**TECHNICAL UNIVERSITY OF CLUJ-NAPOCA**

FACULTY OF AUTOMOTIVE, MECHATRONICS AND MECHANICAL ENGINEERING

DEPARTMENT OF MECHATRONICS AND MACHINE DYNAMICS

**SEMESTER PROJECT**

**SINGLE-STAGE INDUSTRIAL GEARBOX**

at

**ELEMENTS OF MECHANICAL ENGINEERING**

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**Chapter 1. Introduction**

**1.1 Project theme**

Design a single stage speed reducer gearbox based on a spur gear (an elementary gearing) that can be used for an industrial mixer. The conceptual design of the mechanical power transmission is presented in Fig. 1.1. It consists of a three-phase induction motor (1), a single stage spur gear reducer (2), two coupling element (3) and the industrial process (4). The material used for the gears is OLC 45 quality carbon steel and for the shafts OL 50 carbon steel. Each student will use their given input data to design the mechanical power transmission.



***Fig. 1.1.*** *Kinematic diagram of the mechanical power transmission.*

Input data:

*n = 42* student number

*P2* = 9.8 [kW] – output power

*ns* = 1000 [RPM] – synchronous speed of the motor

*i12* = 7.2 (transmission ratio)

*z1* = 25 (number of teeth of the input gear)

*Lh* = 15.000 [hours] - number of running hours

**1.2 Gear speed reducers**

**1.2.1 Introduction**

Speed reducers, also referred to as gearboxes or gear reducers, are enclosed mechanical gadgets between a motor and a piece of machinery that utilize gear trains to increase torque and lower speeds on a drive. In general, a speed reducer is a housing that contains no less than two sets of gears (depending on ration desired), supporting bearings, shafts and seals for realizing gear, worm or gear-worm types of transmission, thus making it a very important part of mechanical power transmission systems.

**1.2.2 Types of speed reducers**

1. According to the different stages types of gear reducers, there are single stage gear drive and multi-stages speed reductor.
2. According to the shape of the gears, there are cylindrical gear reducer, bevel gear reducer and bevel-helical gear reducer.
3. According to the assembling of transmission, there are parallel shaft gear motor, right angle shaft gear motor speed reducer speed reduction gearbox and in-line shaft motor reductor.

**1.2.3 How does it work?**

A gear reducer is generally used for low-speed and high-torque transmission systems. The output gear of a speed reducer has more teeth than the input gear. So, while the output gear might rotate more slowly, reducing the speed of the input, the torque is increased. To sum up, the combination of large and small gears will reduce speed while increasing the torque speed reducer structure. The ratio of the number of rotations of a driver gear to the number of rotations of a driven gear is known as a gear ratio. By changing the torque/speed output, a machine (usually a motor or an engine) can be precisely controlled and better results attained. Torque output of a speed reducer can be calculated by multiplying the output torque of the motor and reduction ration (Note that the actual torque output of the speed reducer shall not exceed its rated torque). In decelerating the motor, gearboxes also reduce the reflected load inertia to the motor by a factor of the square of the gear ratio.

**Chapter 2. Selecting The Actuator**

* 1. **Selecting the AC motor**

To select the AC motor, we have to find out the motor’s supply frequency in hertz and the number

of pairs of magnetic poles (p)

*f- motor supply's frequency in hertz*

*p-number of pairs of magnetic poles*

So we have: , and P = 3

The **Actuator power**, Pm [kW] is calculated by next formula:

where,

To find we apply:

*one pair of bearings efficiency* =

We chose:

We know that and ns = 1000 and we can select the AC motor. The nominal speed chosen

must be smaller than the syncronous speed.

The selected **AC motor** for the current attributes is the **ASU 71a – 6** with  = 900 and Pn=7,5.

Now, the slip is calculated with the formula:

s =

*-synchronous speed [RPM]*

*-rotor nominal speed [RPM]*

**2.2 Power transmission kinematics**

**1. Determining the number of teeth of the output gear:**

To determine the number of teeth of the output gear we calculate from:

In our case .

The condition is met so will be used further.

**2. Determining the input/output shaft speed:**

*[RPM]*

*[RPM]*

**3. Determining the power transmitted by input shaft:**

1. **Determining the input/output shaft torque:**

**Chapter 3. Spur Gear Design**

**3.1 Gears tooth strength analysis and verification**

**Pitch line velocity** is calculated as:

= 3.2849 [m/s]

Where:

**Equivalent torque** is:

[daN\*cm] = 115.31 [

**Load (service) factor** is:

Where:

The load distribution factor takes values between 1 and 1.22. For me, is 1.13. The load dynamic factor considers errors of execution and assembly of the gears and should be chosen based on precision class and pitch line velocity. In our case it is 1.2

**The contact stress** represents the distance between the centers of the gears and is calculated according to the formula:

22.418

The pressure angle is and the axial coefficient is chosen for a medium speed reducer with a value of 0.4 .

is the closest whole value greater than , which is 150 in [mm]. With this value we find the minimum gear module:

Now, we choose m according to the gear module ISO, m = 2.25 (witch is greater than ).

**Bending stress (verification)**

,

**The modular coefficient of the gear** needed is calculated from:

Where:

The bending stress must be smaller than the allowable bending stress

= 1886

Where

C-safety coefficient

C = between 1.5 and 2 = 1.9 and 43(4300 in our case) from the table.

**Spur Gears Design**

The gear face width is B= 75 mm.

45

**Output gear (round up the obtaied value)**

**Input gear (round up the obtaied value)**

10,1875

**Chapter 4. Output Shaft Design**

* 1. **Pre-dimensioning**

The **pre-dimensioning diameter is determined at torsional stress** because at this point the length of the shaft is not known.

[cm] = 6.33 [cm]

The **torsional shear stress** must have values between 120 and 250. Low values are used in order to consider the bending effect. In this case we consider , Next, we have to choose a value for the preliminary diameter that must be greater or equal to

We choose = 65 mm.

**The preliminary length of the output shaft** is:

( 36 )

**Forces acting on a spur gear mesh**

[cm]

The tangential force:

= 332 [daN]

The radial force:

**4.2 Shaft loading diagram**

Reaction forces and bending moments on the:

Vertical plane:

= 166 [daN]

782.973[daN/cm]

Horizontal plane:

We obtain the resulting reaction forces:

[daN] = 177[daN]

From which we obtain the resulting bending moment

[daN cm] = 833.22 [daN/cm]

The equivalent bending moment is :

[daN cm] = 386.96[daN/cm]

For a material OL50

So,

**The diameter in critical section of the shaft**

= 2,061 [cm]

( 47 )

Because a key will be used to assembly the gear with the shaft, the value of must

be increased by 4%. The results are rounded to -> d = 55 [mm]

**4.3 Final geometry of the output shaft**

**The diameter of the end shaft** is

= 3.67 [cm]

( 48 )

Where 0,63 \*

( 49 )

we choose a final value of diameter

38 [mm] (

For the **length of the shaft** we choose a short series

The **seal diameter** is chosen as

The length

0,6 \* 50 = 30 [mm]

The **bearing diameter** is:

And **the shoulder diameter and length** are:

57[mm]

3 [mm]

**4.4 Choosing longitudinal parallel key**

Keys are used to transmit torque from a rotating machine element to the shaft. There are two failure mechanisms for a key: it can be sheared off or it can be crushed due to the compressive bearing forces.

To calculate the required key length contact stress we will choose the dimensions based on d.

b=6 [mm]

h=6 [mm]

The minimum key length is

=0.0743[cm]

Where,

The final length of the key must be correlated with the width of the output gear. We must verify the relation:

2.58 [cm]

We choose

Next, we must verify the shaft key at shear stress:libe

Where,

Because the loading capacity is usually considered 1.5-times higher than with one key, dimensioning at contact stress and verification at shear stress use the following formulas:

338.2

must be smaller than which is 960

We verified the relationship: > 60[mm] > 50 [mm] >48[mm]

**4.5 Verification of shaft deflection and critical speed**

**The deflection in the vertical plane is:**

= 8.971[cm]

Where,

**The deflection in the horizontal plane is:**

Where,

3,051 [cm]

**The vibrations:**

The static deflection is:

[cm]

The critical speed is:

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