Conceptual Design of Gum Arabic Crushing Machine

A Thesis Submitted to University of Khartoum in Partial fulfillment of the Requirements of the Degree of B.Sc. in Agricultural Engineering

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DEDICATION

- To our mothers who made us succeed in doing this research.
- To the greatest gentlemen in our lives; our Fathers.
- To everyone who was counting the seconds to witness with us our moment of happiness.

With our love

Researchers
Acknowledgement

First of all, praise for who guides to complete this project and also gratitude to Dr. Omar Adam Rahama For his assistance and supervision. We would like to content our gratitude for all our doctors in our agricultural engineering department, all who supported us to complete the project. Special gratitude to Engineers of Lambda Company, our peers, and members of faculty of engineering.
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Abstract
Some engineering properties include the aridness and dimensions for varieties of large and small Gum Arabic are found. The moisture content for samples of Gum Arabic was found by using moisture content measuring device. The force required to crush Gum Arabic was measured using strength measure. The power required to crush Gum Arabic was calculated (0.86 kw) and applied by using appropriate motor (2hp). Then design of the Gum Arabic crushing machine was done successfully.
المستلخص

* تم إيجاد بعض الخصائص الهندسية والتي تشمل المتانة والأبعاد للعينات الكبيرة والصغيرة للصمغ العربي.
* تم إيجاد المحتوى الرطبي لعينات من الصمغ العربي بإستخدام جهاز قياس المحتوى الرطبي.
* القوة المطلوبة لكسر العينات الصغيرة تم حسابها بإستخدام جهاز قياس المتانة.
* الطاقة المطلوبة لتكسير الصمغ العربي تم حسابها (0.83) وطبقت بإخدام موتور قدرته 2 حصان ومن ثم تم تصميم الآلة بنجاح.
CHAPTER 1
Introduction

1.1 Overview:

Sudan is the world’s largest of Acacia Gum, which is one of the four important agricultural export commodities from Sudan, along with livestock cotton and sesame. Over the last 20 years, Acacia Gum export value amounted on average to 40 million US$ annually. While there has been government intervention the marketing of all remains. Acacia Gum is mostly produced by small-scale farmers in traditional rain-fed farming areas they represent up to 20% of Sudan’s population and are among the poorest the impact of current Acacia Gum marketing policy has not been beneficial to this group. This has led to reduced production and consequently exports decling for the past forty years at an average rate of 2.2% per annual.

The Acacia Gum belt spans over 10 states of Sudan around one of the country’s total surface or 500,000 km, principally in the traditional rain fed areas of western and central Sudan. It is estimated that 6to 8 % of the Gum belt is under acacia tree cover .The Cordovan region produces more than half of the Sudanese gum. Darfur is important gum producing region. However Darfur’s gum production potential comparable with Cordovan, is limited by its remoteness and the current conflict. Generally acacia trees are resistant to periods of low rainfall , however the combination of severs drought of the mid-seventies and mid-eighties , civil conflict , population movement and change in farming practices have negatively impacted Acacia Gum production in North Darfur . As a result, the gum Arabic belt is moving south towards clay soil areas with better; acacia over expanding in Blue Nile and the southern parts of Southern Cordovan.
The technology and machinery used in the production of gum Arabic very traditional and at earlier stage, Some farmers used new tool called Son key but it need a great efforts more than axe. There are only two tools of production are (Axe, Son key) and both resulted damaging many trees because tapping unjust and lack of knowledge, especially as the tapping worker is not the owner of a group of trees that he tapping it. Many of them are working in partnership on the basis of production for such quarter a half of production, so the product may be interested only in the size of the production at that specific season.
1.2 A. Importance of Gum Arabic / Background:
1. Gum Arabic is the dried exudates produced from the trunk and branches of the Acacia Senegal tree, known as hashab or hard gum, and the Acacia seyal tree, known as talha or flaky gum. Gum Arabic is a pale white to orange brown solid which breaks with a glassy fracture. If stored properly, it stays unaltered for decades. Gum Arabic is a complex polysaccharide that has food, pharmaceutical and technical applications; its known uses go back about 5,000 years.
2. Sudan is the world’s largest producer of gum Arabic. It produces mostly hashab, principally in the traditional rain fed areas of western and central Sudan. Gum Arabic is produced across sub-Saharan Africa, from Senegal, Mali and Nigeria to Ethiopia and North of Kenya.

Gum Arabic Exports from Sudan (1970 to 2005)

Figure 1.1 gum arabic export from sudan

3. The supplementary revenues generated by gum Arabic are crucial to the Livelihoods of about 6 million people in Sudan who live in traditional rain fed farming areas, where the incidence of rural poverty is in the range of 65 to 90 percent.
4. Gum Arabic is primarily produced by small-scale farmers who give priority to food crop production (usually sorghum or millet) to secure family nutritional needs but seek other sources of income to meet the household’s basic needs other than grains. They harvest gum Arabic because this activity constitutes a crop diversification strategy to mitigate
crop failure. In addition, the acacia tree’s long lateral root system reduces soil and wind erosion. It has a regenerating impact on the land. However, gum Arabic production does compete with food and cash crops for labor resources and land allocation.

5. Agricultural operations, including gum Arabic harvesting, are primarily financed by village traders using the *sheil* system. Typically, the traders provide cash, seeds, tools but also basic commodities (water, sugar, tea…) for the households to get by during the “hunger gap”. Farmers pay back in kind at prices determined early in the season and usually integrating important credit charges.

6. All the gum Arabic produced in Sudan, mostly hashab, is exported. Sudan has always been the largest world producer and exporter of gum. From the 50’s to the early 90’s, Sudanese gum accounted for 80 percent of the global gum trade.

7. However, considerable year-to-year variations and overall declining gum exports from Sudan - consequences of two severe Sahalian droughts (mid-70s and mid-80s), political unrest and inadequate marketing arrangements - have resulted in the emergence of new gum producing countries, chiefly Chad and Nigeria, which produce mostly talha. Over the last 15 years, Sudan’s share in the world markets has declined sharply and is now below 50 percent. World exports of talha are almost on par with exports of hashab.
World Trade of Raw Gum Arabic

Figure 1. 2  world trade of raw gum arabic

8. Gum Arabic is used for its properties as an emulsifier, thickener, binder, stabilizer and adhesive. It is believed that soft drinks and confectionary represent 70 percent of the demand for gum Arabic.

9. Gum Arabic is generally used as an additive which represents a small portion of the cost of the finished product. It is regarded by end users as having technical advantages which makes it difficult to replace completely in many applications. This makes demand for gum quite price inelastic; supply is the key factor on the demand side.

10. In the 70s and 80’s, because of reduced supply from Sudan, end-users started to integrate substitutes (principally starches). However, since the 90’s, with the emergence of Chad and Nigeria as gum talha producers, use of substitutes has reduced sharply.

11. Talha has become hashab’s main competitor. Talha gum is substantially cheaper than hashab because it has inferior technical properties for some of gum Arabic’s important uses such as in the soft drinks industry but has the same chemical composition.

12. Demand for gum Arabic is driven up by the increasing world consumption of soft drinks and sweets. It is reinforced by the attention given by consumers to food products quality and naturalness. Because of
its high fiber content, gum Arabic has recently found a new range of applications in the dietetic food and health sub-sectors.

13. Four processors account for about 70 percent of the world trade of raw gum. Based in Europe and the USA, they buy raw gum for further transformation and re-sale as additive for the industry. The USA is the largest single market for gum Arabic, accounting for approximately 30 percent of the total trade. Europe is around 20 percent of the world trade. Confectionary represents the major use for gum in Europe while soft drinks production is the largest in the USA. Japan accounts for a little less than 10 percent of World trade. India, South Korea and China are emerging markets; it is believed that the demand from these countries is mainly for talha.

Figure 1. 3 areas covered by the gum arabic in sudan
Gum Arabic belt

1.3 Objectives of the Project:
1. Design appropriate type of Gum Arabic machine with high productivity.
2. Reduction of time & total load needed for preparation of Gum Arabic for export.
3. Determination some physical and engineering properties of Gum including weight, dimensions and hardness of different varieties.

1.4 Methodology of the Project:
1. Search for data in previous studies and projects.
2. Conduct experiments laboratory to find some physical and engineering properties of Gum Arabic.
3. Apply solid work program on drawing the Gum machine.
4. Summarize recommendations for further studies in field.

1.5 Overview content:
The research is composed of five chapters.
Chapter two contains type of gum Arabic, Physical properties of agricultural materials, processing of gum Arabic in Sudan and machines in the field.
Chapter three contains the varieties which are used in the study of Gum Arabic engineering Properties design of crushing gum Arabic machine.
Chapter four contains results and discussion.
Chapter five contains conclusion and recommendations.
CHAPTER 2
Literature Review

2.1 Types of Gum Arabic:

Gum Arabic from the Sudan is a product of *Acacia Senegal* and *Acacia seyal* species. *Acacia Senegal* var. *Senegal* is the only variety which grows in the Sudan and is the main source of commercial gum Arabic (hashab). On the other hand, both varieties of *Acacia seyal* i.e. var. *seyal* and var. *fistula* are found in Sudan. The former is characterized by normal spines and green, white or red bark while var. *fistula* is characterized by inflated spines (ant-galls and a whitish bark. Both varieties produce a commercial gum referred to as "talha"

Family: Mimosaceous legumes (leguminosae – Mimosoideae)

Vernacular Names: Wait gum tree, veer (French), Gum Arabic tree, gum tree, three horned Acacia (English), Katter (Arab).

**Types of hashed:**

1- Hand pick size (HPS).
2- Kibbled.
3- Mechanical powder.
4- Spray powder.

**Types of Talha:**

1- Clean Row of Talha 4mm (G3).
2- Sifting.
3- Powder.
4- Dust of Talha.
# Product Specification (Talha)

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content</td>
<td>15% max</td>
</tr>
<tr>
<td>Total ash</td>
<td>4% max.</td>
</tr>
<tr>
<td>PH</td>
<td>4.1 - 4.8</td>
</tr>
<tr>
<td>Arsenic</td>
<td>3 ppm max.</td>
</tr>
<tr>
<td>Lead</td>
<td>2 ppm max</td>
</tr>
<tr>
<td>Cadmium</td>
<td>1 ppm max.</td>
</tr>
<tr>
<td>Mercury</td>
<td>1 ppm max.</td>
</tr>
<tr>
<td>Heavy metals</td>
<td>20 ppm max</td>
</tr>
<tr>
<td>Insoluble material</td>
<td>0.5% max.</td>
</tr>
<tr>
<td>Solubility</td>
<td>Typically 98% water soluble, but the level of impurities present is subject to variation.</td>
</tr>
</tbody>
</table>

## General Properties:

**SOLUBILITY**

Soluble up to 55% concentration. Gum Arabic is truly soluble in cold water. Other gums are either insoluble in cold water or form colloidal suspensions, solutions not true.

**VISCOSITY**

A 20% aqueous solution will give less than 100 cps, i.e. Gum Arabic is not very viscous at such concentrations. High viscosity is obtained only at concentrations of 40% - 50%

**FILM-FORMING**

Gum Arabic's superb film-forming properties make it ideal for some confectionery coatings and lithographic plate solutions.

**EMULSIFIER**

Gum Arabic produces highly stable emulsions making it very useful in the preparation of oil-in-water food flavour emulsions, particularly for citrus oils.
<table>
<thead>
<tr>
<th><strong>COLOR</strong></th>
<th>Colorless (top quality) to pale straw color (average quality).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TASTE</strong></td>
<td>Gum Arabic has no off-taste. The taste of flavoring products co-spray dried with Gum Arabic is not affected or dulled by Gum Arabic as the carrier.</td>
</tr>
<tr>
<td><strong>FIBER</strong></td>
<td>Gum Arabic is regarded as 90% &quot;Soluble Fiber,&quot; according to the latest researches.</td>
</tr>
<tr>
<td><strong>CALORIC VALUE</strong></td>
<td>Generally defined as POLYSACCHARIDE DIETARY FIBER WITH REDUCED CALORIC INTAKE.</td>
</tr>
<tr>
<td><strong>CHOLES TROL REDUCER</strong></td>
<td>Human dietary intake studies have indicated a reduction in blood cholesterol levels when Gum Arabic amounts (25 grams per day) are ingested in solution.</td>
</tr>
<tr>
<td><strong>TOXICOLOGICAL STATUS</strong></td>
<td>&quot;Generally Recognized as Safe&quot;.</td>
</tr>
</tbody>
</table>
2.2 Gum Arabic Processing:

2.2.1 Gum Arabic cleaning:

Prior to sale, there is a basic cleaning process. This cleaning process is labor intensive and includes such methods as:

- Crude sieving.
- Hand selection.
- Hand grading and picking of bark etc.
- The main purpose of this cleaning process is the removal of sand, bark and any extraneous material.
2.2.2 Packing:

[Image: packing of gum arabic]

All gum for export must be packed in double bags. The outer should be new and sound. Used bag may serve as inner bag, but it must be clean, dry and strong.

2.3 Machines in Sudan:

All the exciting types of Gum Arabic machines are considered traditional machines since their only purpose is to grind gum to powder and they are not aware of the other benefits.

If they separate the Gum Arabic with the right way; so that the Gum must remain uncrushed after separated to get a higher benefits of gum Arabic and that was the purpose of the design of our Gum Arabic machine.
CHAPTER 3

MATERIALS AND METHOD

3.1 Varieties studied:

Two Gum varieties were obtained from local market in Soba both of them were cultivated in Cordovan in the West of Sudan.

Figure 3.1  gum arabic raw and final size
3.2 Gum Arabic physical and engineering Properties:

Some physical and engineering properties of Gum Arabic for our design were studied in Masaii factory in soba, the department of civil engineering and faculty of pharmacy at the University of Khartoum.
The moisture content of the Gum taken from some varieties was obtained.
The dimensions included: the length, the width and the thickness.
The force required to crush the Gum was measured in kw.

3.3 Determination of the geometric mean diameter:

The geometric mean diameter of gum can be determined using the following formula:

\[ D_g = (abc)^{1/3} \]

\( D_g \) = Gum geometric mean diameter (cm).
\( a \) = average length (cm).
\( b \) = average width (cm).
\( c \) = average thickness (cm).

For small varieties:
\( D_g = 1.4 \) cm.

For large varieties:
\( D_g = 21.22 \) cm.

3.4 Determination of the Gum cross-section area:

The cross-section area of the gum can be determined using the following equation:

\[ A = D_g \times L \]

\( A \) = the cross-section area of Gum mm\(^2\)
\( L \) = average length of the Gum mm.

For small varieties:
\( A = 0.000286 \) m\(^2\)

For large varieties:
\( A = 0.0645 \) m\(^2\)
Crushing force:

For small varieties:
\[ F = 0.0146 \text{ N}. \]

For large varieties:
\[ W_T = W_i \cdot N \]
\[ N = \text{number of small varieties.} \]
\[ 2.72 = 0.004231 \cdot N \]
\[ N = 642. \]
\[ \therefore F_T = F_i \cdot N \]
\[ F_T = 0.0146 \cdot 642 = 9.37 \text{ N} \]

3.5 Determination of the Gum Arabic crushing strength:

The crushing strength of Gum Arabic in Kg mass per unit area can be determined using the following formula:

\[ F_c = \frac{F}{(A \cdot g)} \]

\[ F_c = \text{crushing force N.} \]
\[ A = \text{area of peanut m}^2 \]
\[ g = \text{gravitational acceleration m/s}^2 \]
\[ F_c = \frac{9.37}{0.064 \cdot 9.81} = 14.8 \text{ N} . \]
3.6 **Determination of the Gum Arabic moisture content:**

The moisture content of the Gum was determined by advice.

3.7 **Design of Gum Arabic machine:**

3.7.1 **Description of the machine:**

In Sudan Crushing gum Arabic was life work manually by laborer, and we will replace it by a designed machine. Which consist of the following component:

Frame- feet hopper- hammer mill and power system.
3.7.1.1 The frame:

It supports the entire machine and it carries the prime mover, hammer mill, the hopper.

3.7.1.2 The Feed Hopper:

This structure is the unit in which Gum Arabic is feed into the crushing chamber. The conical into the crushing hopper is mounted on the crushing unit at an inclination of the gum angle of repose. A flow rate control device was located at the hopper base and used to obtain varying gate opening between the hopper and the crush unit; by this device; the quantity of gum entering into the gum chamber per unit time wasRegulated and varying feed rates were achieved.

3.7.1.3 The Crushing Unit:

It consist two rollers in the crush chamber one of this rollers (drum) is driven by a belt and pulley arrangement, while the other (perforated concave) is stationary. The rotary roller has three crushing beaters welded at angle to its surface and running through it is entire length. The clearance between the drum and the perforate concave can be calculated. During machine operation, the gum from the hopper drops between rollers. The crushing bar of the rotary roller collects and compresses it against the perforated concave and by this action the gum is crushed.

3.7.1.4 The Power Source:

The power system consists of an Ac electric motor and belt and pulley drive by which runs the hammer mill.
3.7.2 Machine performance:

3.7.2.1 Hammer mill performance:

The performance of crushing mechanism is measured by crushing efficiency, the amount of mass gum damage.

Crushing performance parameters are affected by the following factors:

1- Design factors: Beater diameter, concave length.
2- Operating parameters: Beater speed, concave clearance and material feed rate.
3- Crop condition Crop moisture content, crop type.

3.7.2.2 Crushing efficiency:

Crushing efficiency is the percentage of the crushing mass calculated on the basis of the total masses entering the crushing mechanism. It increases asymptotically with concave length up to certain point.

Beater speed is one of the most important variables affecting crushing losses. Crushing losses can be significantly reduced by decreasing the beater speed. Changing the concave clearance ratio (the ratio of the gap at the front to that at the rare of the beater) is done to facilitate crop feeding into the beater, but the effect of this variable on the shelling efficiency is not consistent. Crushing loss increase with material feed rate, which is generally expressed in terms of ton/hr.
3.7.3 **Design Calculation:**

### 3.7.3.1 **Determination Of The Power Required For Crushing Gum**

**Arabic:**

\[ P_c = W \times K \times F_c \times \ln(L_1/L_2) \]  \( (1) \)

**Pc** = power required to crush (Kw).

W = crushing capacity (kg/hr).

Assume the capacity = 185 (kg/hr).

\[ P_c = 185 \times 1.2 \times 14.8 \times (14.7) = 865.2 \text{ w.} \]

Considering the transmission efficiency, the required motor power (Pm) is given as:

\[ P_m = P_e \times f_e \times f_c \times i_e \times n_c \]

Assuming the transmission efficiency of the motor is 80%, the value obtained using above equation is \( P_m = 0.8652 \text{Kw.} \)

Take the motor pulley diameter = 75.89 mm.

Take the motor speed = 1440 rpm.

### 3.7.3.2 **The total reduction:**

The reduction needed to obtain the required speed of crushing Gum Arabic is calculated by:

\[ P_C = F \times R = F \times (2\pi n/60) \times r \]

\[ P_C = \text{Required power to crush gum w.} \]

\( F = \text{crushing force N.} \)

\( R = \text{radius of the beater mm.} \)

\( N = \text{therequiredspeed rpm.} \)

\[ : n = 35.27 \text{ rpm.} \]

Then the reduction:

\[ \text{Reduction} = (N_{\text{motor}}/N_{\text{requiredReduction}}): \]

\[ (1440/35.27) = 40.8 \]

Since the pulleys have a maximum reduction of 7, then we need two sets of pulleys to get the required reduction:

Assume first reduction = 7
Second reduction = 5.820

3.7.3.3 The velocity ratio of the driven and driving pulley:

Since there are two sets of pulleys:

First reduction:

The velocity ratio of the driven and driving pulley is given as:

\[ \frac{d_2}{d_1} = \frac{n_1}{n_2} \]

\( d_1 \) = effective diameter of smaller pulley mm.

\( d_2 \) = effective diameter of large pulley mm.

\( n_1 \) = motor speed rpm.

\( n_2 \) = speed of the intermediate shaft rpm.

Assuming the motor diameter = 75.89 mm and first reduction = 7.

\[ \frac{d_2}{75.89} = 7 \]

\[ \therefore d_2 = 531.2 \text{ mm}. \]

Second reduction:

The velocity ratio of the driven and driving pulley is given as:

\[ \frac{d_2}{d_1} = \frac{n_1}{n_2} \]

\( d_1 \) = effective diameter of smaller pulley mm.

\( d_2 \) = effective diameter of large pulley mm.

\( n_1 \) = speed of intermediate shaft rpm.

\( n_2 \) = speed of the machine shaft rpm.

Assuming the intermediate shaft diameter = 77.5 mm and second reduction:

\[ \frac{d_2}{77.5} = 5.82 \]

\[ \therefore d_2 = 451.05 \text{ mm}. \]
3.7.3.4 **Belts design:**

Two sets of pulleys need two sets of belts according to the reductions, and calculated by:

**Drum reduction:**

The driving pulley $d_1 = 77.5$ mm (assumed), then:

First reduction, $d_2 = 531.2$ mm.

**Belt length:**

\[
L = 2c + 1.57(d_1 + d_2) + \left(\frac{d_2 - d_1}{4c}\right)^2
\]

$L = \text{belt length mm.}$

$d_1 = \text{diameter of smaller pulley mm.}$

$d_2 = \text{diameter of large pulley mm.}$

$C = \text{center distance between the two pulleys.}$

\[
C = \frac{b + \sqrt{b^2 - 32(d_2 - d_1)^2}}{16}
\]

$B = 4L - 6.28(d_2 - d_1)$

$D_2 < C < 3(D_2 + D_1)$

$531.2 < C < 1821.27$

Assume $C = 218$ mm.

\[
L = 2 \times 218 + 1.57(531.2 + 75.89) + \left(\frac{531.2 - 75.89}{4 \times 218}\right)^2
\]

$L = 1389 \text{ mm} = 54.6 \text{ in}$
\[ B = 4 \times 1389 - 6.28(531.2 - 75.89) \]

\[ B = 2696.6 \text{ mm}. \]

\[ C = \frac{2696.6 + \sqrt{2696.6^2 - 32(531.2 - 75.89)^2}}{16} \]

\[ C = 336.9 \text{ mm}. \]

\[ \therefore L = 2 \times 336.9 + 1.57(7531.2 + 75.89) + \left( \frac{531.2 - 75.89}{4 \times 336.9} \right)^2 \]

L=1627.2 mm = 64 in.

For standard belt (3V).

\[ \theta = 180 - 2 \sin^{-1}\left( \frac{531.2 - 75.89}{2 \times 336.9} \right) \]

\[ \theta = 94.9^\circ. \]

Determine the correction factors from Figures (7-14) and (7-15):

\[ C_0 = 0.81. \quad C_L = 0.85. \]

Compute the corrected rated power per belt:

\[ P_c = 0815 \times 0.85 \times 2.66 \]

\[ P_c = 1.84 \text{ hp}. \]

Number of belts:

1.07 (use 2 belts).
Summary of Design:
Belt: 3V cross section, 64-in length, 2 belts.
Sheaves: Driver, 75.89mm pitch diameter, 2 grooves, 3V. Driven, 531.2mm pitch
diameter, 2 grooves, 3V.
Center distance: 336.9 mm.

Motor reduction:
Second reduction = 5.82
d₁ = 77.5 mm, d₂ = 451.05 mm.

\[ L = 2c + 1.57(d_1 + d_2) + \left(\frac{d_2 - d_1}{4c}\right)^2. \]

\[ C = \frac{b + \sqrt{b^2 - 32(d_2 - d_1)^2}}{16} \]

\[ B = 4L - 6.28(d_2 - d_1) \]

\[ D_2 < C < 3(D_2 + D_1) \]

\[ 451 < C < 1585.65 \]

Assume \( C = 500 \) mm.

\[ \therefore L = 2 \times 500 + 1.57(451.05 + 77.5) + \left(\frac{451.05 - 77.5}{4 \times 500}\right)^2 \]

\[ L = 1829.8 \text{ mm} = 72 \text{ in} \]

\[ B = 4 \times 1829.8 - 6.28(451.05 - 77.5) \]

\[ B = 4971 \text{ mm}. \]

\[ C = \frac{4971 + \sqrt{4971^2 - 32(451.05 - 77.5)^2}}{16} \]
\[ C = 621.2 \text{ mm}. \]

\[ \therefore L = 2 \times 621.2 + 1.57(77.5 + 451.05) + \left( \frac{451.05 - 77.5}{4 \times 621.2} \right)^2 \]

\[ L = 2072 \text{ mm} = 81 \text{ in.} \]

For standard belt (5V).

\[ \theta = 180 - 2 \sin^{-1}\left( \frac{451.05 - 77.5}{2 \times 621.2} \right) \]

\[ \theta = 145^\circ. \]

Determine the correction factors from Figures (7-14) and (7-15):

\[ c_0 = 0.92. \quad c_L = 0.94. \]

Compute the corrected rated power per belt:

\[ P_c = 0815 \times 0.85 \times 2.66 \]

\[ P_c = 1.06 \text{ hp}. \]

Number of belts:

1.13 (use 2 belts).

**Summary of Design**

Belt: 5V cross section, 81-in length, 2 belts.

Sheaves: Driver, 77.5mm pitch diameter, 2 grooves, 5V. Driven, 451.05mm pitch diameter, 2 grooves, 5V.

Center distance: 621.2 mm.

**3.7.3.5 Design of the shaft:**

There are two shafts needed to operate the machine with the required speed.
Design of intermediate shaft:

\[ W = \frac{2 \times 3.14 \times N}{60} = \frac{2 \times 3.14 \times 205}{60} = 21.54 \text{ r/s} \]

\[ T = \frac{P}{W} \]

\[ T = \frac{0.085598 \times 1000}{21.54} = 39.74 \text{ N.m} \]

\[ T = (T_1 - T_2) \times R = 39.74 \]

\[ \frac{T}{R} = T_1 - T_2 = 150 \text{ N} \quad \rightarrow \star \]

\[ \frac{T_1}{T_2} = e^{\mu \theta} \]

\[ \frac{T_1}{T_2} = e^{\left(\frac{0.4 \times 94.9 \times \pi}{180}\right)} = 1.939 \]

\[ T_1 = 1.939 \times T_2 \]

By substitute \( T_1 \) in equation \( \star \)

\[ (1.939 - 1)T_2 = 150 \text{ N} \]

\[ T_2 = 160 \text{ N} \]

\[ \therefore T_1 = 309.8 \text{ N} \]

\[ T_T = T_1 + T_2 \]

\[ T_T = 470 \text{ N} \]
Second pulley in the intermediate shaft:

\[ T = (T_3 - T_4) \times R = 39.74 \]

\[ \frac{T}{R} = T_3 - T_4 = 1025.54 \, N \quad \rightarrow * \]

\[ \frac{T_3}{T_4} = e^{\mu \theta} \]

\[ \frac{T_3}{T_4} = e^{\left(\frac{0.4 \times 35 \times \pi}{180}\right)} = 1.27 \]

\[ T_3 = 1.27 \, T_4 \]

\[ T_4 = 3707.3 \, N \]

\[ T_3 = 4708 \, N \]

\[ T_T = 8415.6 \, N \]

\[ M_{\text{max}} = 8415.6 \times 0.5 = 4207 \]

\[ D^3 = \frac{\pi}{16 \tau} \times 10^{-6} \times \sqrt{(K_p M_{\text{max}})^2 + (K_t M_t)^2} \]

\[ D^3 = \frac{\pi}{16 \times 48.3} \times 10^{-6} \times \sqrt{(1.7 \times 4207)^2 + (1.7 \times 39.74)^2} \]

\[ D = 0.03 \, m \]

**Summary of Design**

Material of the intermediate shaft = [C1040].

Diameter of the intermediate shaft = 0.03 m.
Design of the crusher shaft:

The crushing shaft is subjected to constant torque and bending moment. But in actual practice the shaft is subjected to a fluctuating torque and bending moment. The equivalent twisting moment can be determined using the following equations:

\[ P = 855.98 - 0.855 \times 0.02 = 855.96 \text{ w.} \]

\[ T = \frac{2\pi N}{60} = \frac{2\pi \times 35.27}{60} = 3.7 \text{ r/s} \]

\[ T = \frac{P}{W} \]
\[ T = \frac{855.96}{3.7} = 231.3 \text{ N.m} \]

\[ T = (T_1 - T_2) \times R = 231.3 \]

\[ (T_1 - T_2) \times \left(\frac{0.451}{2}\right) = 231.3 \]

\[ \frac{T}{R} = T_1 - T_2 = 1028.6 \text{ N} \quad \to \ast \]

\[ \frac{T_1}{T_2} = e^{\mu \theta} \]

\[ \frac{T_1}{T_2} = e^{\left(\frac{0.4\times145\times\pi}{180}\right)} = 2.75 \]

\[ T_1 = 2.75 \times T_2 \]

By substitute \( T_1 \) in equation \(*\)

\[ (2.74 - 1)T_2 = 1028.6 \text{ N} \]

\[ T_2 = 587.8 \text{ N} \]

\[ \therefore \quad T_1 = 1616.4 \text{ N} \]

\[ T_T = T_1 + T_2 \]

\[ T_T = 2195.2 \]
Figure 3.4  bending moment and shear force diagram

\[ R_1 + R_2 = 2195.2 \, N \]

Taking the torque around \( R_2 \):

\[ R_1 \times 80 = 2195.2 \times 100 \]

\[ R_1 = 2744 \, N \]

\[ R_2 = -548.8 \]

\[ M_{\text{max}} = 2195.2 \times 20 = 43902 \]

Center

\[ 548.8 \times 40 = 21952 \]
9.37 \times 185 = 1733.45

R_1 + R_2 = 17733.45

R_1 = R_2 = 866.7

866.7 \times 80 = 69338

M_{max} = \sqrt{(21952)^2 + (69338)^2} = 72729.9

D^3 = \frac{\pi}{16\tau} \times 10^{-6} \times \sqrt{(K_p M_{max})^2 + (K_t M_t)^2}

D^3 = \frac{\pi}{16 \times 48.3} \times 10^{-6} \times \sqrt{(1.7 \times 72729.9)^2 + (1.7 \times 231.3)^2}

D = 0.08

NOTE:

The shaft material is: [C 1040 STEE].

The shaft Diameter is: 0.08 m.
Figure 3.5 main shaft "beaters"
3.7.3.6 Design of bearing:

The crushing shaft:
(d=80mm).

For the dynamic capacity of the bearing assume that bearing life was 20000 hours and the selected type of bearing:

\[ P = x F_r + y F_a \]

Axial load \( F_a = 0 \).

\[ F_r = \sqrt{2744^2 + 548.8^2} = 2798.3 \text{ N}. \]

\[ P = X F_r = 3357 \text{ N}. \]

Life time = 20000 hr.

\[ L = \frac{L H * N * 60}{10^6} = \frac{20000 * 35.27 * 60}{10^6} = 42.3 \]

\[ C = 2798.3 * 42.3^{1/3} \]

\[ C = 9.7 \text{ KN}. \]

\[ \because \text{ the selected bearing is:} \]

Designation = 6816

da = 84
Da = 96
ra = 0.6

The intermediate Shaft:
d=30mm.

\[ P = x F_r + y F_a \]
Axial load \( F_a = \) zero.

\[
F_r = \sqrt{470^2 + 470^2} = 4731.4 \text{N}
\]

\( P = X F_r = 5677 \text{ N} \).

Life time = 20000 hr.

\[
L = \frac{L H + N \times 60}{10^6} = \frac{20000 \times 205.7 \times 60}{10^6} = 246.8
\]

\( C = 2798.3 \times 246.8/3 \)

\( C = 17.5 \text{ KN} \).

\( \therefore \text{ the selected bearing is:} \)

Designation = 6306

da = 36.5

Da = 65.5

ra = 1

### 3.7.3.7 Design of key:

The intermediate Shaft:

Diameter of shaft = 30 mm.

Material of key \([C_{1010}]\). S.F = 3

\[
\sigma_p = \frac{379}{3} = 126.3 \text{MPa}
\]

\[
TS = \frac{126.3}{2} = 63.16 \text{MPa}
\]

Design of square key:

\( H = W = \frac{ds}{4} = \frac{30}{4} = 7.5 \text{mm} \).

Length of key:

\[
L = \frac{2T}{TS \times D + W} = \frac{2 \times 39.74 \times 1000}{63.16 \times 30 \times 7.5} = 5.59 \text{mm}
\]

\( \therefore L < b = 12 \text{mm} \)
Summary of design:
Diameter of the shaft = 30 mm.
Material of the key = [C_{1010}].
[H, W] of the key = 7.5 mm.
Length of the key = 5.59 mm.

Crushing Shaft:
Diameter of shaft = 80 mm.
Material of key [C_{1010}], S.F=3

\[ \sigma_P = \frac{379}{3} = 126.3 \text{MPa} \]

\[ TS = \frac{126.3}{2} = 63.16 \text{MPa} \]

Design of square key:

\[ H = W = \frac{ds}{4} = \frac{80}{4} = 20 \text{mm}. \]

Length of key:

\[ L = \frac{2T}{TS \cdot D \cdot W} = \frac{2 \cdot 313 \cdot 1000}{63.16 \cdot 80 \cdot 7.5} = 4.57 \text{mm}. \]

\[ \therefore L < b = 12 \text{mm} \]

Summary of the design:
Diameter of the shaft = 80 mm.
Material of the key = [C_{1010}].
[H, W] of the key = 20 mm.
Length of the key = 4.57 mm.
CHAPTER 4
Implementation and Results

From previous chapter, it found that the items of crushing Gum Arabic machine are:

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame</td>
<td>Angular mild steel, 1500<em>1225</em>764mm</td>
</tr>
<tr>
<td>crushing machine housing</td>
<td>Galvanized material</td>
</tr>
<tr>
<td>Beaters</td>
<td>3 mild steel sharp shaped projection</td>
</tr>
<tr>
<td>Drum</td>
<td>Mild steel 420 mm diameter</td>
</tr>
<tr>
<td>Perforated concave</td>
<td>Mild steel, semi circular shape, 750mm length, 21.30*11.20mm slot size</td>
</tr>
<tr>
<td>Clearance between the drum and the perforated concave</td>
<td>10.00 mm</td>
</tr>
<tr>
<td>crushing main shaft</td>
<td>Mild steel 80 mm diameter, 110 mm length</td>
</tr>
</tbody>
</table>
Figure 4.1 case of the crusher
Figure 4.2 concave and pulleys
CHAPTER 5

Conclusions and recommendations

Conclusion:

The following conclusion for this study:

1) Dimensions, weight and hardness of two Gum Arabic varieties at certain moisture content have been successfully obtained.

2) At 15% wb max moisture content large variety had an average weight, length, width and thickness.

3) At 8% wb min moisture content the small variety had an average weight, length, width and thickness

Recommendations:

Extensive study of Gum Arabic physical and engineering properties must be done to establish a good floor for design.
References


2. Policy note, export marketing of acacia gum from Sudan. World Bank 2007


6. R.S. KHURMI & J.K. GUPTA Mechanical Design


8. Unit Operation of Chemical Engineering – McCabe & Smith – 3 ed.
**APPENDIX A**

Table A1 weight and dimensions of small variety:

<table>
<thead>
<tr>
<th>NO</th>
<th>Weight (g)</th>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Thickness (mm)</th>
<th>Strength (kg/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.672</td>
<td>26.93</td>
<td>15.63</td>
<td>13.37</td>
<td>5</td>
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<tr>
<td>2</td>
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<td>24.30</td>
<td>23.63</td>
<td>13.10</td>
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<tr>
<td>3</td>
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<td>9.89</td>
<td>13.00</td>
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<tr>
<td>4</td>
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<tr>
<td>5</td>
<td>1.050</td>
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<td>3.00</td>
<td>13.00</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>5.565</td>
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<td>13.01</td>
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<td>7</td>
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<td>8</td>
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<td>9.41</td>
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</table>

**AVE** | 4.231 | 20.44 | 12.77 | 10.55 | 7.33 |
Table A2 weight and dimensions of large variety:

<table>
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<tr>
<th>No</th>
<th>Weight (kg)</th>
<th>Length (cm)</th>
<th>Width (cm)</th>
<th>Thickness (cm)</th>
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<td>10</td>
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<td>11</td>
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<td>9</td>
<td>11</td>
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</table>

AVE 2.72 30.43 22.12 14.18
Figure 4.3 angle of wrap correction factor

Figure 4.4 angle of wrap correction factor