HCM UNIVERSITY OF TECHNOLOGY

MACHINE ELEMENTS

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Lab Report

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Contents

List of Tables

List of Figures

Chapter 1

Slip coefficient and Slip curve of Belt drive

1.1 Nomenclature

a	center distance, mm	n	rotational speed, rpm
f	coefficient of friction	Q	load, $kg \cdot F$
d	diameter, mm	α	wrap angle, $\circ$
F_0	initial tension, N	β	slack angle due to load Q, $\circ$
F_{ms}	friction force, N	Δh	difference between h_i and h_f, mm
F_t	tangential force, N	ϕ	drag coefficient
g	gravitational acceleration at sea level, m/s^2	ϕ_{crit}	critical drag coefficient
		$\bar{\xi}$	average slip coefficient
h_f	distance between outer sides of the belt after applying load Q, mm	$\tilde{\xi}$	relative slip coefficient
		ξ	slip coefficient
h_i	distance between outer sides of the belt before applying load Q, mm	$_1$	subscript for driving pulley
		$_2$	subscript for driven pulley

1.2 Aim

1. Investigating on the slip phenomenon of belt drive.
2. $\tilde{\xi}$ and ξ determination.
3. Determining F_0.
4. Drawing slip curve - load diagram.

1.3 Technical rules on safety

Students must comply with the technical rules on safety in the laboratory.

1.4 Conducting and dealing with experimental results

1.4.1 Determine the parameters for the experimental model

- Diameters of the pulley:

  $d_1 = 67.8\,\text{mm}$

  $d_2 = 165\,\text{mm}$

- Belt type: flat belt.
- Rotational speed: see table (1.1).
- Contact angles:

  $\alpha_1 = 180 - 57 \times \dfrac{d_2 - d_1}{a} \approx 162.3°$

  $\alpha_2 = 180 + 57 \times \dfrac{d_2 - d_1}{a} \approx 197.6°$

- Initial tension:

  $h_i = 124\,(\text{mm}),\ h_f = 94\,(\text{mm}),\ Q = 4.1\,(\text{kg}\cdot\text{F})$

  $\Delta_h = |h_f - f_i| = 30\,(\text{mm}),\ \beta = \arctan\dfrac{2\Delta_h}{a} \approx 10.78°$

  $F_0 = \dfrac{Qg}{2\sin\beta} \approx 107.48\,(\text{N})$

- Tangential force: see table (1.1).

1.4.2 Measure and deal with the measured results of F_0

1.4.3 Measure and deal with the measured results in order to determine the $\bar{\xi}$ and ϕ.

Filling out the measured results in table 1.1 and calculate the coefficients. Using the formulas $\xi = 1 - \dfrac{d_2 n_2}{d_1 n_1}$ and $\phi = \dfrac{F_t}{2F_0}$, we obtain the following table:

No.	F_0 (N)	n_1 (rpm)	n_2 (rpm)	ξ	F_t (N)	ϕ
1	107.48	283.62	114.04	0.018	3.1	0.014
2	107.48	330.47	133.35	0.018	8.8	0.041
3	107.48	273.83	110.27	0.02	14.4	0.067
4	107.48	307.52	123.71	0.021	20.2	0.094
5	107.48	354.42	142.43	0.022	22.1	0.103

Table 1.1: Experimental results of the slip coefficient

Averaging the values of ξ yields $\bar{\xi} \approx 0.0198$

1.4.4 Establish a graph of slip curve

From the data above, we can approximate the best fitted line through the data points (assuming linearity since ϕ does not reach critical value)

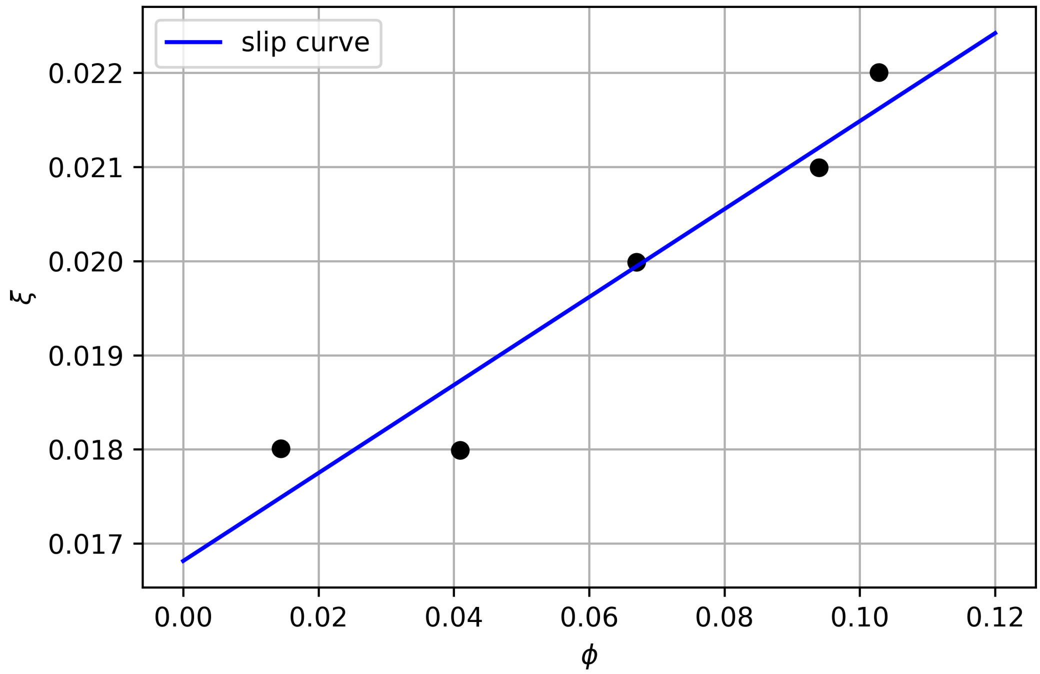

Figure 1.1: The clip curve is established by the experimental data.

1.5 Discussion and conclusions

In summary:

- Slip coefficient from experiment is in allowable range ($0.01 \div 0.02$).
- The slip curve is in agreement with theory (error is smaller than 5%). Since ϕ does not exceed critical value (the motor is frequency-controlled), we can safely assume linearity for the curve.
- Possible errors:
  - manually measure dimensions in the kit.
  - rounding.
  - incorrect reading of rotational speeds.
- The slip coefficient and slip curve is considerably accurate due to reliable instrument

1.6 Review questions

1. Define the types of slip in the belt drive.
2. The method determining the slip coefficient in the belt drive.
3. The relationship between F_t and F_0
4. Present the formula determining ϕ and the ϕ_{crit} of the kinds of belt drives.

Chapter 2

Determination of Tensile Force of Bolts

2.1 Nomenclature

$[F_{cb}]$	tension force at failure of common bolt, N
$[F_{sb}]$	tension force at failure of steel bolt, N
$[\sigma_{cb}]$	tension at failure of common bolt, MPa
$[\sigma_{sb}]$	tension at failure of steel bolt, MPa
d	nominal diameter of M8 bolt, mm
F_c	tension force of hydraulic cylinder
F_{cb}	tension force at failure of common bolt, N
F_{sb}	tension force at failure of steel bolt, N

2.2 Aim

1. Help students understand more clearly about tensile force of some types of steels, the relation between central M_k and localized strain of material.
2. Help students approach methods, measuring devices in determining tensile force.

2.3 Safety Procedures

1. Safeguard is compulsory when straining the bolt.
2. Close the machine gate when operating.

2.4 Experimental Report

No.	Experiment with $d = 8$ mm	
	F_{sb}	F_{cb}
1	33898	37377
2	33574	37053
3	34211	36426
4	33727	37053
5	34211	36426
Avg	33323.4	36867

Table 2.1: Tension force at failure of common and steel bolts

2.5 Data plot

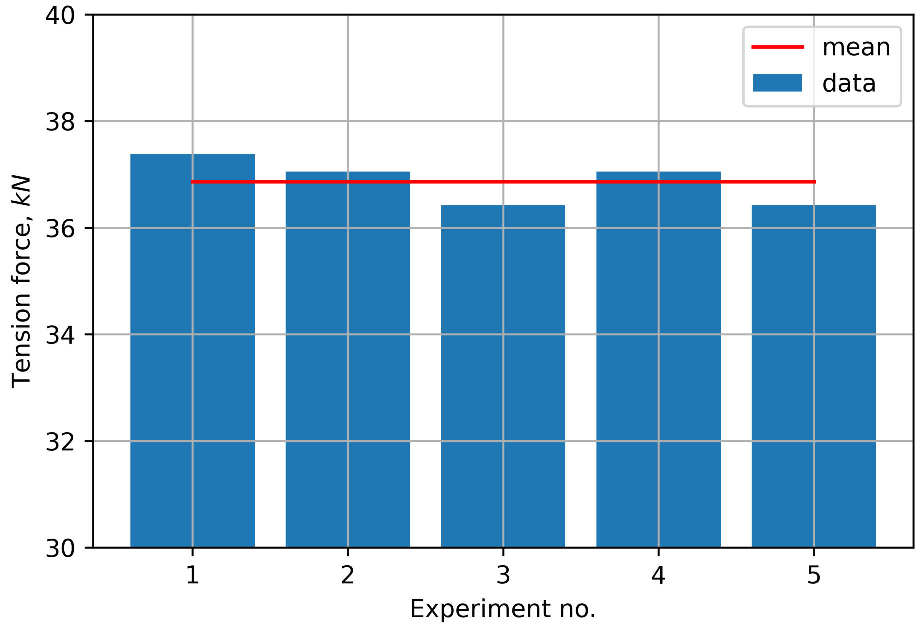

Figure 2.1: Tension force at failure of common bolt

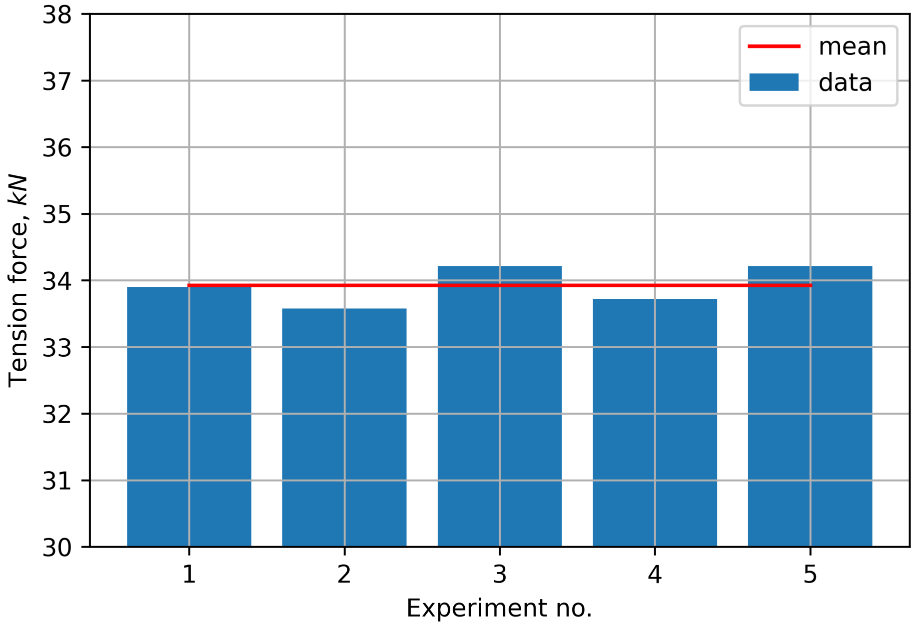

Figure 2.2: Tension force at failure of steel bolt

Chapter 3

Determination of Tightening Coefficient of Threaded Joints

3.1 Nomenclature

d	nominal diameter of the bolt, mm
F_v	tightening force, N
K	tightening coefficient
T_v	tightening moment, $\mathrm{N \cdot m}$

3.2 Aim

1. Understand deeply the theory of screw coupling.
2. Use the wrench to determine the T_v.
3. Understand the principle and use load cell to measure the F_v on the bolt;

4. Determine $K = \dfrac{1000T_v}{Vd}$ and understand the relationship between T_v and F_v, as well as the factors of assembling condition of the joint.

3.3 Technical rules on safety

Students must comply with the technical rules on safety in the laboratory.

3.4 Experimental report

3.4.1 Determine the parameters of threaded joint and measuring tools

3.4.2 Experimental results

No.	Nominal diameter $d = 8$ (mm)		
	T_v (N · mm)	F_v (N)	K
1	16.5	28.75	
2	17.6	324.3	
3	19.1	393.8	
4	22.4	4872	
5	27.9	622.9	
Average value			

Table 3.1: The experimental results

3.4.3 $K - T_v$ diagram

3.4.4 Compare theoretical results with experimental results

Using formula $K = \frac{T_v}{V_d} = 0.5\left(\frac{d_2}{d}\right)\left[\left(\frac{D_{tb}}{d_2}\right)f + \tan(\gamma + \rho')\right]$

3.5 Discussion and conclusions

3.6 Review questions

1. Show the role and importance of finding F_v and T_v in reality.

2. Explain the meaning of K.

3. Explain the principles of ultrasonic operation and force measuring tool.

4. Determine K according to the theory of screw coupling.

5. Compare K in cases of with and without lubrication to the joints. Then draw your conclusions.

Chapter 4

Determination of External Force Coefficient of External Threaded Joints

4.1 Nomenclature

A	area of the raw section, mm^2
F	applied force, N
F_H	horizontal component of F, N
F_V	vertical component of F, N
$J_{x'x'}$	moment of inertia along XX-axis, $\mathrm{kg} \cdot \mathrm{mm}^2$
k	safety factor
V	tightening force, N
V_{max}	maximum tightening force, N
W	bending moment of the raw section, $\mathrm{N} \cdot \mathrm{mm}$
y_{max}	maximum distance, mm
z	a coefficient
α	contact angle, $^\circ$
χ	external force coefficient
$\bar{\chi}$	average value of χ
ΔF	force difference between each experiment, N

4.2 Aim

1. Help students understand clearly about the method of determination of the external force coefficient by theory.
2. Help students calculate the tightening force in the case of force acting in any direction.
3. Help students approach to the methods, instruments and determine the tightening force, deal with the experimental results to determine the external force coefficient.

4.3 Technical rules on safety

Students must comply with the technical rules on safety in the laboratory.

4.4 Experimental report

Each group conducts the experiment with the given α and F

$\alpha = -5^\circ$

$F = 303.6\,(\mathrm{N})$

$\Delta F = 15\,(\mathrm{N})$

4.4.1 Theoretical calculation of the external force coefficient

Measuring the size of bolts and assembled details to determine the external force coefficient by using theory.

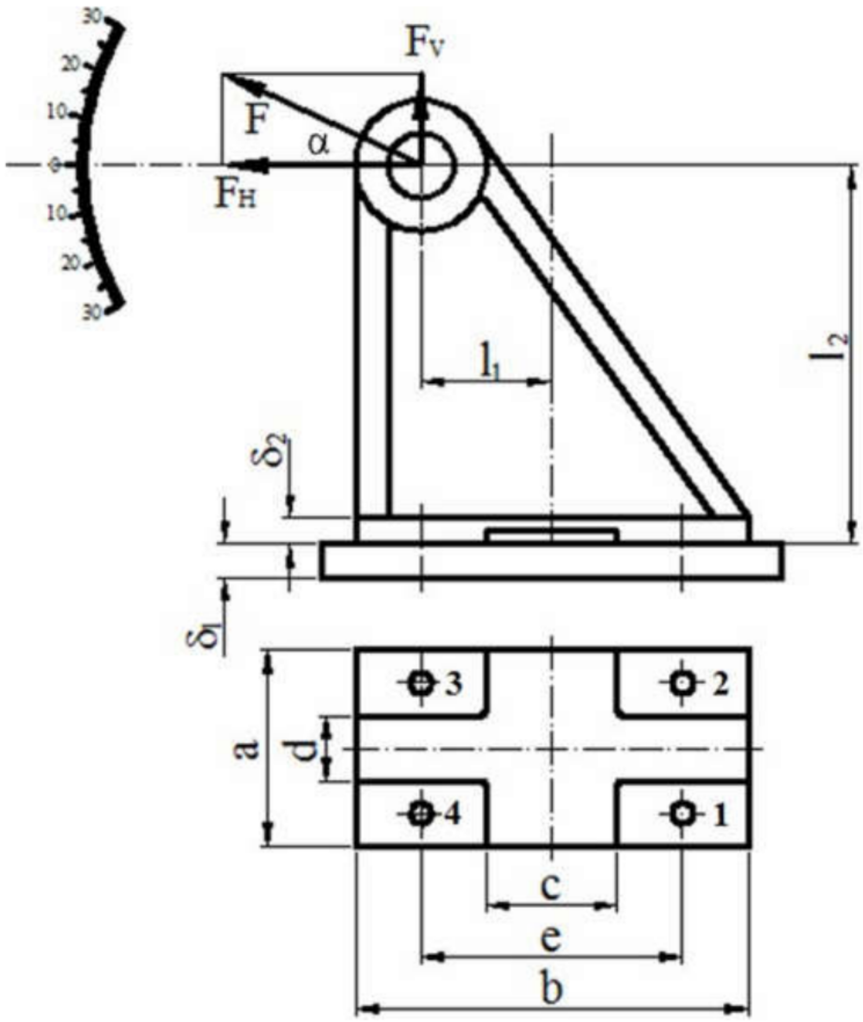

Figure 4.1: Model of experimental calculation

4.4.2 Calculating V

$$V = \frac{k}{z}\left(F_V + \frac{MA}{W}\right) = \frac{k}{z}\left(F_V + \frac{MA_{yc}}{J}\right)(1-\chi) \tag{4.1}$$

$$V = \frac{kF_H + (1-\chi) f F_V}{f_z} \tag{4.2}$$

According to formulas (1) and (2), selecting V max for these two values.

Note: The tightening force for surfaces not separated is defined by the formula:

$$V = \frac{k}{z}\left(\frac{(F_V l_1 \pm F_H l_2) A y_{max}}{J_{x'x'}} - F_V\right)(1-\chi)$$

where $J_{x'x'} = \dfrac{(a-b)(b^3-c^3)}{12}$

$A = (a-d)(b-c)$

$y_{max} = \dfrac{b}{2}$

Tightening the bolt with the tightening force $V = V_{max}$ (using equations 4.1 and 4.2) and checking by measuring device.

4.4.3 Measured results and process

We increase the load by hydraulic cylinder 5 to reach values: $F_1, F_2, ..., F_N$. They occur on the display screen (these values are less than F) and fill in column 2 of Table 4.1. The values $F_i = F - i\Delta F$.

Write down the value of tightening moment, tightening force V_{tni} by load cell method and put them into columns 3, 4 of Tables 4.1.

4.4.4 Calculate the external force

Calculate the following values:

1. $F_{Vi} = F_i \sin\alpha$

2. $F_{Hi} = F_i \cos\alpha$

3. $M_i = F_{Hi}l_1 \pm F_{Vi}l_2$

and put these values into column 5, 6 of table 4.1.

In this experiment, $l_2 = 0$ and $Y_i = \dfrac{e}{2}$, therefore $M_i = F_{Hi}l_1$

$$V_{tni} = V_0 + \chi\left(\frac{F_{Vi}}{z} + \frac{M_1Y_1}{\sum z_iY_i^2}\right) = V_0 + \chi\left(\frac{F_{Vi}}{z} + \frac{F_{Hi}l_1 \pm F_{Vi}l_2}{2e}\right)$$

where $i = 1, 2, ..., N$

Here, χ is determined by the formula:

$$\chi_i = \frac{V_{tni} - V_{tn1}}{\dfrac{F_{Vi} - F_{V1}}{z} + \dfrac{(F_{Hi} - F_{H1})l_1 + (F_{Vi} - F_{H1})l_2}{2e}}$$

According to the experimental model, $z = 4$, $e = 200\,(\text{mm})$, $l_1 =$ (mm), $l_2 =$ (mm) and then write down the results into column 7 of table 4.1.

Therefore, the average value of external force coefficient through N measuring times

$$\bar{\chi} = \frac{\chi_1 + \chi_2 + ... + \chi_{N-1}}{N - 1} \tag{4.3}$$

No.	F_i (N)	V_{tni} (N)	F_{Vi} (N)	F_{Hi} (N)	χ_i
1	303.2	3025			
2	287.8	3097			
3	271.4	3221			
4	257.8	3304			
5	242.8	3426			
6	227.8	3525			

Table 4.1: The experimental results

From the experimental results, plot the curve illustrated the relationship between χ_i and F_i.

4.4.5 Discussion and conclusions

Comparing the theoretical results with experimental results and then drawing conclusions.

4.4.6 Review questions

1. The role and importance of determining the tightening force and the tightening moment in reality.

2. The meaning of χ and determining this coefficient by the fundamental theory.

3. Determining the required tightening force of the bolt to avoid segregation and slip.

4. Comparing the tightening coefficient in the cases of the joint with and without lubrication, and then drawing conclusions.

Chapter 5

Applying Computer Software in Calculating Machine Elements

5.1 Nomenclature

q	standardized coefficient of shaft diameter
T	torque on shaft

5.2 Aim

Helping students understand the method, how to use the design software to select and test the general machine elements.

5.3 Technical rules on safety

Students must comply with the technical rules on safety in the laboratory.

5.4 Experimental report

5.4.1 Problem

Given the transmission system as shown in below figure.

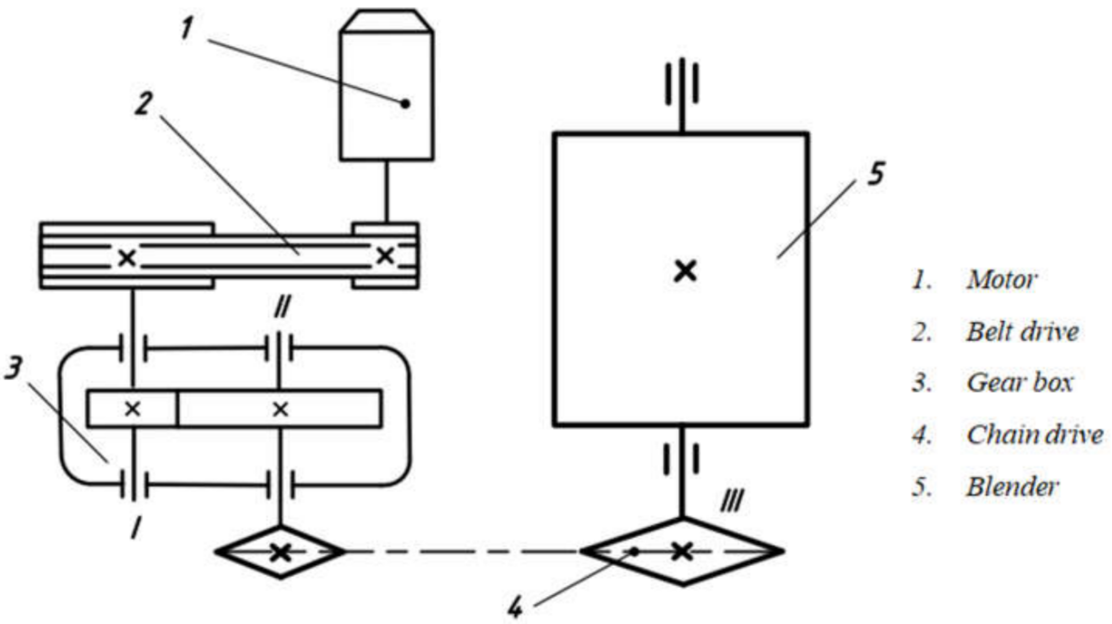

Figure 5.1: Transmission system for the blender

Initial data

- Capacity of blender: $P_3 = 4$ (kW)
- Number of revolution of blender: n_3 (rpm)
- Service life cycle: $L_h = 8$ (years)

- 1-way rotation, work 2 shifts, static load (300 working days per year, 8 hours per 1 working shift)
- Number of revolution of motor: $n_{dc} = 1420$ (rpm).
- Efficiency:
  - Belt drive $\eta_d = 0.95$.
  - Spur gear drive $\eta_{br} = 0.96$.
  - Bearings $\eta_{ol} = 0.99$.
  - Chain drive $\eta_x = 0.95$.
- The gears are calculated by ISO standard, the material is ENC60, the coefficients including $K_A = 1$, $K_{Hv} = 1.2$, $K_{H\beta} = 1.2$, $K_{H\alpha} = 1$ are input into Autodesk Inventor.
- The belt drive is calculated by DIN 2215 standard. Choose $d_1 = 180$ (mm), center distance $a = d_2$, the belt length, DIN belt type. The coefficient such as $P_{RB} = 3.8$ (kW), $k_1 = 1.2$.
- The chain is selected by ISO 606:2004 (EU) standard.

Pr	Parameters				Pr	Parameters				Pr	Parameters			
	P_3	u_1	u_2	u_3		P_3	u_1	u_2	u_3		P_3	u_1	u_2	u_3
1	2.5	2	2	3	31	6.5	4	2	3	61	12	3	2	4
2	2.5	2	2.24	4	32	7	3	2.24	3	62	12	4	2.24	2
3	2.5	4	2.5	4	33	7	4	2.5	4	63	12.5	3	2.5	3
4	3	2	3.15	3	34	7	3	3.15	4	64	12.5	3	3.15	4
5	3	2	3.55	3	35	7	2	3.55	3	65	12.5	4	3.55	2
6	3	4	4	2	36	7	3	4	4	66	12.5	3	4	4

	P_3	u_1	u_2	u_3		P_3	u_1	u_2	u_3		P_3	u_1	u_2	u_3
7	3	2	2	3	37	7.5	4	2	2	67	12.5	4	2	3
8	3	4	2.24	3	38	7.5	4	2.24	3	68	12.5	4	2.24	2
9	3.5	3	2.5	2	39	7.5	4	2.5	3	69	13	4	2.5	4
10	3.5	4	3.15	2	40	8	4	3.15	3	70	13	3	3.15	4
11	3.5	3	3.55	2	41	8	4	3.55	2	71	13	2	3.55	2
12	3.5	3	4	4	42	8	4	4	3	72	13	3	4	2
13	4	4	2	3	43	8	2	2	3	73	13	4	2	3
14	4	3	2.24	3	44	8.5	2	2.24	2	74	13	3	2.24	3
15	4	3	2.5	4	45	8.5	2	2.5	3	75	13	2	2.5	4
16	4	4	3.15	2	46	8.5	3	3.15	2	76	13	4	3.15	4
17	4	3	3.55	3	47	8.5	2	3.55	2	77	13.5	4	3.55	4
18	4	3	4	2	48	8.5	4	4	3	78	14	3	4	2
19	4	4	2	3	49	9.5	2	2	3	79	14	2	2	4
20	4	4	2.24	3	50	9.5	4	2.24	4	80	14	3	2.24	2
21	4.5	3	2.5	2	51	10	4	2.5	4	81	14	3	2.5	4
22	4.5	3	3.15	3	52	10	4	3.15	3	82	14.5	4	3.15	4
23	5.5	4	3.55	4	53	10.5	4	3.55	4	83	14.5	3	3.55	4
24	5.5	2	4	3	54	10.5	2	4	4	84	15	3	4	2
25	6	3	2	4	55	10.5	2	2	4	85	15	2	2	3
26	6	2	2.24	4	56	10.5	2	2.24	2	86	15	4	2.24	3
27	6	4	2.5	4	57	10.5	2	2.5	2	87	15.5	3	2.5	3
28	6	4	3.15	3	58	11	4	3.15	3	88	15.5	3	3.15	4
29	6	4	3.55	3	59	11	3	3.55	3	89	16	4	3.55	2
30	6.5	2	4	3	60	11.5	2	4	4	90	16	4	4	3

P_3	u_1	u_2	u_3	P_3	u_1	u_2	u_3	P_3	u_1	u_2	u_3

Table 5.1: Projects

5.4.2 Results

The distribution table of transmission ratio

Parameters	Shaft			
	Motor	I	II	III
P (kW)	4.758	4.475	4.253	4
u	$1 \to 1$	$1 \to 3$	$3 \to 2.5$	$2.5 \to 4$
n (rpm)	1420	473.33	189.33	47.33
T (N · mm)	31999	90288	214526	807099

Table 5.2: Table of transmission ratio

Table of gear drive parameters

No.	Parameter	Result
1	Selected material	EN C60
2	Center distance	$a = 160\,(\text{mm})$
3	Module	$m = 4\,(\text{mm})$
4	Number of teeth	$z_1 = 23$
5	Number of teeth	$z_2 = 57$
6	Pitch circle diameter	$d_1 = 92\,(\text{mm})$
7	Pitch circle diameter	$d_2 = 228\,(\text{mm})$
8	Face width	$b_1 = 64\,(\text{mm})$
9	Face width	$b_2 = 60\,(\text{mm})$
10	Radial force	$F_r = 714.346\,(\text{N})$
11	Tangential force	$F_t = 1962.649\,(\text{N})$
12	Gear speed	$v = 2.28\,(\text{m/s})$

The belt drive parameters table

The chain drive parameters table

5.5 Discussion and conclusions

Students compare the computational results in Inventor software with the theoretical results. Then draw conclusions when we use Inventor software.

5.6 Review questions

No.	Parameter	Result
1	Belt type	V-Belt DIN 2215 (17x2240)
2	Number of belt	$z = 3$
3	Belt speed	$v = 13.383\,(\mathrm{m/s})$
4	Initial tensile force	
5	Tensile force on each side	$F_t = 125.165\,(\mathrm{N})$
6	Tensile force on the tight side	$F_1 = 553.254\,(\mathrm{N})$
7	Tensile force on the slack side	$F_2 = 197.734\,(\mathrm{N})$
8	Tangential force	$F_p = 355.521\,(\mathrm{N})$
9	Radial force	$F_r = 711.895\,(\mathrm{N})$
10	Wrap angle	$\alpha_1 = 137.61°, \alpha_2 = 222.39°$
11	Belt length	$L_d = 2283\,(\mathrm{mm})$
12	Pulley width	$B = 63\,(\mathrm{mm})$
13	Center distance	$C = 572.572\,(\mathrm{mm})$

No.	Parameter	Result
1	Chain type	Roller Chain 16B-3-106
2	Number of chains	$k = 3$
3	Number of chain links	$X = 106$
4	Tangential force	$F_p = 2517.405\,(\mathrm{N})$
5	Tensile force on the tight side	$F_1 = 2540.238\,(\mathrm{N})$
6	Tensile force on the slack side	$F_2 = 22.834\,(\mathrm{N})$
7	Radial force	$F_r = 2555.607\,(\mathrm{N})$
8	Contact angle	$\alpha_1 = 132.11°, \alpha_2 = 227.89°$
9	Center distance	$C = 626.966\,(\mathrm{mm})$
10	Drivsing sprocket diameter	$D_p = 170.421\,(\mathrm{mm})$
11	Driven sprocket diameter	$D_p = 679.304\,(\mathrm{mm})$