VIETNAM NATIONAL UNIVERSITY HO CHI MINH CITY
HCM UNIVERSITY OF TECHNOLOGY
FACULTY OF MECHANICAL ENGINEERING - MECHATRONICS DEPARTMENT

ME3011

Design Project Report

Submitted To:
Nguyen Tan Tien
Asst. Professor
Faculty of Mechanical
Engineering

Submitted By:
Nguyen Quy Khoi
1852158
CC02
HK192

HCMC, October 2, 2020

Acknowledgements

I would like to give a special thank to Prof. Nguyen Tan Tien, my supervisor to instruct me and fix my report to meet industrial standard.

Abstract

In machine design, every machine element must be calculated in a systematic matter. In this course, students are provided with essential skills to formulate almost every dimension manually, thus further improving their engineering skills before engaging the high-energy, fast-paced workforce.

When a machine element is being developed, it must satisfy some key engineering specifications such as being able to operate under designated lifespan, low cost and high efficiency. Other aspects are less important but also determined the overall design of the element include compactness, noise emission, appearance, etc.

To optimize the process of machine design, the general principles are considered as follows:

1. Identify the working principle and workload of the machine.
2. Formulate the overall working principle to satisfy the problem. Proposing feasible solutions and evaluating them to find the optimal design specifications.
3. Find force and moment diagram exerting on machine parts and characteristics of the workload.
4. Choose appropriate materials to make use of their properties and improve efficiency as well as reliability of individual elements.
5. Calculate dynamics, strength, safety factor, etc. to specify dimensions.
6. Design machine structure, parts to satisfy working condition and assembly.
7. Create presentation, instruction manual and maintenance.

In this report, I will design a fairly simple system to provide a concrete example of finishing all the tasks above.

Contents

List of Figures

List of Tables

Chapter 1

Design Problem

Nomenclature

C_a	number of shift daily, shifts	P	design power of the mixing tank, kW
K_{ng}	working days/year, days	T_1	working torque 1, $\mathrm{N \cdot m}$
L	service life, years	T_2	working torque 2, $\mathrm{N \cdot m}$
n	rotational velocity of the mixing tank, rpm	t_1	working time 1, s
		t_2	working time 2, s

1.1 Problem

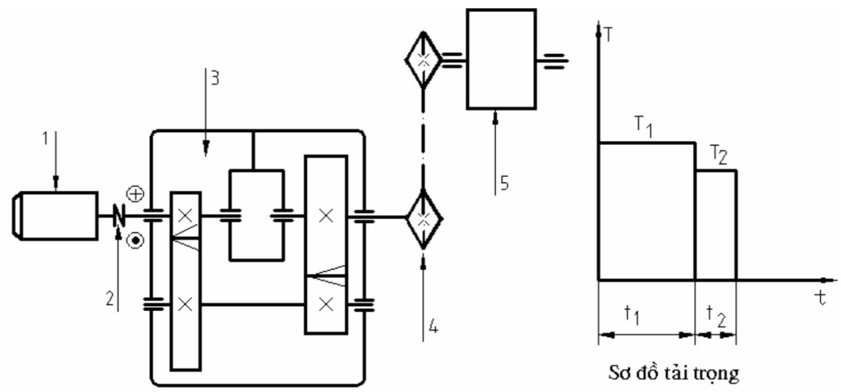

Figure 1.1: Working principle diagram and workload of the mixing machine: 1) electric motor, 2) elastic coupling, 3) two-stage coaxial helical speed reducer, 4) roller chain drive, 5) mixing tank (one-directional, light duty, operate 1 shift, 8 hours each)

1.2 Mixing machine parameters

From the parameters given in the document, we have:

$P = 7$ (kW)	$t_1 = 15$ (s)
$n = 65$ (rpm)	$t_2 = 11$ (s)
$L = 8$ (years)	$T_1 = T$ (N · m)
$K_{ng} = 260$ (days)	$T_2 = 0.7T$ (N · m)
$Ca = 1$ (shifts)	

1.3 Requirements

- 01 report.
- 01 assembly drawing.
- 01 detailed drawing.

1.4 Design problem

1. Decide the working power of the electric motor and transmission ratio of the system.
2. Calculate and design machine elements:
   (a) Calculate system drives (belt, chain or gear).
   (b) Calculate the elements in speed reducers (gears, lead screws).
   (c) Draw and calculate force diagram exerting on the transmission elements.
   (d) Calculate, design shafts and keys.
   (e) Choose bearings and couplings.
   (f) Choose machine bodies, fasteners and other elements.
3. Choose assembly tolerance.
4. Bibliography

Chapter 2

Choose Motor

Nomenclature

n_{sh}	rotational speed of shaft, rpm	u_{sys}	transmission ratio of the system
P_{mo}	calculated motor power to drive the system, kW	T_{mo}	motor torque, $\mathrm{N \cdot mm}$
		T_{sh}	shaft torque, $\mathrm{N \cdot mm}$
P_{sh}	operating power of shaft, kW	η_b	bearing efficiency
P_w	operating power of the belt conveyor given a workload, kW	η_c	coupling efficiency
		η_{ch}	chain drive efficiency
u_1	transmission ratio of quick stage	η_{hg}	helical gear efficiency
u_2	transmission ratio of slow stage	η_{sys}	efficiency of the system
u_{ch}	transmission ratio of chain drive	$_1$	subscript for shaft 1
u_h	transmission ratio of speed reducer	$_2$	subscript for shaft 2
		$_3$	subscript for shaft 3

Known parameters From Chapter 1, we know that:
$P = 7\,\mathrm{kW}$, $n = 65\,\mathrm{rpm}$
$T_1 = T$, $T_2 = 0.7T$
$t_1 = 15\,\mathrm{s}$, $t_2 = 11\,\mathrm{s}$

2.1 Choose motor for the mixing tank

The choice of motor will affect the entire system, so it is necessary to pick the right one.

Calculate system overall efficiency From Table 2.3 [1]:

- 1 elastic coupling which connects the motor and the speed reducer. $\eta_c = 1$
- 4 sealed rolling bearings. 3 of which belong to the speed reducer and the last one is used for the shaft of the mixing tank. $\eta_b = 0.99$

- 2 sealed pairs of helical gear drive which connect the shafts inside the speed reducer. $\eta_{hg} = 0.97$

- 1 sealed roller chain drive connecting the speed reduce and the mixing tank. $\eta_{ch} = 0.96$

Aggregate all efficiencies yields:

$$\eta_{sys} = \eta_c \eta_b^4 \eta_{hg}^2 \eta_{ch} = 1 \times 0.99^4 \times 0.97^2 \times 0.96 = 0.87$$

Calculate required power for operation The power P from Chapter 1 applies for systems with single loading input. In case of varying load each cycle, the equivalent power is calculated using Equation 2.13 [1]:

$$P_w = P\sqrt{\frac{\left(\frac{T_1}{T}\right)^2 t_1 + \left(\frac{T_2}{T}\right)^2 t_2}{t_1 + t_2}} = 7 \times \sqrt{\frac{\left(\frac{T}{T}\right)^2 \times 15 + \left(\frac{0.7T}{T}\right)^2 \times 11}{15 + 11}} = 6.2\ (\text{kW})$$

$$P_{mo} = \frac{P_w}{\eta_{sys}} = \frac{6.2}{0.87} = 7.14\ (\text{kW})$$

Calculate n_{mo} The purpose is to Using Table 2.4 [1]:

- 2-level transmission speed reducer, spur gear type. $u_h = 11$

- 1 chain drive, roller type. $u_{ch} = 2$

Multiplying all transmission ratio yields:
$u_{sys} = u_h u_{ch} = 11 \times 2 = 22$
$n_{mo} = u_{sys} n = 22 \times 65 = 1430$ (rpm)

Choose motor To work normally, the maximum operating power of the chosen motor must be no smaller than P_{mo}. In similar fashion, its rotational speed must also be no smaller than n_{mo}. Thus, from Table P1.3 [1], we choose motor 4A132S4Y3 which operates at 7.5 kW maximum and 1455 rpm, which makes $n_{mo} = 1455$ rpm.
Recalculating u_{sys} with the new P_{mo} and n_{mo} derived from the chosen motor, we obtain:

$$u_{sys} = \frac{n_{mo}}{n} = \frac{1455}{65} = 22.38$$

Retaining the transmission ratio of the speed reducer (i.e. let $u_h = const = 11$), the new transmission ratio of the chain drive is then:

$$u_{ch} = \frac{u_{sys}}{u_h} = \frac{22.38}{11} = 2.03$$

2.2 Calculate power, rotational speed and torque

Let P_{sh1}, n_{sh1} and T_{sh1} be the transmitted power, rotational speed and torque onto shaft 1, respectively. Similarly, P_{sh2}, n_{sh2} and T_{sh2} are the transmitted parameters onto shaft 2 and P_{sh3}, n_{sh3} and T_{sh3} are used for shaft 3. Unless otherwise stated, these notations will be used throughout the next chapters.

Power The entire system is described followed by calculation as follows:
Chain drive power is affected by the bearings on the shaft of the mixing tank.
$P_{ch} = \dfrac{P_w}{\eta_b} = \dfrac{6.2}{0.99} = 6.26$ (kW)
Shaft 3 power is affected by the chain drive.
$P_{sh3} = \dfrac{P_{ch}}{\eta_{ch}} = \dfrac{6.26}{0.96} = 6.52$ (kW)
Shaft 2 power is affected by the bearings and gear drives on shaft 3.
$P_{sh2} = \dfrac{P_{sh3}}{\eta_b \eta_{hg}} = \dfrac{6.52}{0.99 \times 0.97} = 6.79$ (kW)
Shaft 1 power is affected by the bearings and gear drives on shaft 2.
$P_{sh1} = \dfrac{P_{sh2}}{\eta_b \eta_{hg}} = \dfrac{6.79}{0.99 \times 0.97} = 7.07$ (kW)

Rotational speed The design goal of the speed reducer is to lubricate both driven gears equally, which has a size disadvantage. Therefore, the transmission ratio of each pair of gears is calculated using Equation 3.12 [1]:

$$u_1 = u_2 = \sqrt{u_h} = \sqrt{11} = 3.32$$

Then,
from motor to shaft 1: $n_{sh1} = n_{mo} = 1455$ (rpm)
from shaft 1 to shaft 2: $n_{sh2} = n_{sh1}/u_1 = 1455/3.32 = 438.70$ (rpm)
from shaft 2 to shaft 3: $n_{sh3} = n_{sh2}/u_2 = 438.70/3.32 = 132.27$ (rpm)

Torque Subsequently, the torque is calculated as follows:
$T_{mo} = 9.55 \times 10^6 \times P_{mo}/n_{mo} = 9.55 \times 10^6 \times 7.14/1455 = 46892.66$ (N · mm)
$T_{sh1} = 9.55 \times 10^6 \times P_{sh1}/n_{sh1} = 9.55 \times 10^6 \times 7.07/1455 = 46423.73$ (N · mm)
$T_{sh2} = 9.55 \times 10^6 \times P_{sh2}/n_{sh2} = 9.55 \times 10^6 \times 6.79/438.70 = 147857.49$ (N · mm)
$T_{sh3} = 9.55 \times 10^6 \times P_{sh3}/n_{sh3} = 9.55 \times 10^6 \times 6.52/132.27 = 470919.44$ (N · mm)

In summary, we obtain the following table:

	Motor	Shaft 1	Shaft 2	Shaft 3
P (kW)	7.14	7.07	6.79	6.52
u	-	1	3.32	3.32
n (rpm)	1455	1455	438.70	132.27
T (N · mm)	46892.66	46423.73	147857.49	470919.44

Table 2.1: Output specifications

References

[1] Chat Trinh and Uyen Van Le. *Thiet Ke He Dan Dong Co Khi*. 6th ed. Vol. 1. Vietnam Education Publishing House Limited, 2006.