Design and Development of Pneumatic Cotton Picker

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Abstract: This research provides a new technology to the farmers in the field of harvesting which is ergonomically low weight, used for picking of cotton bolls. This machine could be used by medium and small-scale farmers for cotton picking as large harvesters available in the market are generally very costly and are used in large farms which uses the spindle mechanism for the harvesting of cotton reducing the cotton fibre strength and quality. Pneumatic picker can be used as a picking mechanism which would reduce the cost of picking and maintain the quality of cotton fibre compared to the spindle harvesters.

Keywords: cotton picker, pneumatic cotton picker, methodology, design calculations, conclusion

1. Introduction

Cotton defined as “A soft white fibrous substance which surrounds the seed of the cotton plant and is made into textile fibre and thread for sewing”. It can be defined as “A crop plant with white hairs”. Cotton harvesters or so called cotton pickers are readily available in the market but are expensive and reduce the quality of cotton fibres. In India, cotton is still hand-picked which gives a high quality cotton but requires more time for picking.

Spindle type cotton harvesters is a type of cotton picking machine. It uses a spindle which is rotating at high speed about their axes, attached to the drum. The cotton fibre gets wrapped around the spindle and is taken off by a special device called as doffer and is collected in the storage tank. Due to the wrapping of cotton around spindle bars the cotton fibre gets stretched reducing the cotton fibre strength and the quality of the cotton. It also increases the trash content during picking.

Many research conducted in the field of pneumatic cotton-picking machine for increasing their efficiency in cotton boll quality various papers were presented in the field of development of cotton picker. Some of the literature are listed in support of development of cotton picker.

Ankit Sharma, S.S Ahuja and V.P Sethi developed a machine concluded that the maximum efficiency could be achieved by using 25mm diameter Suction pipe and suction pressure of 45mm of Hg. Minimum trash content was observed by using a 20mm diameter Suction pipe and suction pressure of 30mm of Hg.[1]

Nikhil Gedem and Prof A.K. Mahalle developed a machine which uses an IC-engine as a power source and an impeller coupled with the output shaft of the IC engine. The impeller runs at a speed of 3500rpm and its function is to create the required suction force to suck the cotton bolls. The bolls sucked are stored in a tank which is mounted above the IC engine on the frame.[2]

M. Muthamil Selvan, C. Divaker Durairaj, K. Rangasamy designed a pneumatic cotton picker which was cost efficient and can be operated by 2 people at the same time. They used a nylon filter mesh to prevent the cotton fibres to enter the impeller and the IC engine. The cost of picking the cotton/kg was around ₹10/kg. It is cost, time and energy efficient machine.[3]

2. Materials and Methods:

The prime mover (5.736 kW, 5,500rpm) mounted with the aspirator directly on the shaft. A polypropylene container of 25litre capacity fixed on the frame as the cotton collection drum. A circular cotton filter 100 mm diameter and 225 mm high, made from nylon mesh, was attached inside the collection drum vertically on a suitable flange to restrict the entry of cotton inside the aspirator. A 25 mm diameter PVC hose fixed on top of the collection drum with a tank nipple as picks up pipe for a length of 1,200 mm. The eye of the impeller connected with the bottom of the collection drum with a 75 mm diameter sealed duct.

2.1. Working of prototype

As shown in fig.1, the prime mover that is, the IC engine coupled with the shaft of impeller. The engine which rotates the crank shaft. The output shaft rotates with high speed would rotate the impeller with same speed upto 5500rpm with output power of 5.736KW. The high-speed impeller would produce the required suction pressure at the eye of impeller so that only cotton bolls would be plucked. The eye of the impeller will be connected to the suction duct, further goes to the storage tank (Polypropylene material). In the storage tank, the hose-pipe will be connected with the Nylon mesh filter which will avoid the cotton fibre to enter the tank, the hose-pipe will be connected with the Nylon mesh filter which will avoid the cotton fibre to enter the
aspirator (impeller). The inside pressure of tank would be maintained at the required value. The air which is sucked inside would be blown out by the centrifugal fan. For the requirement of optimum value suction pressure the suction pipes diameter can be changed. Two people at a time can suck the cotton bolls form the plants. The cotton picked would be collected in a tank.

Table 1: Specification of the unit

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Particulars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall dimensions (l<em>b</em>h),mm</td>
<td>1400<em>400</em>500</td>
</tr>
<tr>
<td>Engine Power</td>
<td>5.73 KW</td>
</tr>
<tr>
<td>Type of aspirator</td>
<td>Centrifugal fan</td>
</tr>
<tr>
<td>Maximum speed of impeller ,rpm</td>
<td>5500</td>
</tr>
<tr>
<td>Type of storage tank</td>
<td>Polypropylene</td>
</tr>
<tr>
<td>Capacity of tank</td>
<td>50L</td>
</tr>
<tr>
<td>Mounting pattern of tank</td>
<td>Vertical</td>
</tr>
<tr>
<td>Type of cotton filter</td>
<td>Nylon mesh</td>
</tr>
<tr>
<td>Mounting of cotton filter</td>
<td>Vertical</td>
</tr>
<tr>
<td>Dimension of cotton filter</td>
<td>100*200</td>
</tr>
<tr>
<td>Type of cotton suction pipe</td>
<td>PVC hose</td>
</tr>
<tr>
<td>Number of suction pipe</td>
<td>2</td>
</tr>
<tr>
<td>Diameter of suction pipe</td>
<td>25mm</td>
</tr>
<tr>
<td>Number of operator</td>
<td>2</td>
</tr>
</tbody>
</table>

Fig 1. Front view of pneumatic cotton picker.[3]

2.2. Design Calculations

A cotton boll can be plucked by pneumatic force of 3.5 KN with discharge 0.04 m$^3$/s at a velocity of 30m/s with suction pipe diameter as 25mm.

Engine Specification (Kawasaki Caliber)
- 110cc
- P=5.736KW
- N=5500rpm
- T=8,66Nm

2.2.1 Diameter of shaft
\[ T=(\pi/16)d^{3} \times T \]

Selecting material C40
\[ S_{m}=380N/mm^{2} \]
FOS = 3
\[ T=(380*0.5)/3 \]
\[ T=63.33N/mm^{2} \]
(Substitute in 1)
\[ (8.66*10^{-3})=(\pi/16)d^{3}*63.33 \]
d=8.8639mm
Increased by 50%
d=8.8639*1.5 = 13.2959mm
Standard size of shaft d=15mm

Diameter of impeller eye \( D_{o} \) is dependent on shaft
\( D_{H} \) is 5/16 times greater than \( d_{s} \)
\[ D_{H}=[(5/16)+1]d_{s} \]
\[ D_{H}=19.687mm \]
Considering diameter of hub is
\[ D_{H}=20mm \]
Velocity of air in impeller 12.73m/s=\( V_{o} \)
Discharge in impeller
\[ Q=V_{o}[(\pi*D_{o}^{2})/4-(\pi*D_{H}^{2})/4] \]
\[ D_{o}=0.06638m=66.38mm \]
Standard diameter \( D_{o}=70mm \)

Fig 2. Cross section of impeller.[2]

Fig 3. Velocity diagram
Width of Impeller, 
\[ b = \frac{Q}{\pi \cdot \epsilon \cdot V_{f1} \cdot D_1} \]
\[ \epsilon = 0.85, b = 0.04598 \text{m} = 45.9807 \text{mm} \]
Outlet Dia. 240mm = \(D_2\)
\[ U_2 = \frac{\pi \cdot D_2 \cdot N}{60} \]
\[ U_2 = 69.115 \text{m/s} \]
Normal Discharge angle 20 -25 deg.
Outlet angle of impeller \(\theta\) = 20 deg.
\[ V_{f1} = V_{f2} = 4.6539 \text{m/s} \]
\[ \tan \theta = \frac{V_{f2}}{U_2 - V_{w2}} \]
\[ V_{w2} = 56.3285 \text{m/s} \]
Velocity angle at Outlet
\[ \tan \beta = \frac{V_{f2}}{V_{w2}} \]
\[ \beta = 4.723 \text{deg} \]
\[ V_r = \sqrt{(U_2^2 - V_{w2})^2 + V_{f2}^2} \]
\[ V_r = 13.607 \text{m/s} \]

2.2.3 Pressure Calculation
Pressure created by impeller at the outlet.
\[ P = 249.08 \cdot 1.1 \cdot (0.04 \cdot 39.37/1.53 \cdot 10000)^2 \]
\[ P = 1234.77 \text{ Pa} \]
Now,
\[ P = \rho \cdot g \cdot H \]
\[ H = 225.10 \text{m} \]
\[ V_2 = 45.36 \text{m/s} \]
Velocity generated at the outlet of impeller is
\[ 45.36 \text{m/s} \]
Now,
Pressure difference \(\Delta P = P_2 - P_1\)
\[ \Delta P = 100990.23 \text{ N/m}^2 \]
Pressure Ratio = \(P_2 / P_1\)
\[ = 0.0121 \]
This pressure difference can easily suck cotton from cotton boll.

Hose pipe design.
Impeller to the tank Pipe diameter.
\[ Q = A \cdot V \]
\[ 0.04 = \frac{\pi \times D_{pipe}^2}{4} \times 45.36 \]
\[ D_{pipe} = 75 \text{mm} \]
Velocity inside the pipe is
\[ A_1V_1 = A_2V_2 \]
\[ V = 206.4384 \text{ m/s} \]
Velocity inside the tank
\[ A_1V_1 = A_3V_2 \]
\[ \frac{\pi}{4} \cdot 0.1^2 \times 56.617 = \frac{\pi}{4} \cdot 0.37^2 \times V_2 \]
\[ V_2 = 8.48 \text{ m/s} \]
Velocity at suction pipe
\[ Q = A_1V_3 \]
\[ 0.04 = 2 \times \frac{\pi}{4} \times 0.025 \times V \]
\[ V = 40.7436 \text{ m/s} \]
As velocity at suction is 40.7436 and the required velocity is 30m/s so, the cotton bolls can easily pick cotton from cotton boll

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Conclusion:
1. The velocity at the suction pipe is 40.74 m/s
2. This cotton-picking machine would give a good quality of cotton when compared with the spindle type cotton picking machine.
3. This machine would be less time consuming than the spindle type machine.

References:-