

The main objective of this work shows the development of experimental set up of integrated bamboo processing machine and force evaluation with a capability of doing two operations in a single unit.

Keywords—Bamboo, Splitting, Slicing, Dies.

I. INTRODUCTION

Bamboo is considered for its strength, which depends upon the species, climatic factors and the moisture content. Bamboo is strong, though not stronger than the timber of Sal or Teak. Seasoning is essential prerequisite for maintaining the appearance and strength of bamboo products and structure. Unseasoned bamboos are highly susceptible to insects and fungal attack, decay and mechanical degradation. Seasoning of bamboos has to be done properly and carefully as rapid drying results in splitting. Bamboo can be cut and split easily with handsaw or knife. Immature bamboos are soft and pliable and can be moulded to desired shape.

Presently for all processing of bamboo, individual machines are available. The main theme involved in this work is to Design & Fabricate a machine with specialty of multiple operations of bamboo processing in a single unit. Hence, comprehensive bamboo processing machine is fabricated and tested for all successful runs. The design evolves a new concept of bamboo processing machine with multiple operations with help of multipurpose die, which eliminate the disadvantages offered by the present processing machines, which are for single operation only.

The design involves a new concept of making a special purpose of die for splitting and slicing, the concept behind this is that, the machine is kept common for both the operations; only the die for splitting and slicing is different. This will eliminate the use of special machine for slicing which is to be done after splitting the bamboo. In this research, different types of dies are fabricated for slicing purpose which includes used of different type of cutting material, different types for tool positioning for slicing.

II. CONVENTIONAL MACHINE

The various traditional processes carried on this different machine from initial stage i.e. cross cutting of bamboo to splitting, knot removing, slice making, stick length setting etc. Fig. 1 to 5 shows different types of machines.



Fig. 1. Cross cutting machine



Fig. 2. Splitting machine



Fig. 3. Knot removing machine



Fig. 4. Slice making machine



Fig. 5. Stick length setting

III. INTEGRATED BAMBOO PROCESSING MACHINES

Integrated bamboo processing consists of the following components.

- 1. Hydraulic machine frame
- 2. Hydraulic Double acting actuator
- 3. Hydraulic pump
- 4. AC motor
- 5. Direction control valve
- 6. Check valve
- 7. Pressure gauge
- 8. Pressure relief valve
- 9. Oil reservoir
- 10. Multipurpose die with housing



Fig. 6. Constructional line diagram

A. Working

At first, the AC motor is energized which creates the flow of fluid at high pressure it get transfer to the direction control valve. The 4/3Direction control valve (DCV) is used to direct the flow. Then through DCV the fluid is controlled and allow to flow through various direction.

The pressure is controlled by pressure relief valve which controlled the overflow condition. The bypass check valve is used in case of return flow of fluid to reservoir. The pressure gauge is used to measure applied pressure during working condition. The direction control valve helps to flow fluid in cylinder due to which the motion of cylinder takes place. The forward motion helps to feed bamboo in die, and return motion helps to set next bamboo in die for further process.



Fig. 7. Integrated machine (side view)



Fig. 8. Integrated machine (back view)

B. Focus On Multipurpose Die

Die is the machining element which is one of the most important and essential element in the field of bamboo processing machine. Die is used to break down the bamboo (raw material) and convert it into finish product such as tooth pick, ice-cream, sticks etc.

Die is made of three tool plates which are placed inside the single housing. This plates are kept as one by one inside the housing so that right from splitting to the end of finish product can be achieved.

C. Housing

It is one of the robust hollow shaped bar. It is to placed it outside the tool plates which covers & gives support to the plates. This housing is fixed to the machine below the actuator in certain distance. After that introduce plates one by one in reverse sequence which makes a complete die.

D. First Tool Plate

There are 8 cutting tools which are arranged vertically in an angle and welded to the middle spindle as well as the plate. These cutting tools are used to cut/ split the bamboo in 8 equal parts vertically and then allow to feed to the next tool plate.





Back

E. Second Tool Plate

In this 5 tools are arranged horizontally like steps in 1/8th part of the circle. This tool cut the bamboo in slicing and then allow feed to the last tool plate.

F. Third Tool Plate

In this 6 to 8 tools are placed according to the requirements which are arranged tangentially to the 2nd tool. In this, bamboo will cut in square size/ according to the required shaped.

G. Tool Geometry



Fig. 10. Tool geometry

IV. NECESSARY COMPONENTS IN HYDRAULIC CIRCUIT

Fig. 11 to 16 shows various components in hydraulic circuit, fig 17 to 20 shows other components and fig. 21 shows hydraulic circuit.



Fig. 11. Direction control Valve



Fig. 12. Pilot operated check valve



Fig. 13. Fixed displacement pump



Fig. 14. Filters or Strainers



Fig. 15. Pressure relief valve



Fig. 16. Cylinder



Fig. 17. Housing



Fig. 18. Motor



Fig. 19. Coupling



Fig. 20. Oil reservoir



Fig. 21. Hydraulic circuit diagram

- 1. Injection cylinder
- 2. Pilot Check Valve
- 3. Direction Control Valve
- 4. Return Line Filter With Bypass Check
- 5. Fixed Displacement Pump
- 6. Filter or Strainer
- 7. Breather Filter
- 8. Pressure Relief Valve
- 9. Reservoir
- 10. Pressure Gauge

A. Working:

The fluid, i.e. the oil is stored in a reservoir. The reservoir is provided with a breather float to maintain the oil level in the reservoir. A fixed displacement pump is used to pump the oil. A filter is provided to remove any contaminants present in the oil. A pressure gauge is provided inline to monitor the pressure developed. The oil enters the direction control valve (DCV) and is diverted to the head side of the piston of the cylinder. A pressure relief valve is provided to overcome any overload conditions. As oil is non-compressible fluid it builds up pressure against the head. This pressure exerted pushes the plunger towards the piece of bamboo which located vertically on the tip of the housing which contains tool plates use for splitting the bamboo and process go on. After the process has been completed, the solenoid valve is actuated which changes the spool position. This diverts the flow of oil to the rod end of the cylinder. The oil from the head side flows into the reservoir. As the oil builds up the pressure, the piston moves back to its original position.

After the plunger gets back to its original position, some period of time is allowed to allocate new bamboo piece and to collect the product and further same process continue .In this way the required bamboo product especially Incense sticks are obtained.

B. Assembling

Coupling of motor and pump: The pump and the motor are mounted on the same level, and their shafts are coupled together by a three jaw insert type coupling. The advantage of this type of coupling is that, if there is jerk between the two shafts the insert will only break, this insert can be easily replaced of the whole coupling.

Reservoir mounting: The reservoir is mounted on the same level as that of the motor and pump. The outlet of the reservoir and the inlet of the pump are almost on same level. The reservoir is bolted to the frame.

Mounting of frame: The frame of the whole machine is fabricated considering aesthetic design features. The size of the frame is decided to allow proper and spacious mounting of all other parts.

Mounting of modular valves: The modular valves are mounted on a single station manifold. The whole unit is mounted on the upper part of the frame and behind the L-frame. This positioning is done to avoid any interference in the work space, so that the pressure setting can be done easily with the help of pressure relief valve.

Mounting of cylinder: Since it is required to keep the sufficient distance between the cylinder and housing so that the plunger movement should not get disturb and housing which consist of tool plates should fixed properly and rigidly. This was done by taking a 12mm thick plate and fixing the cylinder with the help of Allen screws.

Mounting of housing: Housing is one of the robust hollow shaped bar placed just below the actuator. Housing is made up of 3-tool plates.

Connection of all the components by hose pipe: To complete the hydraulic circuit and allow the flow of oil to transmit power, the components are connected with the help of hose pipes. The inlet of the hydraulic pump is connected to the outlet of the reservoir. The outlet of the pump is connected to the inlet of the single station manifold. Now the port A of the manifold is connected to the head side of the cylinder and the port B is connected to the reservoir. This completes the pipe connections.

Assembly of control panel: The control panel is assembled by connecting the different components according to the electrical circuit, which is explained earlier. This control panel is placed in side of the machine.

These all types of components are set so that the desired product will collect below die in a collector and then allow to send in next process like polishing, finishing etc.

V. TRIALS AND EXPERIMENTATION

Trails and experiments were conducted to study the effects of various machining parameters on bamboo operations. These studies have been processing undertaken to investigate the effects of various sizes of bamboo, speed, cutters and other machine parameters on torque, energy and time required in processing operations. During experimentation various variety and sizes of bamboo samples are collected and processed at three different speeds. For splitting operation different diameter of bamboos were taken into consideration for obtaining cutting force required to split bamboos of different diameters. The result of the same is shown below. In the next step the already splitted bamboo pieces are forced on to the slicing tool and it gets sliced in four pieces, the actual slices are also shown in fig. 4.

TABLE I. OBSERVATION TABLE FOR COMBINED DIE

Bamboo No	Size of bamboo	Size of slice in mm.	Pressure (MPA)
1	small	2	6.66
2	small	2	6.70
3	medium	2.5	6.70
4	medium		6.8

In this combined die, it is tried to perform both the operations at a same time, splitting and then followed by slicing, for this combined die which contains both splitting and slicing tools is fabricated followed by one another. In this die as shown below in fig. 25 the distance of tool tip is denoted by T1 and distance between the tool end is denoted by T2 and as it can be seen that the distance T2 is lesser than T1, that means the tool will split the bamboo, but as soon as it gets cuts it cannot find place to flow out as T2 is less than T1 the available space at T2 is not sufficient enough to allow the slices to flow out, so it gets stuck between the two slicing tools.



Fig. 22. Distance between two successive tools of slicing die.

As this combined die was a failure, it is then decided to make separate dies for both the operations, which could be used on single machine. Further Splitter die is fabricated having 8 splitting and 6 splitting tools. The observation table and force calculation for both the dies is shown below.

Area Of different size bamboos

- 1. $A = \pi / 4 (28.12 \ 2 \ -11.422) = 518.07 \ mm.$
- 2. $A = \pi / 4 (30.252 13.372) = 578.29$ mm.
- 3. $A = \pi / 4 (512 312) = 1288.05$ mm.
- 4. $A = \pi / 4 (52.072 32.072) = 1321.66$ mm.
- 5. $A = \pi / 4 (582 382) = 1507.96 \text{ mm}$
- 6. $A = \pi / 4 (26.302 11.302) = 442.96 \text{ mm}$
- 7. $A = \pi / 4 (582 38) = 1507.96 \text{ mm}$

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8 $A = \pi / 4 (31.562 - 14.302) = 621.67 \text{mm}$

9 $A = \pi / 4 (50.562 - 322) = 1202.68 \text{mm}$

10 A = $\pi/4$ (61.82 -402) = 1742.98mm

Pressure = Force / Area

Bamboo No	Inner Dia (mm)	Outer Dia (mm)	Area mm2	Pressure (MPA)	Force Applied (N)
1	11.45	28.12	518.07	6.670	3455.55
2	13.37	30.25	578.29	6.670	3857.21
3	31	51	1288.05	6.867	8845.06
4	32.07	52.07	1321.66	6.867	9075.89
5	38	58	1507.96	6.867	10355.19

TABLE II. FORCE CALCULATION FOR 8 SPLITTER DIE

TABLE III. FO	RCE CALCULATION I	FOR 6 SPLITTER DIE
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Bamboo No	Inner Dia (mm)	Outer Dia (mm)	Area mm2	Pressure (MPA)	Force Applied (N)
1	11.30	26.30	442.96	6.660	2923.536
2	38	58	1507.96	6.670	10103.33
3	14.30	31.56	621.67	6.867	4264.65
4	32.	50.56	1202.68	6.867	8250.38
5	40	61.8	1742.98	6.867	11956.84

Pressure is taken from the pressure gauge which is fitted on the main line of machine; the average pressure comes out to be 6.876 Mpa for both 8 splitter die and 6 splitter die, the above tables shows that, there is no change in pressure required for splitting either with 6 tools or with 8 tools, so 8 splitter die is kept for further calculations.

After splitting, slicing operation is carried out. The observation table for slicing dies are mentioned below.

TABLE IV. OBSERVATION TABLE FOR SLICING DIE WITH STRAIGHT HSS TOOLS

Bamboo No	Size of bamboo	Size of slice in mm.	Pressure (MPA)
1	small	1.5	6.60
2	small	1.5	6.60
3	medium	1.7	6.70
4	medium	1.7	6.70
5	large	2.2	6.80

The above table shows that the pressure required to make slices of splitted bamboo of different sizes in nearly same, so it is considered the average of the above readings, that comes out to be 6.70 Mpa. The slices obtained from straight HSS tools are not acceptable, just because the quality of slices obtained was not up to the mark, there are 5 tools in one die to make five slices out of one splitted bamboo, the main drawback behind this dies being not giving slices up to the mark was same as of the drawback of combined die, the distance between tool tip and the tool was much lesser, as tools are placed one after the another. There was no problem of space for slices to flow out. As the distance decreases the slices tries to flow out and in the process it damages themselves. So to get the slices of the required specification, it is required to fabricate another die, with some different material, HcHcr material was considered and tools are made with wire cut process. In these tools the distance between tool tip and tool end was much lesser than the HSS tools. In this die three tools are kept on the first level followed by two tools in between the three tools of first level, the shape looks like an inverted pyramid. This unique shape of this die will allow the slice to flow out. The observation table of this die is shown below.

TABLE V. OBSERVATION TABLE FOR INVERTED DIE

Bamboo No	Size of bamboo	Size of slice in mm.	Pressure (MPA)
1	small	2.3	6.30
2	small	2.3	6.40
3	medium	2.5	6.40
4	medium	2.5	6.40
5	large	2.8	6.70

The above observation table shows that the pressure required to make slices out of splitted bamboo is nearly same for all sizes and there is no difference in required pressure when the tool material is change. In this inverted die also the slices were not of required quality, so another die is fabricated which will give required quality of bamboo slices, the material is same as HcHcr and took the shape of first die. In other words the tools are straight, as shown in figure. As the distance between tool tip and tool end is much lesser than HSS tool, this die worked for us and finally required quality of bamboo slices is obtained. The observation table of straight HcHcr tool die is shown below.

 TABLE VI.
 Observation Table For Slicing Die With Straight HCHCR Tools

Bamboo No	Size of bamboo	Size of slice in mm.	Pressure (MPA)
1	small	1.7	6.30
2	small	1.7	6.30
3	medium	1.8	6.30
4	medium	1.8	6.30
5	large	2.0	6.30

The above table shows that the pressure required to make slices from split bamboo is same for all the sizes of bamboo, the operation was also very free flowing, and the slices obtained from this die was also up to the mark.

The figures below shows the different dies for splitting and slicing and the slices obtained from it.





Fig. 23. Six and eight spliter die



Fig. 24. Combined die



Fig. 25. Inverted die



Fig. 26. Straight HcHcr tools die



Fig. 27. Split bamboo pieces



Fig. 28. Slicing of splited bamboo



Fig. 29. Die along with slices of bamboo

All the above tables and figures shows that the die with straight HcHcr tool gives us the required quality of slices, and also the pressure required, for slicing different sizes of bamboo is less and the operation is smooth as well. So from above mentioned experimentation it is observed that die with straight HcHcr tools is performing well.

A. Limitations

Limitations of Integrated Bamboo processing machine is

- 1. Splitting and slicing operation is not possible at a time on work station.
- 2. If we use the combine die then bamboo is not flowing properly because of tapered tool and there is a jamming of bamboo.

VI. NEW CONCEPT

To overcome this types of limitation, a new concept is developed i. e. Integrated bamboo processing machine which is operated by compressed air and work station is arranged in horizontal direction. In this machine single tool is place for slicing operation and rotating tools are arrange in such a way that after slicing operation bamboo slice will come in contact with rotating tool and gives square sticks.

In this, each forward stroke will gives slices and then five to six square sticks.

VII. CONCLUSION

- 1. Force required to cut bamboo of 38 mm inner diameters is 10,356 N using 8 splitter die.
- 2. Force required to cut bamboo of 40 mm inner diameter is 11,957 N using 6 splitter die.

- 3. Force required to cut bamboo using 6 splitter die is less as compared to 8 splitter die.
- 4. Time required to process bamboo using modified machine is less as compared to conventional machine.
- 5. Initial cost of conventional machine is larger as compared to modified bamboo processing machine.
- 6. Labour cost is high in conventional bamboo processing machine as compared to modified machine.

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