7.1 REVIEW OF THE WORK:

Turmeric being the major cash crop of Indian farmers, it is to be processed efficiently with minimum processing cost. Even India ranks first in the production of turmeric, it is still processed in India by traditional method. The traditional method has major drawbacks like high consumption of heat, high labour cost and low quality of the processed Rhizomes.

From the literature review and discussion with the experts from the agricultural sector, it is decided to remove the drawbacks of the traditional method and to design the new turmeric processing plant. The research work is carried out in following steps:

* Design of the blancher.
* Modeling of blancher on Uni-Graphics™ software.
* Thermal and structural analysis.
* Mathematical model.
* Fabrication and testing.

7.2 DESIGN OF THE BLANCHER:

Considering the drawbacks of traditional method, field problems and literature review, mobile blancher is designed. The design of the blancher is carried out by traditional method. The stresses and deflection values are calculated by assuming the blancher steam receiver to be a hollow, simply supported shaft with uniformly distributed load. The hollow shaft is also designed for combined bending and torsion and assuming the blancher to be a thin cylindrical pressure vessel subjected to internal pressure. The model is then created on Uni-Graphics™ software, Figure 7.1 show an assembled blancher model with various components. Table 7.1 show the dimensions of blancher components and specification.
The assembled blancher model is then imported to hypermesh™software for mesh generation and then to ANSYS™ software for thermostructural analysis.

Table 7.1 Dimensions and specification

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Component Name</th>
<th>Thickness in mm</th>
<th>Size in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Casing</td>
<td>3</td>
<td>500 Φ x 750</td>
</tr>
<tr>
<td>2</td>
<td>Steam pipe</td>
<td>2</td>
<td>Φ inner 18.75</td>
</tr>
<tr>
<td>3</td>
<td>Steam Receiver</td>
<td>5</td>
<td>Φ inner 55</td>
</tr>
<tr>
<td>4</td>
<td>Hand wheel</td>
<td>Φ rod 30</td>
<td>Φ total 400</td>
</tr>
<tr>
<td>5</td>
<td>T-Joints</td>
<td>2</td>
<td>Φ inner 24</td>
</tr>
<tr>
<td>6</td>
<td>Steam pipe holes</td>
<td>25 spacing</td>
<td>Φ 5</td>
</tr>
<tr>
<td>7</td>
<td>Plummer block</td>
<td>10 x 100</td>
<td>Φ inner 65</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Name of Item</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Capacity</td>
<td>50 Kg per batch</td>
</tr>
<tr>
<td>2</td>
<td>Size</td>
<td>750 x 500 mm</td>
</tr>
<tr>
<td>3</td>
<td>Ambient Temperature</td>
<td>25°C TO 40°C</td>
</tr>
<tr>
<td>4</td>
<td>Steam Temperature</td>
<td>110°C TO 120°C</td>
</tr>
<tr>
<td>5</td>
<td>Steam Pressure</td>
<td>1 bar To 1.2 bar</td>
</tr>
<tr>
<td>6</td>
<td>Steam Flow Rate</td>
<td>50 To 60 Kg/hr</td>
</tr>
<tr>
<td>7</td>
<td>Loading Time</td>
<td>10 min.</td>
</tr>
<tr>
<td>8</td>
<td>Unloading Time</td>
<td>5 min.</td>
</tr>
<tr>
<td>9</td>
<td>Cooking Time</td>
<td>15 To 20 min</td>
</tr>
<tr>
<td>10</td>
<td>Total Time</td>
<td>30 To 35 min</td>
</tr>
<tr>
<td>11</td>
<td>Fuel</td>
<td>Wood/Agriculture Waste</td>
</tr>
<tr>
<td>12</td>
<td>Calorific Value</td>
<td>12000 to 15000 KJ/kg</td>
</tr>
</tbody>
</table>

Table 7.1 Dimensions and specification
Figure 7.1. An assembled blancher model with components

Figure 7.2 Hypermesh model used for uniform heat distribution
7.3 **MODELING THE BLANCHER:**

As per the design dimensions and specification required, a blancher model is created on Uni-Graphics™ software. The model is created in following steps:

* Model of blancher housing with cavity for loading and unloading.
* Model of steam receiver and steam pipes.
* Model of plummet block and supporting stand.
* Model of steam receiver blocks and handwheel.
* Model of trolley for blancher with wheels.
* Assembling the components.

APPENDIX-III show the various steps to create the model.

7.4 **THERMOSTRUCTURAL ANALYSIS:**

The details of the structural material SS 304L of which blancher is made are mentioned in the Table. 1.2. The analysis is done with standard material test reports. The thermal analysis is carried out by finite element method using ANSYS™ software, quadratic and eight noded heat transfer quadrilateral shell elements are used for thermal analysis. The analysis is carried out in the following steps:

7.4.1 **Mesh Generation:**

The imported model from Uni-Graphics™ software is meshed in the hypermesh™ software with the quadrilateral 2D shell and 3D brick elements to generate the mesh. The total number of lines are 10082, number of surface area are 2851 with number of 2D elements 72391 and number of 3D elements 18289 are required to create the meshed model. Figure 7.2 show the hypermesh housing model used for uniform heat distribution.

7.4.2 **Heat flux and temperature distribution:**

The hypermeh model is tested firstly for uniform heat and temperature distribution. The blancher surface temperature is kept uniform at 50°C, 75°C, 100°C,
125°C and the heat released by steam in the inner pipe of the blancher is at 200°C. Twenty load cases have been considered between the given temperature range and time limit for 3 minutes, 6 minutes, 9 minutes, 12 minutes and 15 minutes respectively. Table 7.2 shows the result of twenty load cases and Figure 7.4 shows the uniform distribution of heat flux throughout the blancher at different load conditions. The uneven heating of turmeric Rhizomes is controlled due to uniform distribution of heat flux throughout the blancher, which improves the quality and quantity of Rhizomes. The heat flux is uniform throughout the blancher for temperature limits between 50°C to 120°C surface temperature and 200°C steam temperature.

<table>
<thead>
<tr>
<th>Temp. °C</th>
<th>HEAT FLUX in W/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>For 3 min.</td>
</tr>
<tr>
<td>50</td>
<td>0.01968</td>
</tr>
<tr>
<td>75</td>
<td>0.01705</td>
</tr>
<tr>
<td>100</td>
<td>0.01443</td>
</tr>
<tr>
<td>125</td>
<td>0.0118</td>
</tr>
</tbody>
</table>

Table 7.2 The distribution of heat flux for all load cases

Figure 7.3 shows the thermal analysis result for uniform heat distribution. The distribution of temperature throughout the blancher is also analysed for housing and assembly. The thermal analysis is carried out for temperature 120°C, 150°C, 180°C and 210°C and pressure 3 bar, 6 bar and 9 bar respectively. Figure 7.5 and 7.6 shows the finite element analysis results for temperature distribution in blancher housing and assembly and only housing at temperature 150°C and pressure 3 bar. Similarly the finite element results were obtained at different temperature and pressure.
conditions, which were found within the safe limits and there is uniform temperature distribution through the blancher.

Figure 7.3 Thermal analysis results with temperature and time limits

Figure 7.4 The Graph of thermal analysis results with temperature and time limits
Figure 7.5: Finite Element Analysis Results

Case - 4: Temperature 150°C, Pressure 3 bar

[Assembly/Housing Temperature Distribution Plot]

Figure 7.6: Finite Element Analysis Results

Case - 4: Temperature 150°C, Pressure 3 bar

[Housing Temperature Distribution Plot]
7.4.3 : Deflection and stress analysis :

The blancher and its components are analysed for deflection and stress distribution for various temperature and pressure conditions. Table 7.3 shows the results of deflection and stress distribution for different load conditions. Figure 7.7, Figure 7.8, show the graph of deflection. From the graph, it is observed that the deflection in assembly remains almost constant for temperature 120°C to 180°C but it increases with increase in pressure from 3 bar to 9 bar. From deflection analysis results it is observed that deflection of the steam tube is high compared to other parts of blancher, it may be due to load of the turmeric Rhizomes. Since the maximum deflection with respect to design condition is 1.29 mm, it is safe. Figure 7.9 and Figure 7.10 show the graph of stress distribution for different load cases. The stress on the assembly and housing increases with increase in temperature and pressure, but it is almost remains constant with rise in pressure between 6 bar to 9 bar. From stress analysis results it is observed that high stresses are developed on the steam receiver since, all the load is applied on the steam receiver. The designed value of stress with respect to loading and boundary conditions is 140.5 N/mm², it is safe to operate.

From temperature analysis result it is observed that the temperature of steam receiver is highest, it is because of high temperature of steam in it. Since the blancher is designed to operate between temperature limits 120°C to 180°C, it is safe. The finite element analysis result for various load cases are plotted in Appendix – IV.

7.5 MATHEMATICAL MODEL :

A mathematical model is developed by considering the blancher to be a pressure vessel with negligible momentum. The sample calculations were made to calculate steam flow rate and time required to process the turmeric Rhizomes. It is found that 18.25 minutes time is required to process the turmeric Rhizomes.

Heat flow rate is estimated to heat 50 kg and 100 kg of turmeric Rhizomes by assuming average pressure of steam 1.5 bar, atmospheric temperature 30°C and overall heat transfer coefficient 160 J/m²s°C. It is found that the steam flow rate
required is 20.504 kg/hr to process 50 kg Rhizomes and 40.99 kg/hr to process 100 kg of Rhizomes. The estimated values of mathematical model are compared with experimental results which show that 15 to 20 minutes time is best suited for turmeric processing to obtain the good quality turmeric Rhizomes. 20.504 kg/hr of steam flow rate is required to process 50 kg of Rhizomes per batch and it is predicted that 40 kg/hr to 50 kg/hr of steam flow rate is required to process 100 kg of Rhizomes per batch.

7.6 FABRICATION AND TESTING:

The blancher model is fabricated by stainless steel (SS 304 L). The test is carried out at the farmhouse, Takalgaon, for boiling 50 kg of finger Rhizomes per batch in three different batches i.e. 15 minutes, 20 minutes and 25 minutes respectively. Monitoring the flow rate constant the values of temperature, pressure and the necessary parameters are noted.

In the first batch of turmeric boiling for 15 minutes, it was observed that the piercing and skin removal is very difficult for further processing of Rhizomes. There is non-uniformity in the color, which indicates that the curcumin content is not uniform, hence 15 minutes boiling is not recommended.

In the second batch of turmeric boiling for 20 minutes, it was observed that the piercing and skin removal is easy for further processing of Rhizomes. There is uniformity in the color of the Rhizomes, which indicates that the curcumin content is uniform. The fibers, visible core in the Rhizomes indicates that the curcumin content is better compared with the previous batch, hence it is recommended.

In the third batch of turmeric boiling for 25 minutes, it was observed that the piercing and skin removal is very easy but the Rhizomes are very soft, hence they get damaged during piercing, skin removal and unloading. There is uniformity in the color of the Rhizomes, but the fibers and cores generated with Rhizomes are not uniform and strong due to over boiling, hence 25 minutes boiling is not desirable. Table 7.4 shows effect of steam boiling on physical properties of turmeric Rhizomes.
### Results and Discussion

<table>
<thead>
<tr>
<th>Pressure in bar</th>
<th>Max. Deflection in mm</th>
<th>Max. Stress in N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Assembly</td>
<td>Housing</td>
</tr>
<tr>
<td>3</td>
<td>0.1843</td>
<td>0.1551</td>
</tr>
<tr>
<td>6</td>
<td>0.2757</td>
<td>0.1729</td>
</tr>
<tr>
<td>9</td>
<td>0.3672</td>
<td>0.1973</td>
</tr>
</tbody>
</table>

### Allowable Temperature: 120°C, Deflection 1.29 mm, Stress 140.5 N/mm²

<table>
<thead>
<tr>
<th>Pressure in bar</th>
<th>Max. Deflection in mm</th>
<th>Max. Stress in N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Assembly</td>
<td>Housing</td>
</tr>
<tr>
<td>3</td>
<td>0.1817</td>
<td>0.1522</td>
</tr>
<tr>
<td>6</td>
<td>0.2733</td>
<td>0.1701</td>
</tr>
<tr>
<td>9</td>
<td>0.3648</td>
<td>0.1945</td>
</tr>
</tbody>
</table>

### Allowable Temperature: 150°C, Deflection 1.29 mm, Stress 140.5 N/mm²

<table>
<thead>
<tr>
<th>Pressure in bar</th>
<th>Max. Deflection in mm</th>
<th>Max. Stress in N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Assembly</td>
<td>Housing</td>
</tr>
<tr>
<td>3</td>
<td>0.1857</td>
<td>0.1492</td>
</tr>
<tr>
<td>6</td>
<td>0.2710</td>
<td>0.1673</td>
</tr>
<tr>
<td>9</td>
<td>0.3626</td>
<td>0.1893</td>
</tr>
</tbody>
</table>

### Allowable Temperature: 180°C, Deflection 1.29 mm, Stress 140.5 N/mm²

<table>
<thead>
<tr>
<th>Pressure in bar</th>
<th>Max. Deflection in mm</th>
<th>Max. Stress in N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Assembly</td>
<td>Housing</td>
</tr>
<tr>
<td>3</td>
<td>0.2072</td>
<td>0.1462</td>
</tr>
<tr>
<td>6</td>
<td>0.2690</td>
<td>0.1645</td>
</tr>
<tr>
<td>9</td>
<td>0.3607</td>
<td>0.1893</td>
</tr>
</tbody>
</table>

### Allowable Temperature: 210°C, Deflection 1.29 mm, Stress 140.5 N/mm²
Figure 7.7 Deflection plot for assembly with respect to temperature and pressure

Figure 7.8 Deflection plot for housing with respect to temperature and pressure
Figure 7.9 Stress plot for assembly with respect to temperature and pressure

Figure 7.10 Stress plot for housing with respect to temperature and pressure
### Table 7.4: The effect of steam boiling on physical properties of Rhizomes

<table>
<thead>
<tr>
<th>Turmeric</th>
<th>Length in mm</th>
<th>Breadth in mm</th>
<th>Thickness in mm</th>
<th>Weight gm</th>
<th>Volume cm³</th>
<th>density g/cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh Rhizome</td>
<td>69.72</td>
<td>24.42</td>
<td>22.99</td>
<td>25.62</td>
<td>24.23</td>
<td>1.05</td>
</tr>
<tr>
<td>Boiled Rhizome</td>
<td>71.29</td>
<td>25.19</td>
<td>24.08</td>
<td>35.31</td>
<td>43.24</td>
<td>0.81</td>
</tr>
</tbody>
</table>

### Table 7.5: The effect of steam boiling on turmeric Rhizomes

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Time in min.</th>
<th>Skin Removal</th>
<th>Stick piercing</th>
<th>Color uniformity and curcumin content.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>Difficult</td>
<td>Difficult</td>
<td>Non uniform yellow color, Core is easily visible</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>easy</td>
<td>easy</td>
<td>Uniform yellow color, Core is easily visible</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
<td>easy</td>
<td>easy</td>
<td>Uniform yellow color but there is loss of quality due to very soft Rhizomes, core is slightly visible</td>
</tr>
</tbody>
</table>
Table 7.6 The effect of steam boiling on curcumin and oleoresin content

The volume of the Rhizome before boiling is 24.23 cm³, where as it increases to 43.24 cm³ i.e. around double the original volume. Table 7.5 shows the effect of steam boiling on turmeric Rhizomes. The steam boiling for 20 minutes gives better results compared to 15 minutes and 25 minutes of boiling. Table 7.6 shows the effect of steam boiling on curcumin and oleoresin content in turmeric Rhizomes. Here also the result of 20 minute boiling are better compared to 15 minutes and 25 minute boiling respectively.

7.7 ANALYSIS OF THE EXPERIMENTATION AND TESTING:

In the test of turmeric boiling using blancher, it is observed and tested that the quality of turmeric Rhizomes by steam boiling is better as compared to boiling by traditional method. The curcumin and oleoresin content of turmeric, which is one of the quality parameter is found better in steam boiling as shown in Table 7.6, hence 15 to 20 minute steam boiling is suggested for better results.

7.7.1 Heat balance sheet:

Assuming the steam supplied at average flow rate 50 kg/hr and using properties of steam at 1.5 bar the heat balance sheet is prepared.

(i) Properties of steam at 1.5 bar. [Table 4.1][Rajput R.K., (2002)]

<table>
<thead>
<tr>
<th>Pressure in Bar</th>
<th>Temperature in °C</th>
<th>Enthalpy in KJ/kg</th>
<th>Specific volume in m³/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2</td>
<td>104.8</td>
<td>2683.5</td>
<td>1.428</td>
</tr>
<tr>
<td>1.5</td>
<td>111.37</td>
<td>2693.4</td>
<td>1.159</td>
</tr>
<tr>
<td>2</td>
<td>120.2</td>
<td>2706.3</td>
<td>0.0885</td>
</tr>
</tbody>
</table>
(ii) Properties of saturated water at 1.5 bar

<table>
<thead>
<tr>
<th>T (°C)</th>
<th>P (KPa)</th>
<th>ρ (Kg/m³)</th>
<th>Cp (kJ/kg-K)</th>
<th>μ x 10⁶</th>
<th>k</th>
<th>Pr</th>
<th>β x 10⁴</th>
<th>ν x 10⁶</th>
<th>σ x 10⁴</th>
<th>λ (KJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>143</td>
<td>951</td>
<td>4.233</td>
<td>258.9</td>
<td>0.685</td>
<td>1.6</td>
<td>8.08</td>
<td>0.27</td>
<td>569</td>
<td>2230</td>
</tr>
</tbody>
</table>

[Sukhatme S.P., (1990)]

(iii) Properties noted during experimentation and from Standard Tables.

[Kothandraman C.P., (2007)]

- Atmospheric Pressure 1.0132 bar, Temperature 30°C
- Water drained out from blancher after boiling = 2 kg at Temperature 80°C
- Temperature of cold water = 20°C
- Blancher surface temperature = 50°C
- Heating time of Rhizomes = 15 minutes
- Inner heat transfer coefficient $h_i = 160$ W/m²K
- Outer heat transfer coefficient $h_o = 15$ W/m²K
- Thermal conductivity of steel rod $K_s = 16$ W/m°C
- Specific heat of turmeric = 3.6 KJ/kg°C
- Temperature of steam from steam receiver and steam pipes = 100°C

**Heat supplied from steam** = $2693.4 \times 12.5 = 33667.5$ KJ

1. Heat utilized
   a. Heat consumed to boil Rhizomes:
      
      \[ Q_a = 100 \times 3.6 \times (111.37 - 30) = 29293.2 \text{ KJ} \]

   b. Heat carried by water drained from the blancher:
      
      \[ Q_b = 2 \times 4.33 \times (80 - 20) = 519.96 \text{ KJ} \]
c. Heat carried away due to convection:

\[ \text{Nu} = 0.36 + \frac{[(0.518 \text{Ra})^{1/4}]}{[1 + (0.559/\text{Pr})^{9/16}]^{ \frac{1}{2} }} \]


(i) For \( \text{Ra} = 10^4 \)

\[ \text{Nu} = 0.36 + \frac{[(0.518(10^4))^{1/4}]}{[1 + (0.559/1.6)^{9/16}]^{ \frac{1}{2} }} \]
\[ = 0.36 + \frac{5.18}{(1+0.58)^{0.444}} \]
\[ = 0.36 + \frac{5.18}{1.218} \]
\[ \text{Nu} = 5.54 = \left( \frac{hD}{K} \right) \]
\[ h_1 = \frac{5.54 \times 0.686}{0.55} \]
\[ = 7.58 \text{ w/m}^2\text{k} \]

(ii) For \( \text{Ra} = 10^7 \)

\[ \text{Nu} = 0.36 + \frac{[(0.518(10^7))^{1/4}]}{[1 + (0.559/1.6)^{9/16}]^{ \frac{1}{2} }} \]
\[ = 0.36 + \frac{29.129}{1.218} \]
\[ \text{Nu} = 24.275 = \left( \frac{hD}{K} \right) \]
\[ h_2 = \frac{24.275 \times 0.686}{0.55} \]
\[ = 33.257 \text{ w/m}^2\text{k} \]

(iii) For \( \text{Ra} = 10^4 \)

\[ \text{Nu} = C \text{Ra}^n \]
\[ = 0.48(10^4)^{0.25} \]
VII - Results and discussion

\[ \text{Nu} = 4.8 = \left( \frac{hD}{K} \right) \]

\[ h_3 = \left( \frac{4.8 \times 0.686}{0.55} \right) \]
\[ = 6.58 \text{ w/m}^2\text{k} \]

(iv) For \( R_a \) = 10\(^7\)

\[ N_U = C.R_a^n, \]
\[ = 0.48(10^7)^{0.25} \]

\[ \text{Nu} = 26.99 = \left( \frac{hD}{K} \right) \]

\[ h_4 = \left( \frac{26.99 \times 0.686}{0.55} \right) \]
\[ = 36.9763 \text{ w/m}^2\text{k} \]

\[ H_{\text{average}} = h_1 + h_2 + h_3 + h_4 \]
\[ = 7.58 + 33.257 + 6.58 + 36.9763 \]
\[ = 21.11 \text{ w/m}^2\text{k} \]

\[ Q_{\text{conv}} = 21.11 \pi \times 0.50 \times 0.75 \times (111.37 - 50) \]
\[ = 1525.72 \text{ Watts} \]
\[ = \left( \frac{1525.72 \times 15 \times 60}{1000} \right) = 1373.15 \text{ KJ} \]

\[ d. \text{ Heat carried due to conduction:} \]

(i) \( Q_{\text{blancher}} = \frac{\{(dT)\}}{[\frac{1}{h_1.A_1} + (\frac{\log (ro/ri)}{(2\pi K L)}) + (\frac{1}{h_0.A_0})]} \]

\[ Q_b = \frac{(111.37 - 50)}{[\frac{1}{160} \times \frac{\pi}{4} \times \frac{50}{100}^2 + (\log 56/50) + \frac{1}{15} \times \frac{\pi}{4} \times \frac{56}{100}^2]} \]
\[ = \frac{61.37}{(0.0321 + 0.0011 + 0.2706)} \]
VII - Results and discussion

\[ Q_{\text{receiver}} = \frac{\{(dT)\}}{[\left(\frac{1}{\ln Ai}\right) + \left(\frac{\log (\text{ro}/\text{ri})}{2\pi KL}\right) + \left(\frac{1}{\text{ho Ao}}\right)]} \]

\[ = \frac{11.37}{(2.63 + 0.0006 + 20.09)} \]

\[ = 0.501 \text{ W} \]

\[ = \frac{(0.501 \times 15 \times 60)}{1000} \]

\[ = 0.45 \text{ KJ} \]

\[ Q_{\text{steam pipe}} = \frac{\{(dT)\}}{[\left(\frac{1}{\ln Ai}\right) + \left(\frac{\log (\text{ro}/\text{ri})}{2\pi KL}\right) + \left(\frac{1}{\text{ho Ao}}\right)]} \]

\[ = \frac{11.37}{(20 + 0.000384 + 175.37)} \]

\[ = 0.0582 \text{ W} \]

\[ = \frac{(0.0582 \times 15 \times 60)}{1000} \]

\[ = 0.0524 \text{ KJ} \]

\[ Q_{\text{conduction}} = 181.86 + 0.45 + 0.0524 \]

\[ = 182.4 \text{ KJ} \]
VII – Results and discussion

e. Unaccounted heat loss :

\[
THS - [a + b + c + d] \\
= 33667.5 - [29293.2 + 519.96 + 1373.15 + 182.4] \\
= 2203.93 \text{ KJ.}
\]

<table>
<thead>
<tr>
<th>Total Heat Supplied</th>
<th>Total Heat Utilised</th>
</tr>
</thead>
<tbody>
<tr>
<td>33667.5 KJ</td>
<td>a. Heat consumed to boil Rhizomes = 29293.2 KJ 87.07 %</td>
</tr>
<tr>
<td>100%</td>
<td>b. Heat Carried by drain water = 519.96 KJ 1.54 %</td>
</tr>
<tr>
<td></td>
<td>c. Heat carried due to convection = 1373.15 KJ 4.07 %</td>
</tr>
<tr>
<td></td>
<td>d. Heat carried due to conduction = 182.4 KJ 0.541 %</td>
</tr>
<tr>
<td></td>
<td>e. Unaccounted Heat loss = 2203.93 KJ 6.55 %</td>
</tr>
</tbody>
</table>

| 33667.5 KJ          | 100%                          |
|                     | = 33667.5 KJ 99.99%           |

Table 7.7 Heat balance sheet

From the heat balance sheet, it is seen that 87.07 % of heat supplied by steam is used to boil turmeric Rhizomes, which indicates the maximum utilization of heat supplied. By providing proper insulation on the blancher, 5 to 8 % of heat can be saved.

7.7.2. Thermal efficiency:

From the table of heat balance sheet, it is seen that the maximum heat liberated by steam is utilized to boil the turmeric Rhizomes. The thermal efficiency of the blancher is determined and it is compared with the efficiency of the traditional method and existing method.

a. Heat supplied to boil the turmeric Rhizomes per 100 kg

\[
Q_s = 100 \times 3.6 (111.37-30) = 29293.2 \text{ KJ} \quad ....7.1
\]
Heat liberated by fuel to boil 100 kg of turmeric Rhizomes by assuming average calorific value of fuel 12000 KJ/kg. 

\[ \text{[ Kothadraman C.P., (2007) ]} \]

i. For traditional method :
\[ \left( \frac{165}{2} \right) \times 12000 = 990000 \text{ KJ} \]

ii. For existing method :
\[ \left( \frac{96.5}{1.5} \right) \times 12000 = 772000 \text{ KJ} \]

iii. For proposed method :
\[ (20 \times 12000) = 240000 \text{ KJ} \]

iv. For prototype method :
\[ \left( \frac{20}{0.5} \right) \times 12000 = 480000 \text{ KJ} \]

From equation 7.1 and 7.2, the thermal efficiency in percentage is calculated as

i. For traditional method :
\[ \left( \frac{29293.2 \times 100}{990000} \right) = 2.95 \% \]

ii. For existing method :
\[ \left( \frac{29293.2 \times 100}{772000} \right) = 3.79 \% \]

iii. For proposed method :
\[ \left( \frac{29293.2 \times 100}{240000} \right) = 12.2 \% \]

iv. For prototype method :
\[ \left( \frac{29293.2 \times 100}{480000} \right) = 6.1 \% \]

From the equation of thermal efficiency, it is observed that the thermal efficiency of the proposed blancher method is maximum. The various waste parts of the plant like leaves of tree, parts of tree, cowdung etc. are used as a fuel, hence it is difficult to find the exact calorific value of fuel. The average calorific value is assumed to be 12000 KJ/kg. Due to open furnace of the boiler, heat liberated by fuel is wasted, hence the efficiency of the plant gets affected. Fuel supplied can be saved by using closed furnace and avoiding open pan in traditional method. Figure 7.11 shows the graph of thermal efficiency of various methods of turmeric processing.
Figure 7.11 A comparative graph of thermal efficiency, capacity of the plant per hour and time in minutes per batch, for various methods of turmeric processing.
7.7.3 Net operational gain

[ for processing 100 kg of turmeric Rhizomes ]:

The evaluation of net operational gain per 100 kg of turmeric processing is carried out by assuming average cost of turmeric Rs. 10000/- per 100 kg and cost of the fuel Rs. 400/- per 100 kg.

a. Labor cost:

For traditional method at least six labors are required to process turmeric i.e. for loading, unloading, firing, boiling etc. and for proposed and prototype method three labors are required, considering three shifts per day with labor charges Rs. 300/- per labor.

The labor charge required per 100 kg.

1. For traditional method = \( \frac{100 \times 5400}{2000} \) = Rs. 270/-

2. For proposed method = \( \frac{100 \times 2700}{6000} \) = Rs. 45/-

3. For prototype method = \( \frac{50 \times 2 \times 2700}{3600} \) = Rs. 75/-

b. Fuel required per 100 kg:

1. For traditional method = \( \frac{82.5 \times 4}{1} \) = Rs. 330/-

2. For proposed method = \( \frac{20 \times 4}{1} \) = Rs. 80/-

3. For prototype method = \( \frac{30 \times 4}{1} \) = Rs. 120/-

Figure 7.12 shows the comparative graph of labor cost, fuel required and total plant cost for various methods of turmeric processing.

c. Quantity gain:

The weight of the turmeric Rhizomes after drying found that there is rise in 7 to 8 kg of Rhizomes due to steam boiling instead of traditional boiling. The quantity gain due to increase in the weight of the Rhizomes is calculated as:

\( 10000 \times 0.08 = \text{Rs}.800/- \)
VII - Results and discussion

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Figure 7.12 A comparative graph of labour cost, fuel cost and plant cost, for various methods of turmeric processing.
Hence, the total quantity gain for traditional method and proposed method is determined as:

(i) Saving in fuel by cost = (82.5 - 20) x 4 = Rs.250/-
(ii) Saving in labor cost = (270 - 45) = Rs.225/-
(iii) Increasing quantity of the Rhizomes by cost = (10000 x 0.08) = Rs. 800/-

Total quantity gain = Rs. 1275/-

d. Quality gain:

There is loss of quality of the Rhizomes in traditional method due to scorching, mudmixing, during loading and unloading etc. The percentage of curcumin and oleoresin content is reduced as shown in table 7.5. With the proposed method of processing the Rhizomes by steam boiling, the quality of Rhizome gets improved. The quality by cost can be calculated by considering 3 %, 6 % and 9 % rise in cost of the turmeric.

(i) For 3 % rise in cost 10000 x 0.03 = Rs. 300/-
(ii) For 6 % rise in cost 10000 x 0.06 = Rs. 600/-
(iii) For 9 % rise in cost 10000 x 0.09 = Rs. 900/-

e. Net gain:

The net gain in cost of the Rhizomes by proposed method for 100 kg of turmeric Rhizomes is determined as:

(i) For 3 % rise in cost of Rhizomes = 300 + 1275 = Rs.1575/-
(ii) For 6 % rise in cost of Rhizomes = 600 + 1275 = Rs.1875/-
(iii) For 9 % rise in cost of Rhizomes = 900 + 1275 = Rs.2175/-

f. Total returns of the investment:

The cost of the proposed method of processing Rhizomes for 100 kg/batch using turmeric blancher is estimated to be Rs.1,40000/-
The returns of investment in percentage

\[ \text{Estimated rise in cost} = \left( \frac{100}{\text{Estimated investment}} \right) \times 100 \]

It is determined for:

(i) 3% rise in sale prize = \( \frac{(1575 \times 100)}{140000} \) = 1.125%

(ii) 6% rise in sale prize = \( \frac{(1875 \times 100)}{140000} \) = 1.340%

(iii) 9% rise in sale prize = \( \frac{(2175 \times 100)}{140000} \) = 1.554%

It is observed from Table 7.8 for the total returns of investment and evaluation result that, by processing 100 kg Rhizomes, there is minimum saving of Rs.1575/- and 1.125% returns of investment. The total returns of investments can be achieved if 9 to 10 tons of turmeric is processed, which can be possible within a week. Hence, within maximum one week the blancher investment is made free.

<table>
<thead>
<tr>
<th>Quantity of Rhizomes in Tons</th>
<th>Cost in Rupees 3% rise</th>
<th>Cost in Rupees 6% rise</th>
<th>Cost in Rupees 9% rise</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>15750</td>
<td>18750</td>
<td>21750</td>
</tr>
<tr>
<td>2</td>
<td>31500</td>
<td>37500</td>
<td>43500</td>
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</tr>
<tr>
<td>6</td>
<td>94500</td>
<td>112500</td>
<td>130500</td>
</tr>
<tr>
<td>7</td>
<td>110250</td>
<td>131250</td>
<td>152250</td>
</tr>
<tr>
<td>8</td>
<td>126000</td>
<td>150000</td>
<td>174000</td>
</tr>
<tr>
<td>9</td>
<td>141750</td>
<td>168750</td>
<td>195750</td>
</tr>
<tr>
<td>10</td>
<td>157500</td>
<td>187500</td>
<td>217500</td>
</tr>
</tbody>
</table>

Table 7.8 Total returns of investment
To Prof. Harkare M.G.
Dept. of Mechanical Engineering
M.G.M. College Nanded

Sub: Testing of SS304L Steel
Ref: Your Letter Dated 13/01/2012
Name of work: Research study Project for Ph.D.

Sir,

The material supplied by you as per your letter under reference for testing is tested in our laboratory as per relevant I.S. and the following results are obtained.

TEST REPORT NO: 1097  DATE OF TESTING: 13/01/2012

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Nominal Dia. (mm)</th>
<th>Actual Dia. (mm)</th>
<th>C/S Area mm²</th>
<th>Yield Load kN</th>
<th>Proof Stress N/mm²</th>
<th>Average Stress N/mm²</th>
<th>Ultimate Load kN</th>
<th>Ultimate Stress N/mm²</th>
<th>Yield Strain</th>
</tr>
</thead>
<tbody>
<tr>
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<td>2</td>
<td>15</td>
<td>175.45</td>
<td></td>
<td>291.87</td>
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<td>3214.59</td>
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<td></td>
<td>2.12 E-03</td>
</tr>
<tr>
<td>3</td>
<td>14.97</td>
<td>175.92</td>
<td></td>
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<td>1657.91</td>
<td>3188.95</td>
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<td></td>
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</tr>
</tbody>
</table>

Principal
Government Polytechnic Nanded