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GEAR TYPE TRANSFER PUMP FOR PALM SUGAR PRODUCTION'S ENGINE BY EVAPORATION METHOD

Sunarno[1], Nuradi[2], Joko Prihartono[3]
[1,2,3]Faculty of Industrial Technology, Universitas Tama Jagakarsa, South Jakarta, DKI Jakarta, Indonesia
[1] 5un2rn0@gmail.com [2] nuradi@jagakarsa.ac.id

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ABSTRACT

Along with the times, the process of managing palm sugar has been developed based on the large scale and how efficient the management process is, in this case the method used is evaporation where the sap is circulated several times for the process of draining the water in the Economizer, for the circulation process there is a pump to be able to accelerating the flow system so that the traditional process continues until the sap becomes half the process (thick sap). For this reason, a gear type pump is used so that it can move fluids with high viscosity. In this case the pump used with maximum specifications, the effective head of the pump installation is 52.1573 m and a capacity of 0.001 m^3/s, and the theoretical pump power is 0.098 kW, while the resulting shaft power is 0.14 kW, the motor has a power of 0.147 kW . As well as the type of External Gear Pump selected with a rotation of 400 rpm and a power of 0.14 kW.

INTRODUCTION

Brown sugar or Javanese sugar is usually associated with all kinds of sugar made from sap (Knight, 2013; Tarigan et al., 2019), which is the liquid secreted from the flowers of trees from the palm family, such as coconut, aren and siwalan. Flowers (*mayang*) or Coconut Flowers that have not yet bloomed are tied tightly (sometimes pressed with two sticks) at the base so that the flowering process is hampered. The food essence that is supposed to be used for blooming flowers accumulates into liquid sugar (Darko et al., 2022; Kumari & Bhargava, 2021). Mayang swells. After the swelling stops, the stems are sliced to gradually release the liquid sugar. The liquid is usually collected in a bucket made from the leaves of the palm tree (Rao et al., 2021). The collected liquid is taken out gradually, usually 2-3 times. This liquid is then heated over fire until thick. Once completely thick, the liquid is poured into bowls made of palm leaves and ready to be marketed.

Brown sugar is mostly used as raw material for sweet soy sauce (Wael et al., 2021). To produce good sugar, you need old and dry firewood, so that the sap from the tree can be boiled quickly (Amzu et al., 2020). If boiling is slow, then fermentation can occur resulting in the formation of acetic acid which causes the sugar to taste sour and soft because it is hygroscopic (absorbs moisture). In many areas, dry and old wood is increasingly difficult to obtain, especially during the rainy season (Zwarts et al., 2023).

This opens up opportunities for coal as a substitute fuel for the brown sugar industry because coal is always available both in the rainy and dry seasons with constant quality. Along with the increasing demand for brown sugar in the market, brown sugar processing machines have been developed to help make the production process faster (Darma et al., 2020; Solomon & Swapna, 2022). The machine uses a gear type pump, among other things, consisting of two functions in one

pump engine component. First, the pump functions to circulate the sap from the tank into the economizer in order to reduce the water content contained in the sap during the evaporation process in the evaporator. The two pumps function to distribute the sap in a semi-condensed state (half-condensed) into the evaporator, so that the coagulation process is complete. As for the other component support tools using stainless steel material.

The research would like to analyze gear type transfer pump for palm sugar production's engine by evaporation method. The researchers expect this study to give more insight into the topic discussed so that readers may gain a wider range of knowledge regarding gear type transfer pump.

METHODS

Generally, the research applied experimental method adjusted with the context of discussion. Below is the research flow implemented.

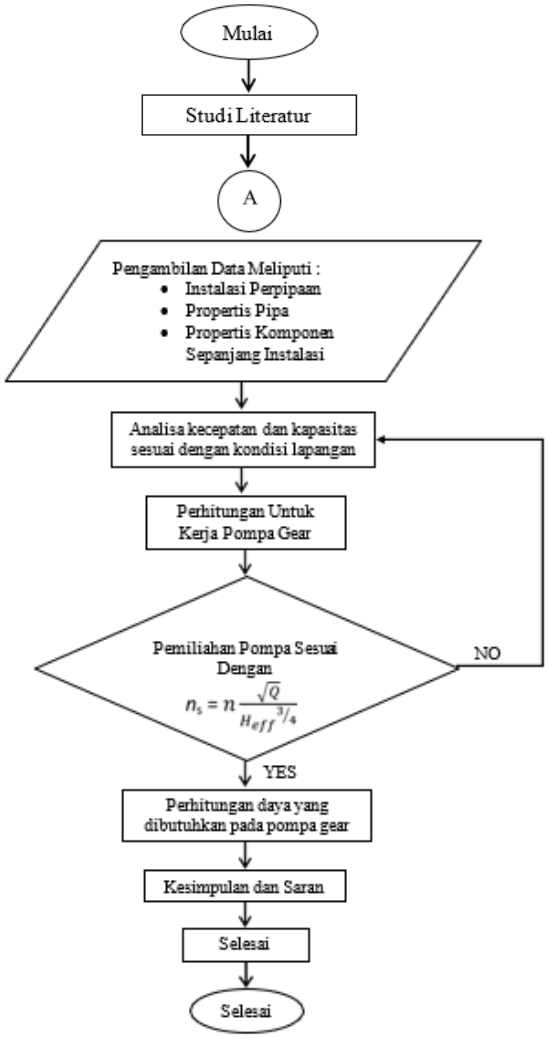


Figure 2. Research Flow

Tools used and testing were conducted in Fabrication Shop by Mitra Usaha Jl. National 11, RT 03/RW 08, Bubulak, West Bogor District, Bogor City, West Java 16115.

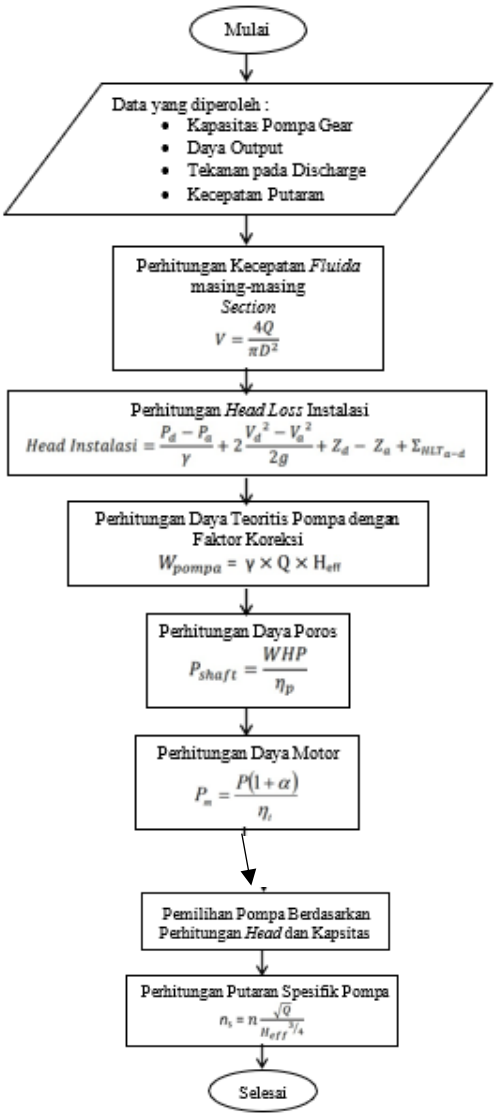


Figure 3. Calculation of Pump Performance

Data collection can be directly from observations or data that is already available within the company. Existing data will be used as a reference in discussing this research report which is useful for obtaining solutions or other better alternatives for this research.

Fluid Data

Fluid Type	: Nira Water
Pump inlet temperature	: 45◦C
Gravity (g)	: 9.81 m/s ^{2}

Nira Tank Data

Capacity : 100 Liters
Head Suction Height : 0.6 m
Head Discharge Height : 1 m

Pump Data

Capacity : 10 Ltr/minute
Output : 0.14 kW
Pressure : 0.3 MPa (3 kgf/cm ^{2})
Rotation : 400rpm
Factory : Oriental Koshim

Pipe Data

- Suction Pipe
  Nominal Pipe Size : Ø50 mm
  Material Type : SS304
- Discharge Pipe
  Nominal Pipe Size : Ø25 mm
  Material Type : SS304

Design Drawings

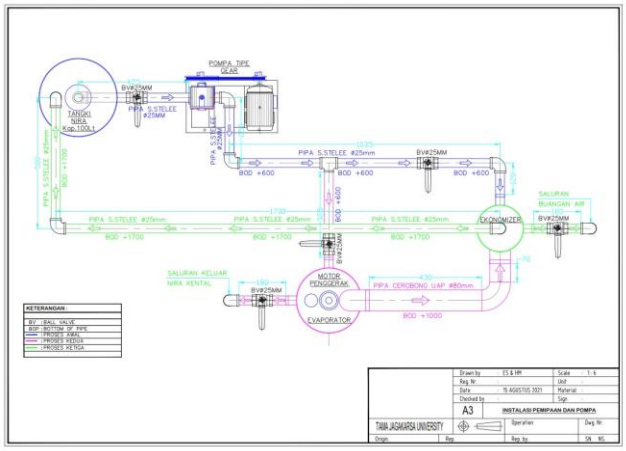


Figure 4. Super Inpost Piping and Pump Installation

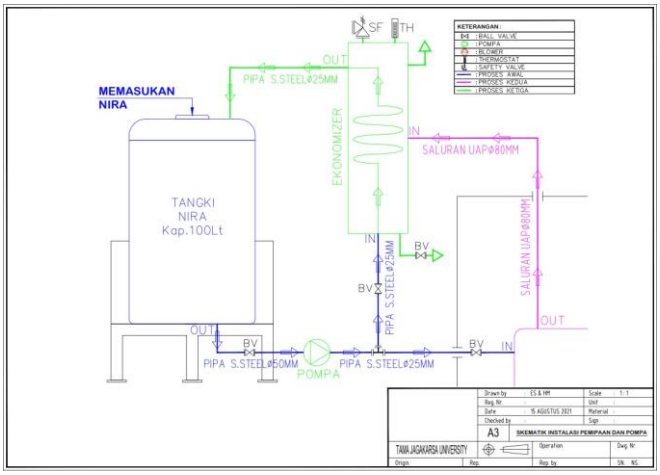


Figure 5. Piping and Pump Installation Schematic

RESULTS AND DISCUSSION

Calculation Analysis

The pump capacity or the amount of fluid obtained from the Nira tank suction to the Economizer and Evaporator can be known in advance the condition of the Nira tank itself, obtained:

Capacity (Q) = $$Q = \frac{10Lt}{min} x \frac{1m^3}{1000} x \frac{1mm}{10s} = 0{,}001 \frac{m^3}{s}$$

Table 1. Palm Sugar Viscosity taken from the Journal "PHYSICOCHEMICAL ANALYSIS OF LIQUID PALM SUGAR (*ANALISIS FISIKOKIMIA GULA AREN CAIR*)"

Repetition	Dial Reading	Factors	Viscocity Value (Cps)
1	61	10	610
2	60,5	10	605
3	61	10	610
4	61,5	10	615
5	63	10	630
Viscocity Average Value			614

Pump inlet fluid temperature (T_1) = 45°C

From Table of Viscosity Rating Results, with $T_1 = 45°C$ maka $\rho = 614 \frac{kg}{...}$

$$\dot{m}_1 = \dot{m}_2$$

$$\rho_1 V_1 A_1 = \rho_2 V_2 A_2$$

Calculation of Fluid Velocity in Action

The capacity will be calculated at the saction as follows.

1) Calculation of the velocity of the fluid flowing from the Nita Tank (a) to the Economizer & Evaporator (b). It is known that the diameter of the pipe section Ø 0.05 m.

$$Q_1 = V_1 A_1$$

$$V_1 = \frac{4Q}{\pi D^2}$$

$$V_1 = \frac{4 \; x \; 0.001 \; \frac{m^3}{s}}{\pi \; x \; (0.05m)^2}$$

$$V_1 = 0{,}5096 \; \frac{m}{s}$$

2) Speed calculation from saction (a) to saction (b). It is known that the pipe section diameter is Ø 0.025 m and because there is a Through Tee, the velocity

$$\boldsymbol{Q_2 = \frac{Q_1}{2} = \frac{0.0001 \frac{m^3}{s}}{2} = 0.0005 \; \frac{m^3}{s}}$$

$$Q_2 = V_2 A_2$$

$$V_2 = \frac{4Q}{\pi D^2}$$

$$V_2 = \frac{4 \; x \; 0.0005 \; \frac{m^3}{s}}{\pi \; x \; (0.025 \; m)^2}$$

$$V_1 = 1{,}0191 \; \frac{m}{s}$$

Pump Installation Head Loss Calculation

Head loss in pump installations consists of two components, namely dynamic head and static head.

1) Dynamic Head Calculation: Dynamic Head can be calculated with the following equation.

$$\sum H_{dyn} = \sum H_{Lmayor} + \sum H_{Lmayor} + \frac{V_d^2 - V_S^2}{2g}$$

2) Pipe Dynamic Head Calculation from S a ction (a) to (b) : With the exit temperature of the Nira tank after circulating for 10 to 15 minutes. 45°C then v = 3830 x 10 $^{-6}$ m/s ^{2}

$$Re = \frac{V_{a-b} \; x \; D_{a-b}}{v} = \frac{0{,}5096 \; \frac{m}{s} \; x \; 0.05 \; m}{3830 \; x \; 10^{-6} \frac{m^2}{s}} = 6{,}651$$

Because the value of Re is ≤ 2300, the flow is Laminar, so to find the Friction Factor:

$$f = \frac{64}{Re}$$

$$f = \frac{64}{6{,}651}$$

$$f = 9{,}6226$$

Then the price for Major Losses is:

$$H_{La-b} = f.\frac{L_{a-b}}{D_{a-b}}.\frac{L_{a-b}{}^2}{2g}$$

$$= 9{,}6226\ x\ \frac{7{,}500m}{0{,}05m}\ x\ \frac{(0{,}5095\ \frac{m}{s})^2}{2\ x\ 9{,}81\ \frac{m}{s^2}}$$

$$= 19{,}0973\ m$$

To find the price of Minor Losses:

1) From the pipe flow expert program, for Nominal Pipe Size = Ø 25 mm
   For Elbow Long Radius 90º, with K = 0.37 for 4 (four) pieces, then:

$$H_{Lm} = f.\frac{L_e\ V}{D\ 2g} = K\frac{V_{a-b}}{2g}$$

$$= 0{,}37\ (4)\frac{(0{,}5095\ \frac{m}{s})^2}{2\ x\ 9{,}81\ \frac{m}{s^2}}$$

$$= 0{,}0195\ m$$

For *Through Tee*, with K = 0.46 as many as 1 (one), then:

$$H_{Lm} = f.\frac{L_e\ V}{D\ 2g} = K\frac{V_{a-b}}{2g}$$

$$= 0{,}46\ (1)\frac{(0{,}5095\ \frac{m}{s})^2}{2\ x\ 9{,}81\ \frac{m}{s^2}}$$

$$= 0{,}0060\ m$$

For Ball Valve, with K = 0.07. A total of 2 (one) pieces, then:

$$H_{Lm} = f.\frac{L_e\ V^2}{D\ 2g} = K\frac{V_{a-b}{}^2}{2g}$$

$$= 0{,}07\ (2)\frac{(0{,}5095\ \frac{m}{s})^2}{2\ x\ 9{,}81\ \frac{m}{s^2}}$$

$$= 0{,}0018\ m$$

So that:

$$\sum H_{La\text{-}b} = \sum H_{Lmayor} + \sum H_{Lminor}$$

$$= 19{,}0973\ m + \ 0{,}0195\ m + 0{,}0060\ m + 0{,}0018\ m$$

$$= 19{,}1246\ m$$

Calculating Pump Installation Head

From Table of Viscosity Value Results, with $T_1 = 45°C$ maka $\rho = 614\ \frac{kg}{m^3}$

It is known that:

$P_a = 1\ atm = 1{,}013\ bar = 1{,}013\ x\ 10^5\ \frac{kN}{m^2}$

$P_d = 3\ bar\ gauge = 4\ bar = 4\ x\ 10^5\ \frac{kN}{m^2}$

$V_d = \ V_2 = 1{,}0191\ \frac{kN}{m^2}$

$V_a = 0$

a $= 2$

$\gamma = \ \rho\ x\ g = 614\ x\ 9{,}81 = 6023{,}34\ \frac{kg}{m^2 s^2}$

$Z_a = 1$ m

$Z_d = 0{,}6$ m

$\sum Hlt_{a\text{-}b} = 19{,}0973\ m$

So that:

$$\text{Installation Head} = \frac{P_d - P_a}{\gamma} + 2\frac{V_d^2 - V_a^2}{2g} + Z_d - Z_a + \Sigma_{HLTa-d}$$

$$= \frac{4\ x\ 10^5\ \frac{kN}{m^2} - 1{,}013\ x\ 10^5\ \frac{kN}{m^2}}{6023{,}34\ \frac{kg}{m^2 s^2}} + \frac{1{,}0191^2\ \frac{m}{s}}{9{,}81\ \frac{m}{s^2}}$$

$$+0{,}6\ \text{m} + 1\ \text{m} + \ 0{,}7611\ m$$

$$= 49{,}5904\ m + 0{,}1058\ m + 2{,}4611\ m$$

$$= 52{,}1573\ m$$

Calculation of Theoretical Pump Power with Correction Factors

Assuming ρ = 20 kg/m^3, the pump power can be calculated as follows:

$$W_{pump} = \gamma \text{ x } \rho \text{ x } Q \text{ x } H_{eff}$$

W_{pump} = Fluid Power
ρ = Fluid density (kg/m^3)
γ = Fluid specific gravity (kg/m^2s^2)
Q = Capacity (m^3/s)
H_{eff} = Effective installation of Head (m)

With the data that has been obtained through the above calculations, the pump power is calculated based on the correction factor, with the formula:

1) $Q_0 = C_Q\ Q_W$
2) $H_0 = C_H\ H_W$
3) $\eta_0 = C_y\ \eta_W$

Q, H, and η represent capacity, total pump head and pump efficiency. Indexes w and 0 represent "clean water" and "thick liquid." With the data that has been obtained through this formula, the plotting process can be carried out with the graphic image below.

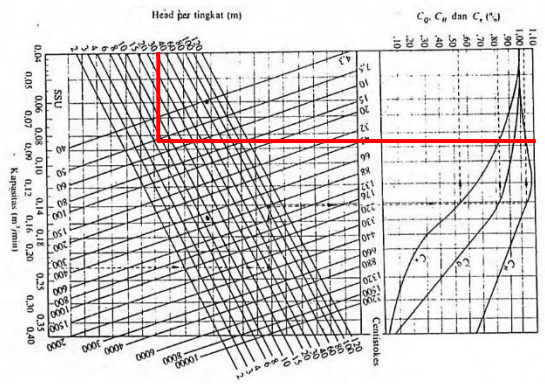


Figure 6. Small Capacity Oil Pump Correction Diagram

Then obtained:

$$Q_0 = 1{,}06$$

$$H_0 = 0.94$$

$$\eta_0 = 0.80$$

$$Q_w = \frac{Q_0}{C_-} = \frac{0{,}001}{0{,}94} = 10{,}2\ x\ 10^{-3}\ \frac{m^3}{s}$$

$$H_w = \frac{H_0}{C_-} = \frac{52{,}1573\ m}{1{,}06} = 49{,}205\ m$$

$$\gamma = \rho\ x\ g = 20\ \frac{kg}{m^2}\ x\ 9{,}81\ \frac{m}{s^2} = 196{,}2\ \frac{kg}{m^2 s^2}$$

So :

$$W_{pompa} = \gamma \; x \; Q_W \; x \; H_W$$

$$W_{pompa} = 196{,}2 \frac{kg}{m^2 s^2} \; x \; 10{,}2 \; x \; 10^{-5} \frac{m^3}{s} x \; 49{,}205 \; m$$

$$W_{pompa} = 98{,}471 \; w$$

$$W_{pompa} = 0{,}098 \; kW$$

$$W_{pompa} = \gamma \; x \; Q_W \; x \; H_W$$

$$W_{pompa} = 196{,}2 \frac{kg}{m^2 s^2} \; x \; 10{,}2 \; x \; 10^{-5} \frac{m^3}{s} x \; 49{,}205 \; m$$

$$W_{pompa} = 98{,}471 \; w$$

$$W_{pompa} = 0{,}098 \; kW$$

Shaft Power Calculation

Shaft power is the power used to drive the pump plus losses in the pump, the amount of which can be calculated as follows.

$$P_{shaft} = \frac{WHP}{\eta_p}$$

It is assumed that the value *of* η_p = 0.7 So the calculation of *the* P_{shaft} can be done as follows.

$$P_{shaft} = \frac{0{,}098 \; kW}{0{,}7}$$

$$P_{shaft} = 0{,}14 \; kW$$

Calculation of Motor Power

The amount of motor power used to drive the pump is determined from the following equation:

$$P_m = \frac{P(1 + a)}{\eta_t}$$

P_m = Starting motor power (kW)
α = Substitute factor (kW)
η = Transmission efficiency

Table 2. Reserve Factor Table

Starter Type	α
Induction Motor	0.1 – 0.2
Small Burning Motor	0.15 – 0.25
Big Burning Motor	0.1 – 0.2

From the table above, the type of motor that drives the induction motor is selected with a value of α = 0.1 As for transmission efficiency, because the pump and motor are coupled by a coupling, so the transmission efficiency value (η_t) = 0.95. So that the motor power (P_m) is obtained:

$$P_m = \frac{0{,}14\ kW\ x\ (0{,}1)}{0{,}95}$$

$$P_m = 0{,}147\ kW$$

Pump Selection

In this study, pump selection was based on specific rotation (ns).

1) Calculation of Pump Specific Speed (ns): Determination of the type of pump is based on the specific speed (ns) of the pump. Then it can be calculated:

$$n_s = 400\ rpm\ \frac{\sqrt{Q}}{n_{eff}{}^{3/4}}$$

$$n_s = 400\ rpm\ x\ \frac{\sqrt{3{,}6\frac{M^3}{h}\ x\ \frac{h}{60min}\ x\ \frac{gal.min}{3{,}785x10^{-3}m^3}}}{(52{,}1573\ m\ x\ \frac{ft}{0.3048\ m})^{3/4}}$$

$$n_s = 46\ rpm$$

So by plotting the value of ns in the figure below, it can be concluded that the pump to be selected is a pump with a gear pump type.

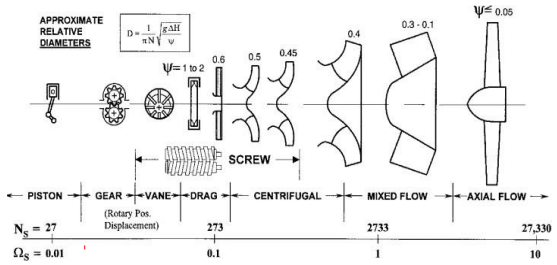


Figure 7. Relationship between Specific Speed and Pump Impeller Type

Conclusion Problem Formulation

Based on the power obtained from manual calculations of 0.147 kW, a Gear pump was selected with the following specifications.

1) Pump Type: Gear Pump;
2) Type: External Gear Pump;
3) Maximum speed: 400 rpm;
4) Maximum Total Head: 52.1573 m ;
5) Capacity: 10 Liters/Minute;
6) Maximum Output: 0.14 kW;
7) Maximum Pressure: 0.3 kgf/cm²; And
8) Manufacturing: ORIENTAL KOSHIM

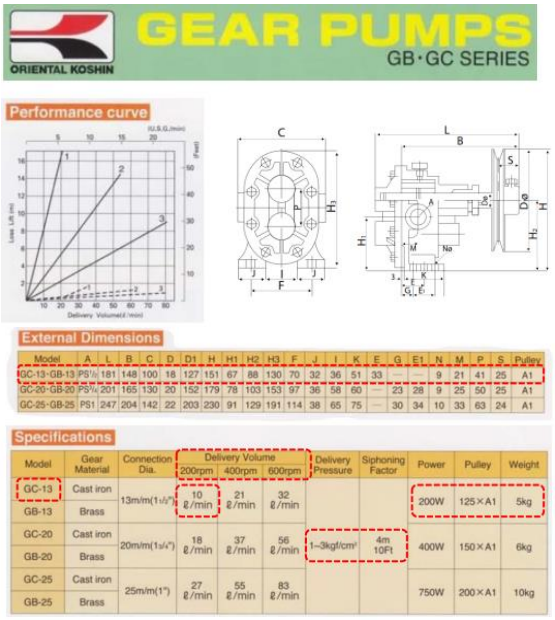


Figure 8. Gear Pumps & Actual Specifications

CONCLUSION

Selection of a pump with a high viscosity standard requires a larger head and higher motor rotation, this affects the performance of the sap flow rate which has thickened towards the evaporator and minimizes the occurrence of obstacles, during the process. The length of the process needed to circulate the sap from the tank to the economizer can be up to 10 to 15 minutes. So that the water content contained in the sap is reduced, from the conclusion above the fluid to be flowed is sap that is semi-finished (semi-condensed) and maximum specifications are needed.

Based on the calculation results that have been obtained, the following conclusions can be drawn:

1) The effective head of the pump installation is 52.1573 m and a capacity of 0.001 m^3/s;
2) The resulting specific spins are 46;
3) The theoretical power of the pump is 0.098 kW, while the resulting shaft power is 0.14 kW, the motor power is 0.147 kW; And

4) The External Gear Pump type was selected with a rotation of 400 rpm and a power of 0.14 kW.

In operating the pump, it must be at maximum performance so as not to interfere with the production process, for this reason it is necessary to have periodic maintenance by checking regularly and making sure to carry out plushing every time production is finished, in order to avoid blockages in pipe installations, due to the movement of dried sap.

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