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DESIGN OF CENTRIFUGAL PUMP FOR A DAIRY APPLICATION

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ABSTRACT

This project report details the design and analysis of a specialized centrifugal pump engineered for the gentle and efficient transfer of Buttermilk. The project's primary objective is to design all essential pump components, such as the impeller, casing, and associated elements, to meet the specified operational conditions, including a 3-meter static suction head, a 5-meter suction pipe, a 15-meter static delivery head, a 20-meter delivery pipe, a flow rate of 1000 liters per minute, and the unique requirement of pumping Buttermilk. The report also highlights the use of computational analysis, particularly CFD simulations, to validate and optimize the design, ensuring that the pump performs effectively while preserving the integrity of the Buttermilk during transport. This project's findings hold significance for the dairy industry, providing a blueprint for the development of hygienic and efficient Buttermilk transfer systems.

profound impact on the industry by minimizing product loss and ensuring the safe and efficient

I. INTRODUCTION

The dairy industry plays a pivotal role in providing consumers with safe and high-quality Buttermilk products. Central to this industry's success is the efficient and hygienic transfer of Buttermilk from production facilities to processing plants. In this context, the design and analysis of a centrifugal pump tailored for Buttermilk transfer are of utmost importance. This project endeavors to address the unique challenges and requirements associated with pumping Buttermilk—a sensitive and perishable fluid. The project focuses on the design and analysis of a centrifugal pump that can maintain the integrity of Buttermilk while meeting specific operational parameters. The fundamental challenge in designing such a pump lies in ensuring that it can handle Buttermilk with care, preventing excessive agitation and preserving its quality while simultaneously achieving the necessary flow rate and head. The operational conditions, such as the static suction head, suction and delivery pipe lengths, discharge rate, and the nature of the fluid itself, present a unique set of constraints. This project aims to create a design that not only fulfills these conditions but also optimizes the pump's performance, reliability, and efficiency.

Efforts to develop specialized pumps for the dairy industry are driven by the need to maintain strict hygienic standards and the preservation of Buttermilk's nutritional and sensory attributes. A pump designed specifically for Buttermilk transfer can have a movement of Buttermilk. The following sections of this report will outline the step-by-step design and analysis process, including material selection, impeller and casing design, and computational analysis to validate the proposed design. This project is a critical step toward advancing the technology that underpins the dairy industry, ensuring that the quality and safety of Buttermilk products are upheld throughout the production chain.

II. OBJECTIVES

The objectives of the project involving the Buttermilk transport pump system are likely to include:

1. **Design Optimization:** To design a pump system that optimally transports Buttermilk with minimum energy consumption, ensuring efficient and cost-effective operation.

2. **Fluid Handling:** To assess the system's ability to handle the specified flow rate of Buttermilk without causing any quality deterioration, such as frothing, separation, or damage.

3. **Hygiene and Safety:** To ensure that the materials used in the system are safe for contact with food products like Buttermilk, addressing health and safety standards and regulations.

4. **Sustainability:** To consider and incorporate eco-friendly and energy-efficient features in the design and operation of the system.

5. **Reliability:** To develop a reliable pump system that can consistently transport Buttermilk without unexpected downtime or maintenance issues.

6. **Performance Assessment:** To evaluate the pump system's performance, including factors such as head resistance, motor power, and efficiency, to ensure it meets the intended requirements.

7. **Quality Control:** To implement quality control measures to monitor the Buttermilk's quality and integrity during transportation, preventing contamination or spoilage.

8. **Cost-effectiveness:** To design a system that balances performance and cost, considering factors such as initial investment, maintenance, and energy expenses.

9. **Compliance:** To ensure that the system complies with relevant industry standards and regulations, particularly those related to food safety and hygiene.

These objectives collectively aim to develop a Buttermilk transport pump system that is not only efficient and reliable but also safe, cost-effective, and environmentally responsible.

III. PRE-REQUISITES

1) Specific speed (Ns) = N$\frac{N\sqrt{Q}}{(Hm)^{3/4}}$

Ns	Type of impeller
10-30	Radial flow -Low runner
30-50	Radial flow -Medium Runner
50-80	Radial flow – High runner
80-160	Mixed flow
160-500	Axial Flow

Table no.1

2) **Standard pipe sizes**: 1/2", 3/4", 1". 1^1/2". 2", 2^1/2", 3", 4", 5", ……….

3) For Lifting Water under room Temperature or for avoiding separation and cavitation Hs<8m (Cavitation Head).

$H_s = h_s + hf_s + h_{fittings}$ Here,

1. h_s = static suction head
2. hf_s = head loss due to friction
3. $h_{fittings}$ = Head loss due to fittings [$hf_s = F_sL_sV_s^2/2gd_s$]

4) total head /gross head / manometric Head: -

$H_m = H_s + H_d$

Where $H_d = h_s + hf_s + h_{fittings} + VD^2/2g$

Here

a) h_d = static delivery head

b) $Hfd = FLV^2/2gd$

5) Minor head loss:

h_L : 1) 0.8 m = Bends

2) 0.28 m = (F.V. + Strainer)

3) 0.3 m = (Foot valve)

4) 0.2 m = (Gate valve)

6) Recommended velocities:

a) V_s = 1.25 m/s to 5.5 m/s

b) V_d = 3.5 m/s to 7.5 m/s

IV. METHODOLOGY

The design procedure consists of seven procedures. They are as follows:

1. Design Discharge
2. Design of suction and delivery Valve
3. Calculation of manometric head
4. Motor selection
5. Impeller design
6. Design of pump shaft and impeller shaft
7. Casing selection

Table no.2

V. MATHEMATICAL CALCULATION

Step 1: Design Discharge:

Q = 1.05*(16.67*10^{-3}) Q =

17.5 * 10^{-3} m^3/s

Step 2: Design of Suction and delivery valve:

from mathematical Calculations, we got values of the diameter and velocities of suction and delivery pipe as follows:

D_s = 0.1016 m	V_s = 2.16 m/s
D_d = 0.0636 m	V_d = 5.5 m/s

Step 3: Calculation of manometric head (Hm):

Calculation of manometric head: Hm = Hs + Hd
From calculations Hm = 4.39 + 58.68 Hm = 63.07 m

Step 4: Motor Selection:

Motor Power = W*Q*Hm / ɳoverall
Where,

1. W = Weight density
2. Q = Discharge
3. Hm = Manometric head

From the above equation,
Motor power comes out to be

MP = 16*10^3 watt or 16 KW

Step 5: Impeller Design:

A) From pre-requisites,
Specific speed (Ns) = N*$Q^{1/2}$/ $Hm^{3/2}$
Ns = 17.02
By standards (pre-requisites)
Selecting radial flow type low runner type impeller

B) Impeller construction:
Our liquid is Buttermilk, so select closed type of impeller.

C) type of vane:
Selecting from Standard vane type , Backward curved vane for highest efficiency where Ɓ < 90^0 , ɳ > 50%.

D) Impeller material:
Selecting phosphorous bronze material from the market as our liquid is Buttermilk.

E) Design of suction nozzle and impeller diameter:

1) dia. of impeller at inlet (D1) = 90 mm
2) dia. of the impeller at an outlet (D2)=247 mm
3) Vane angle at inlet = 32.27^0
4) Vane Angle at outlet = 19.24^0
5) No. of vanes = 7
6) Vane thickness at inlet = 4 mm
7) Vane thickness at outlet = 12 mm

Step 6: Design of impeller shaft and pump shaft:

From the P.S.G. design data book, selecting bush type coupling for the operation.
From P.S.G design data book 7.108, selecting coupling no.4
Shaft diameter = 30 mm
Bearing selection:
a) life in hours : 24000 hrs
b) life in million per revolution : 4147 MR.

Step 7: Casing selection:

Selecting Vortex casing because eddy shock is minimal and the cost is moderate.
By calculation diameter of casing is as follows:

θ	65^0	155^0	245^0	345^0
Dθ	9.25	14.38	17.95	20.99
Cθ	138.12	140.64	142.38	143.96

VI. DRAFTIN G AND MODELLING

Drafting of Centrifugal pump:

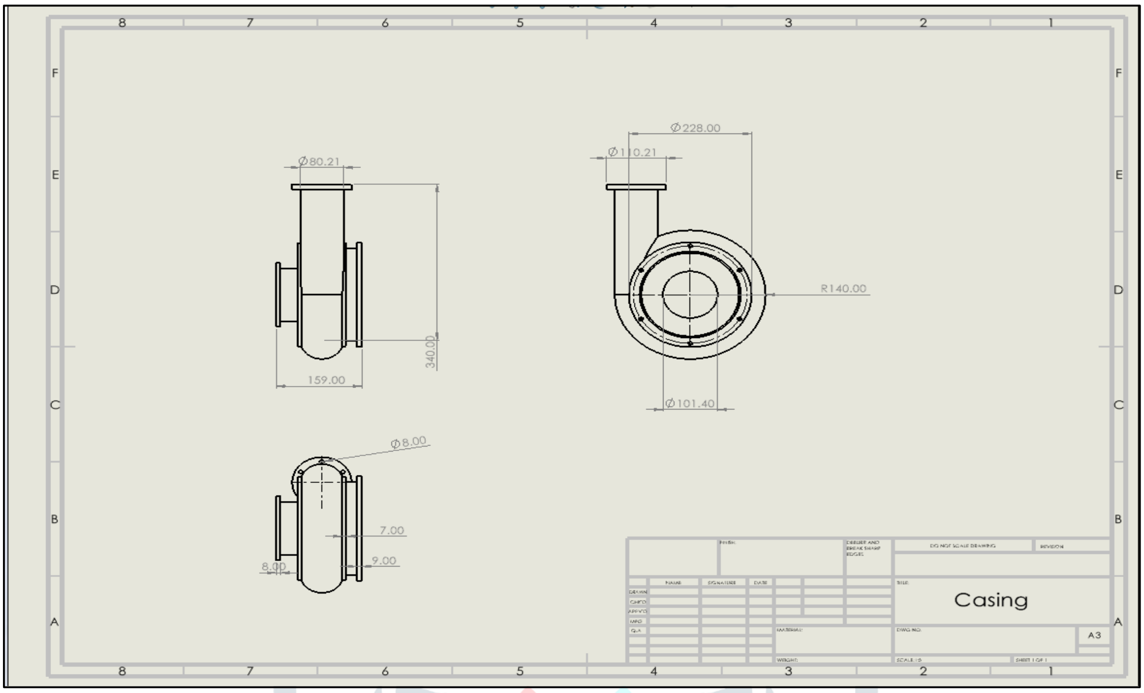

Fig. Casing Draft

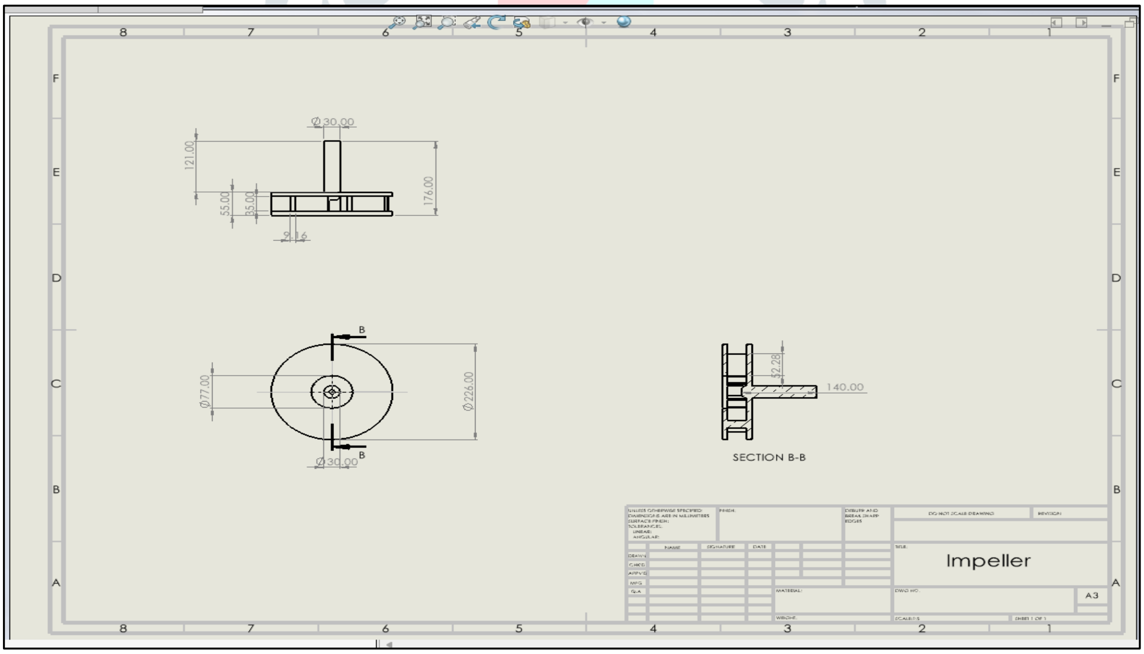

Fig. Impeller Draft

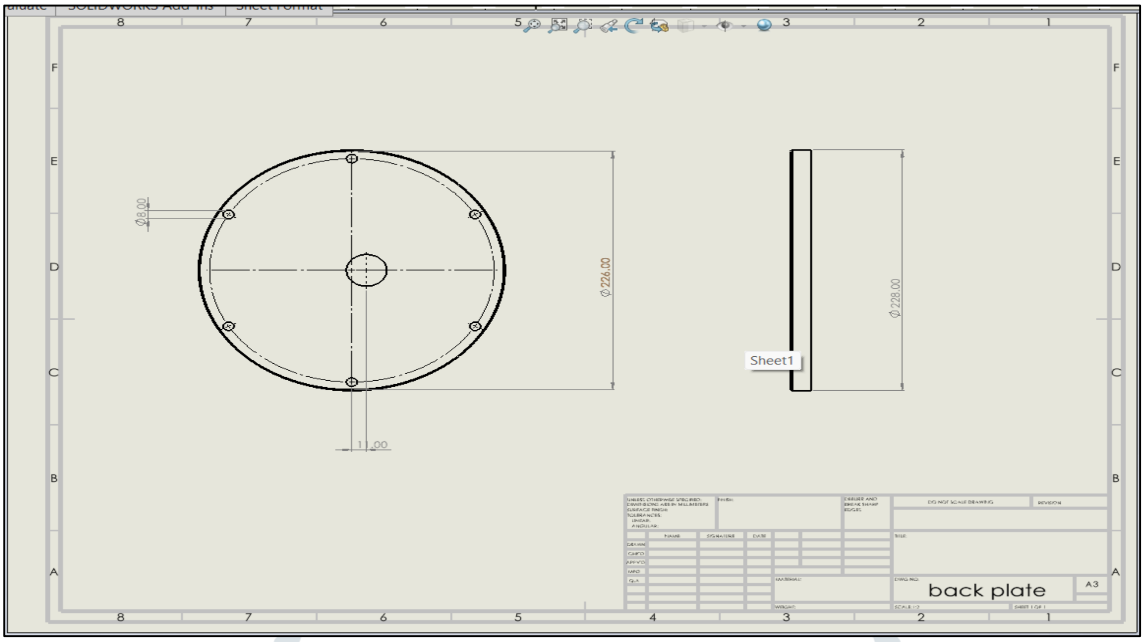

Fig. Backplate draft

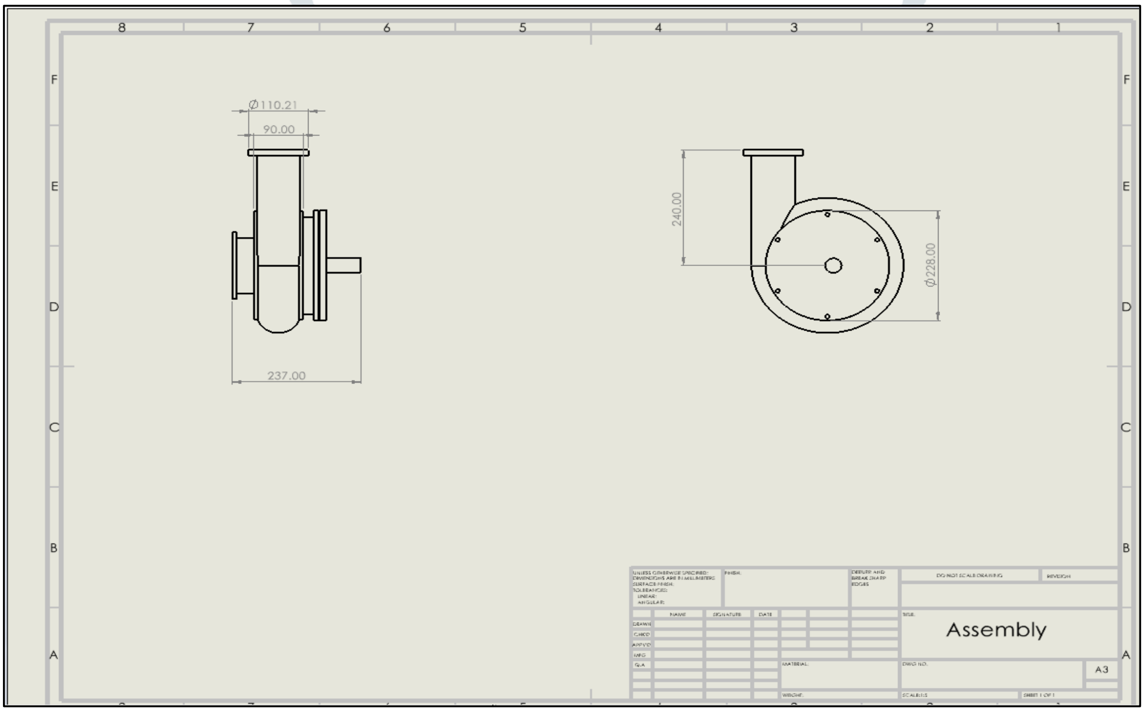

Fig. Assembly Draft

Modeling of Centrifugal Pump:

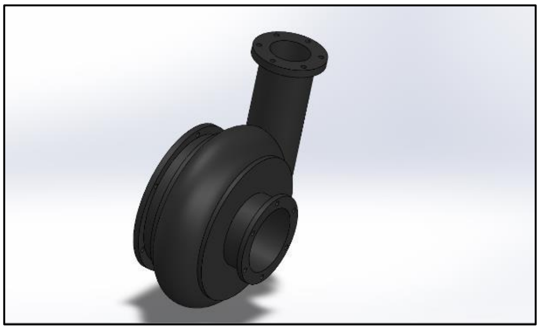

Fig. Casing

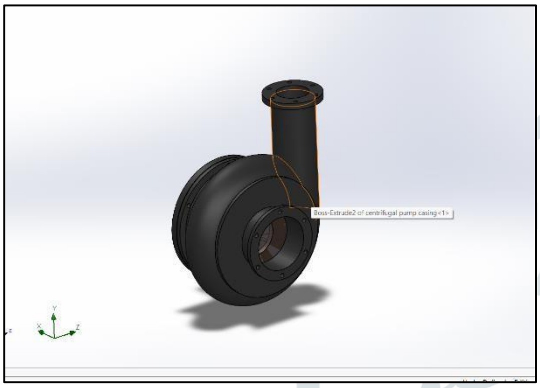

Fig. Assembly

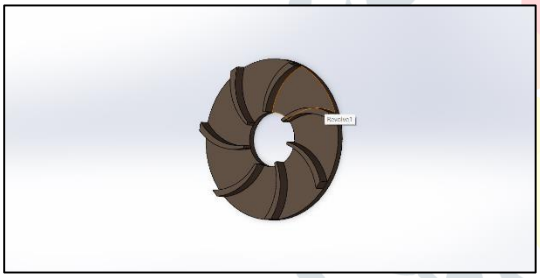

Fig Impeller cross-section

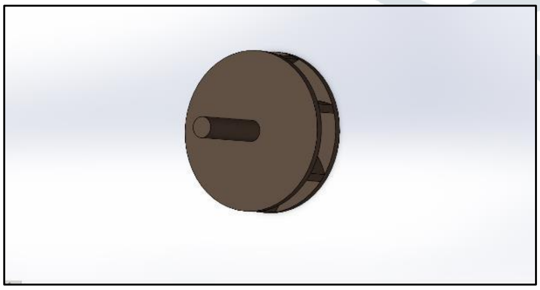

Fig. Impeller

VII. RESULTS AND DISCUSSION

From mathematical analysis we can say that the following parameters are satisfied by our design of the Centrifugal pump:

Result table

Parameters	Description
Static suction head	3 meters
Suction pipe	5 meters
Static delivery head	15 meters
Delivery pipe	20 meters
Flow rate	1000 Lpm
Fluid to be flown	Buttermilk
Design discharge	$17.5 * 10^{-3}$ m^3/s
Velocity at Suction	2.16 m/s
Velocity at Delivery	5.5 m/s
Manometric head	63.07 m
Motor power	16 KW
Specific speed of impeller	17.02
Impeller type	Backward curved vane
Impeller material	Phosphorous bronze
Casing type	Vortex casing
Casing material	Grey cast iron

Table no.3

The discussion of the Buttermilk transport pump system highlights the system's effective design and performance. It maintains the specified flow rate, suitable velocities at both ends and a high manometric head for overcoming resistance. The 16-kilowatt motor power aligns with operational needs. The impeller's specific speed, type, and material make it well-suited for the task, ensuring efficient and safe Buttermilk transport. The choice of a vortex casing made from grey cast iron enhances system stability. In summary, the results indicate a well-designed pump a system capable of efficiently and safely transporting Buttermilk, with implications for both the dairy industry and pump engineering.

VIII. CONCLUSION

In conclusion, the analysis of the Buttermilk transport pump system presented in this study reveals important findings regarding its performance and design characteristics. The system demonstrated the capability to handle the specified flow rate, ensuring the efficient transport of Buttermilk. The velocity measurements at the suction and delivery ends indicate appropriate fluid dynamics within the system. The calculated manometric head of 63.07 meters underscores the system's ability to overcome head resistance effectively. The motor power requirement of 16 kilowatts aligns with the operational needs of the pump. The specific speed of the impeller, measured at 17.02, suggests that the impeller design is well-suited for the given application. The use of phosphorous bronze for the impeller material is appropriate for contact with Buttermilk, ensuring hygienic and corrosion-resistant operation. The choice of a vortex casing made of grey cast iron provides structural stability and durability.

Overall, the results indicate that the pump system is well-designed and capable of efficiently transporting Buttermilk while meeting the specified requirements. This study's findings are valuable for both the dairy industry and pump engineering, highlighting the importance of proper design and material selection for ensuring the safe and efficient handling of food products such as Buttermilk.

IX. REFERENCES

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