Machine Elements I. (GEGET003B-a)

for BSc mechanical engineering students

Weeks	Lectures	Practical lessons
1	The General procedure for Design. Principles of dimensioning and stress calculation of machine elements. Generation of mechanical models. Type of loads – static and variable changing. Types of sinusoidal stresses – reversed and repeated, stress ratio. S-N, Smith and Haigh diagrams. Endurance limit, modifying factors.	Assignment of the design project 1 - Power screw. The load car–rying capacity of a manually operated instrument or tool (screw-jack, press, bench vice or bearing remover, etc.) should be determined. An assembly drawing in scale 1:5 is enclosed about the tool. Data given: nominal diameter and pitch of ISO trapezoidal thread form, nut high and materials of screw and nut. Three students create a group and work as a team on the project. Comprehension of operation. Starting a full scale freehand sketch about the tool – assembly drawing, A2 or A1sized. Parts list.
2	Thread standards and definitions – thread profiles: ISO metric thread form, ISO trapezoidal thread form. The mechanics of power screws, torque requirements, efficiency. Thread stresses due to bending, bearing pressure, root cylinder and buckling.	Workshop practice: presentation on the different thread profiles. Single, double and triple threads. Self-locking. Practice in usage of tools operated by power screws. Models, free body diagrams and stress calculation of power screw. Assumptions, factor of safety, coefficient of friction, material properties. Supervision of completed assembly drawings. Correcting it and starting the mono-detail drawings about the parts.
3	Threaded fasteners, property classes, high tensile steel bolts. Model for bolted joints in tension, joint diagram, static and fatigue loading. Unthreaded fasteners – different type of rivets and pins. Forms and failures of riveted joints. Retainers.	Laboratory work: practical demonstration and experiment with screw jack. Object – to determine the relationship between effort and load for a screw jack when the load is being raised and lowered, value of the coefficient of friction between the screw and nut of the jack, efficiency of screw jack at raising and lowering the load. Starting the preparation of final report on experiment.
4	Shaft connections – parallel and taper keys, straight sided and involute splines, assembly by shrinking and pressure fit. Welded, brazed and bonded joints. Design of shafts for static loads. Torsional deflection. Lateral de–flection and slope due to bending. Critical speeds of shafts.	Supervision and correcting the final report on experiment and the mono-detail drawings. Starting the preparation of final report due to the given data. Final assembly drawing of the instrument based on the corrected freehand sketch – option between conventional and CAD representation.
5	Classification of clutches and couplings. Rigid, self-aligning and elastic shaft couplings. Switchable, friction and electrical engaging and disengaging clutches and couplings. Torque-, rotation- and rotation direction engaged self-operating clutches. Dynamic representation of friction clutches. General procedure for the analysis of friction clutches – torque and energy considerations. Friction materials. Design of disk clutches.	Deadline of the first design project. Giving a written account on the whole design process. Assignment of the design project 2 – Design of disk clutch. Complete dimensioning and stress calculation of the clutch should be fulfilled. A reduced scale design is enclosed. Input data are the speed of prime mover, the mass moment of inertia of the follower shaft, the time function of clutch torque, the frequency of operation and the operating power. Workshop practice: presentation on the friction clutches. Dismantle and assemble of a mechanically actuated multiple disk clutch. Description of the operation. Different starting processes. Time function of the torques, angular accelerations, angular velocities, powers and energies. Work loss during a single clutch-slip period. Efficiency as the function of starting process type and service factor.
6	Design, symbol and dimensioning of couplings and clutches – solid and flanged coupling, flange type gear coupling, Oldham coupling, universal joint, flexible shaft, bellows coupling, rubber-type flanged coupling, tyre coupling, jaw-type compression coupling, positive contact clutches,	Supervision of the first part of final report. Friction materials – heat transfer capacity, coefficient of friction, allowable pressure, pollution. Manufacturers of disk clutches. Standards. Necessary friction surface area due to energy loss. Dimensioning of the hubs and parallel key connections. Estimating and selecting inner and outer disks. Number of disks due to energy loss and friction

	fluid couplings, overload release clutches, centrifugal clutches, overrunning clutches.	moment. Axial force requirements. Pressure distribution among the disks, limitation for the number of disks. Preliminary outlining on a small scale. Stress calculation of the other elements – assumptions.
7	Introduction to Tribology – the science and technology of friction, wear and lubrication. Types of lubrication – hydrodynamic, hydrostatic, elasto–hydrodynamic, boundary and solid-film. Thick-film lubrication. Newton's law of viscous flow, viscosity. Stribeck curves – unstable and stable lubrication, formation of a film. Matematical theory of thick-film lubrication – Reynolds equation. Nomenclature of a journal bearing. Pressure distribution curves. Journal bearing performance – bearing load, bearing friction, lubricant flow and bearing thermal relations. Design charts for hydrodynamic journal bearings. Bearing stability.	Supervision and correction of the completed final report. Design variety of single and multiple disk clutches. Type of toggle linkages. Locking methods of adjusting nut. Solutions to keep the disks from rubbing when the clutch is disengaged. Lubrication. Design aspects of parts made of ductile cast iron.
8	Design process of a steadily loaded hydrodynamic type full journal bearing with constant speed. Selecting the oil type. Classification of hydrodynamic and hydrostatic journal bearings. Elements and designs of journal bearings. Lubricant feed systems.	Supervision of the half-finished assembly drawing about multiple disk clutch. Suggestions for rectification. Fits and tolerances of the mated parts. Connecting appliances and controller. Other type of actuators – electromagnetic, hydraulic. Design of torque engaged self-operating disk clutch installed into a spur gear hub.
9	Terminology and variety of rolling contact bearings. Load carrying capacity, rating life. Load ratings and equivalent loads. Selection of bearings. Lubrication and sealing. Typical bearing arrangements. Bearing mounting requirements – size and type, axial location, seating fits, thermal axial expansion, need to assemble and dismantle.	Deadline of the second design project. Giving a written account on the whole design process. Assignment of the design project 3 – Journal bearing design. Complete dimensioning and stress calculation of a steadily loaded, hydrodynamic type of journal bearing (located at the end or at an intermediate part of the shaft) should be made. Input data are: type of bearing, torque, radial load and rotating speed. Workshop practice: presentation on the journal bearings. Assembly and dismantle of two different type of journal bearing model. The sleeve of full and split bearings, partial bearings. Lubricating systems. Rigid and self-aligning sleeve. Sleeve materials and properties, suggested applications. Starting the dimensioning of the journal bearing. Principal dimensions and checking due to stresses. Surface finish, space function, pressure distribution, dimensionless variables.
10	Definition of gasket and seal. Standard classification system of nonmetallic gasket materials. Load-bearing properties. Gasket design and selection procedure. Static O-ring seals. Seals for rotary motions – radial lip seals, face seals, metal sealing rings, stuffing box, noncontacting seals. Seals for reciprocating motion – O-rings, lip packings, piston rings.	Supervision and correction of the first part of final report. Survey on the cause and type of failures. A real industrial problem on hydrodynamic journal bearings. Bearing temperature. Selection of the cooling system. Lubricant properties, selection. Specification of the fit.
11	Types of brakes – configuration and actuation. Band-, shoe-, drum-, full disk-, caliper disk- and magnetic brakes. Selecting a brake. Equivalent inertias. Torque requirements and energy dissipation due to industrial and vehicle brakes. Temperature considerations due to intermittent and frequent operation. Torque and force analysis of drum brakes. Band and cone brakes – contact pressure, torque capacity, actuating force and moment equation for brake lever. Caliper-disk brakes - torque capacity and actuating force.	Supervision and correction of the completed final report. Dimension of oil ring, oil spreader groove, sleeve and coating. Design of sealing system. Design of cooling system. Foundation of the bearing housing. Design aspects of the housing made of cast iron.
12	Terminology of mechanical springs. Selection of spring materials. Helical compression spring	Supervision of the preliminary design of journal bearing. Modifications. Parts list, main dimensions, fits of mated

	terminology – spring index, spring rate, torsional stress, buckling. Helical extension springs. Helical torsion springs. Belleville spring washers, stacks. Load-deflection characteristics, hysteresis. Flat springs – cantilever and simple beam springs. Torsion bars. Power springs.	elements. Summary sheet of main data.
13	Belt drives – nonpositive and positive flexible-connectors, two- and multiple pulley drives. Forces in moving belt. Arrangement and tensioning devices. Multiple-ply flat-belt drive. V-belt drive. Synchronous-belt drive. Variable-speed belt drive. Design steps of flat- and V-belt drives. Roller-chain drive design procedure. Silent chain drives.	Deadline of the third design project. Giving a written account on the whole design process.Problem solution: design process of a high speed long shaft, supported by deep groove ball bearings. Conventional dimensioning and stress calculation of the shaft. Design the supports – installation and selection. Design the sealing and lubricating systems.
14	Fluid power system and circuit design. Fluid logic systems. Logic elements and actuators. Types of valves. Quarter- and multiple-turn valve actuators (mechanically, electrically, pneumatically and hydraulically operated). Some interesting applications of the machine elements detailed during the lectures of the semester.	Problem solution: design of the short input shaft of a gearbox, supporting by angular contact ball bearings. Rectification of the three projects and tests.

Books, recommended literature:

[1] Németh G., Design of disk clutch, University Publisher, Miskolc, 1991.

[2] Németh G., Belt and Chain Drives, University Publisher, Miskolc, 1991.

[3] Szegedi G. G., Power screw, University Publisher, Miskolc, 1991.

[4] Szegedi G., Journal Bearing Design, University Publisher, Miskolc, 1991.

[5] Shigley, J.E. & L. D. Mitchell, Mechanical Engineering Design, McGraw-Hill International Book Company, Auckland, etc., 1983.

[6] Shigley J.E. & C. R. Mischke, Standard Handbook of Machine Design, McGraw-Hill Book Company, New York, etc., 1986.

Requirements of Machine Elements I.

(for signature)

- Regular attendance at the lectures and practices.

- Execution of the design projects until the closing dates

- Rating of projects should be at least passed

- Rating of written tests should be at least passed

The final examination on the lectures of the subject will take place after the semester. The final examination consists of a written and an oral piece and the mean of the ratings of the three design projects will be counted in the exam mark.

Miskolc, 2019. szeptember 09.

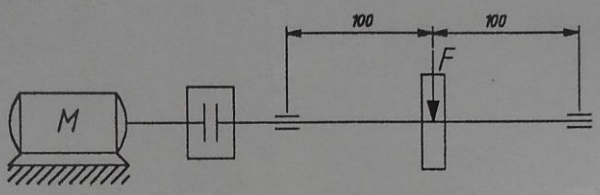
Németh Géza
tárgyfelelős

Date: _____ Name: _____

Group: _____

Machine Element and Design I.

1. A countershaft is driven by an electric motor through a coupling. From the countershaft the power is transmitted by chain drive. The arrangement of the shaft is shown by the figure.



Data:				
	P =	5	kW	motor power
	n =	1440	min^{-1}	speed of the motor
	F =	560	N	load from the sprocket
	S_y =	285	Nmm^{-2}	yield strength for the shaft
	n =	2		factor of safety
	β =	3		von Mises theory

Questions:

a, Where is the weak section of the shaft ?

b, Determine the necessary shaft diameter at the weak section! Choose a recommended shaft diameter from the following serial:
(12, 14, 16, 18, 20, 22, 25, 28, 35, 40, 45, 50, 55, 60, 65, 70, 80)

c, The shaft is supported by deep groove ball bearings. Draw such a bearing in full section.

d, The required life rating is L_h = 15000 h. Determine the necessary basic dynamic load rating, C of the bearing.

2. Draw a flanged coupling in full section and jot down also its symbol!

3. Draw the symbol of a multiple disk clutch!

4. What kind of thread profiles do you know ? Draw one of them with its measures! (p, d'_m, d_r, d, 2α)

5. Prescribe the theory of raising a load by a power screw applied by square thread! Jot down some figure and write some formulas!

6. What is the difference between the hydrodynamic and hydrostatic type of lubrications? Draw a radial type or a thrust journal bearing in full section!

University of Miskolc — Department of Machine Elements

Date: ____________ Name: ____________________ Group: ____________

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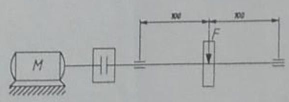

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(1)

$P = 5kW$

$n = 1440\,min^{-1} = 24s^{-1}$

$F = 560N$

$S_y = 285\,Nmm^{-2}$

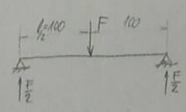
$n = 2$

$\beta = 3$

$l = 0,1m$

(a) At the place of the sprocket. — 2p

(b)



$M = \frac{F}{2}\cdot\frac{l}{2} = \frac{F\cdot l}{4} = \frac{560N\cdot 0{,}1m}{4} = 14Nm$ — 1p

$T = \frac{P}{\omega} = \frac{5000W}{150{,}8s^{-1}} = 33{,}16Nm$ — 1p

$\omega = 2\pi\cdot n = 150{,}8s^{-1}$ — 1p

$\sigma_p = \frac{S_y}{n} = \frac{285Nmm^{-2}}{2} = 142{,}5Nmm^{-2}$ — 1p

$\sigma = \frac{M}{S}$

$\tau = \frac{T}{S_t} = \frac{T}{2S}$

$\sigma_p \geq \sigma_e = \sqrt{\sigma^2 + \beta\tau^2}$ — 1p

$\sigma_p = \sqrt{\sigma^2+\beta\tau^2} = \sqrt{\frac{M^2}{S^2} + \beta\frac{T^2}{4S^2}} = \frac{1}{S}\sqrt{M^2+\frac{\beta}{4}T^2}$

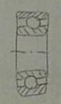
$S = \frac{1}{\sigma_p}\sqrt{M^2+\frac{\beta}{4}T^2} = \frac{1}{142{,}5}\sqrt{(14\cdot10^3)^2+\frac{3}{4}(33{,}16\cdot10^3)^2} =$

$= 224{,}2\,mm^3$

$S = \frac{d^3\pi}{32} \Rightarrow d = \sqrt[3]{\frac{32S}{\pi}} = \sqrt[3]{\frac{32\cdot224{,}2}{\pi}} = 13{,}17mm$ — 3p

The recommended shaft diameter is 14 mm. — 1p

(c)



3p

(d) $L_h = 15000h$, $C = ?$, $p = 3$

$L = \left(\frac{C}{P}\right)^p \rightarrow C = P\sqrt[p]{L}$

$L = \frac{L_h\cdot n}{10^6} = \frac{15000h\cdot 60\frac{min}{h}\cdot 1440min^{-1}}{10^6} = 1296$ — 2p

$C = P\sqrt[p]{L} = \frac{F}{2}\sqrt[p]{L} = \frac{560}{2}\sqrt[3]{1296} = 3053N = 3{,}05kN$ — 2p

Σ18p

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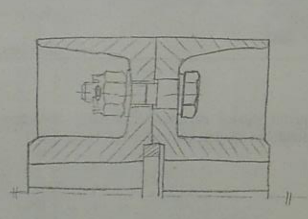
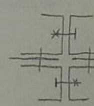
(2)



5p



2p

Σ7p

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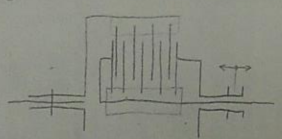
(3)



Σ3p

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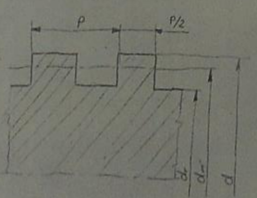
(4) ISO metric thread form

ISO trapezoidal thread form

Square thread form — 2p



$2\alpha = 0°$

3p

Σ5p

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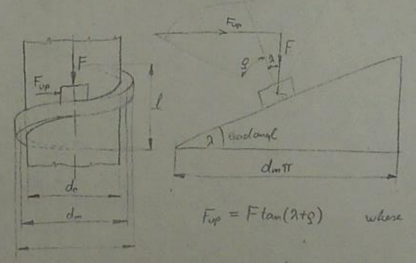
(5)



1 ábra → 2p

2 ábra → 4p

$F_{up} = F\tan(\lambda+\varrho)$ where $\mu = \tan\varrho$ — 2p

$\lambda = \arctan\frac{l}{d_m\cdot\pi}$

$T_{up} = F_{up}\frac{d_m}{2}$ — 1p

Σ9p

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(6)

a) — 2p

b) — 6p

Σ8p

		Osztályzat:	
1.	18p	0 – 20	→ 1
2.	7p	21 – 27	→ 2
3.	3p	28 – 34	→ 3
4.	5p	35 – 41	→ 4
5.	9p	42 – 50	→ 5
6.	8p		
Σ50p			