November 10, 2021

INSTRUCTIONS

Begin each problem in the space provided. If additional space is required, use the paper provided to you.

Work appearing on the backside of any exam page may NOT be graded.

If your solution does not follow a logical thought process, it will be assumed to be in error.

PROBLEM No. 1 (25 points)

Problem 1 consists of 10 questions. Each question is worth 2.5 points.

(a) Clearance fits are generally described as having a gap or space between the mating parts.

Which other type(s) of fits may also have a a gap or space, depending on the parts being manufactured to the allowable tolerance?

Select all that apply.

- ☐ Drive
- ☐ Force
- ☐ Interference
- ☐ Running
- ☐ Transition

(b) Which fit has the smaller tolerance?

- ◯ H9/d8
- ◯ H7/p6

(c) A steel shaft experiences high torque starts and stops. During running, the shaft experiences moderate shocks.

Which is the best choice for heat treating the shaft?

- ◯ Annealing
- ◯ Quenching
- ◯ Tempering
- ◯ Case Hardening

In a few words, justify your answer.

(d) Contact stresses occur between two bodies with differing radii of curvature.

Describe a typical failure due to contact stress.

(e) According to Shigley, *the selection of a material for a machine part...is one of the most important decisions the designer is called on to make.*

M.F. Ashby developed diagrams to assist in rapidly narrowing and choosing groups of materials having similar properties.

You are designing a part with the following material requirements.

— Density (ρ) between 4 and 10 Mg/m^3

— Young's modulus (E) between 60 and 250 GPa

— Strength (S) spanning 25 to 1050 MPa

Select the material(s) that meet the design requirements.

☐ Aluminum alloys
☐ Copper alloys
☐ Lead alloys
☐ Magnesium alloys
☐ Nickel alloys
☐ Carbon steels
☐ Stainless steels
☐ Titanium alloys
☐ Zinc alloys
☐ None of the above

(f) A steel member has a Brinell of $H_B = 275$.

Estimate the ultimate strength of the steel in MPa.

(g) The SAE 5W-30 oil in your car will perform like SAE 5 oil during winter driving in Indiana and like SAE 30 oil during summer driving in Indiana.

◯ True
◯ False

In a few words, justify your answer.

(h) To achieve thick film lubrication in some journal bearings, lubricants above SAE 70 are recommended. To achieve thin film lubrication in other journal bearings, lubricants below SAE 10 are recommended.

◯ True
◯ False

In a few words, justify your answer.

(i) You have been tasked with replacing all journal bearings in a machine with a combination of deep groove ball bearings and spherical roller bearings.

What will be the impact of the change? Select all that apply.

☐ The REBs will be more difficult to access and maintain.
☐ The machine will be noisier.
☐ The rotating shaft(s) will need to be lengthened to accommodate the REBs.
☐ The bearing life will be shorter.
☐ The machine's speed will decrease.

(j) A journal bearing is to be used for a certain application. For a fixed journal diameter, a design team must now choose the journal bearing's length.

A team member suggests choosing a longer journal bearing. How will bearing performance be impacted by the choice of a longer bearing? Select all that apply.

☐ The minimum film thickness will increase.
☐ The temperature rise in the lubricant will increase.
☐ The film pressure will increase.
☐ The lubricant flow rate will increase.
☐ The coefficient of friction will increase.

PROBLEM No. 2 (20 points)

A ball bearing is to be used to support the load from a helical gear drive, where the axial load is 6 kN and the radial load is 14 kN. The bearing's inner ring rotates.

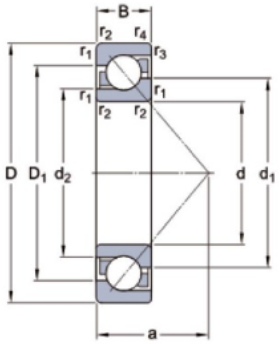
The bearing's bore diameter is $d = 20$ mm.

Determine the following.

(a) Choose a bearing from the catalog below. The catalog rating life is 10^6 cycles.

(b) For the bearing chosen, calculate the equivalent radial load (F_e). Choose the closest value(s) from Table 11-1; do not interpolate.

(c) Is the bearing chosen expected to carry the load with 95% reliability for 10^7 cycles? If not, describe the next analysis step(s).



SKF®

Principal dimensions			Basic load ratings dynamic	static	Fatigue load limit	Speed ratings Reference speed	Limiting speed	Mass	Designation	Dimension series to ISO 355 (ABMA)
d	D	T	C	C_0	P_u					
mm			kN		kN	r/min		kg	–	–
15	35	11,75	18,5	14,6	1,43	17 000	20 000	0,055	▸ **30202**	2CC
	42	14,25	27,7	20	2,08	15 000	18 000	0,094	▸ **30302**	2FB
17	40	13,25	23,4	18,6	1,83	15 000	18 000	0,079	▸ **30203**	2DB
	47	15,25	34,2	25	2,7	13 000	16 000	0,13	▸ **30303**	2FB
	47	20,25	42,8	33,5	3,65	12 000	16 000	0,17	▸ **32303**	2FD
20	42	15	29,7	27	2,65	13 000	16 000	0,099	▸ **32004 X**	3CC
	47	15,25	34,1	28	3	12 000	15 000	0,12	▸ **30204**	2DB
	52	16,25	41,9	32,5	3,55	12 000	14 000	0,17	▸ **30304**	2FB
	52	22,25	54,3	45,5	5	11 000	14 000	0,23	▸ **32304**	2FD
22	44	15	30,9	29	2,85	13 000	15 000	0,1	▸ **320/22 X**	3CC
25	47	15	33,2	32,5	3,25	12 000	14 000	0,11	▸ **32005 X**	4CC
	52	16,25	38,1	33,5	3,45	11 000	13 000	0,15	▸ **30205**	3CC
	52	19,25	44,5	44	4,65	10 000	13 000	0,19	▸ **32205 B**	5CD
	52	19,25	50,4	45,5	4,9	11 000	13 000	0,19	**32205**	2CD
	52	22	57,9	56	6	10 000	13 000	0,22	▸ **33205**	2CE
	62	18,25	46,6	40	4,4	8 500	11 000	0,27	▸ **31305**	7FB

[H]

PROBLEM No. 2 (continued)

PROBLEM No. 3 (20 points)

A journal bearing supports a radial load of 10.8 kN.

The journal diameter is 60 mm. The journal rotates at 7200 rpm.

The bearing length is 60 mm and the bearing diameter is 60.06 mm.

The design requires a minimum film thickness h_0 of not less than 0.021 mm.

Determine the following.

(a) The Sommerfeld number, S.

(b) The lubricant viscosity required (μ) in mPa·s.

(c) Use your result from part (b) to find the average lubricant temperature if the lubricant is SAE 30.

(d) Use the charts in the textbook to find the coefficient of friction, f.

(e) The power lost due to friction in W.

PROBLEM No. 3 (continued)

PROBLEM No. 4 (35 points)

A 57-tooth spur gear is in mesh with a 23-tooth pinion.

The pinion is AISI 4140 nitrided grade 1 steel and rotates at 1000 rpm.

The gear is class 40 cast iron.

The diametral pitch is $P = 6$ teeth/inch and the pressure angle is $\phi = 20°$. The face width is 1.75 inch.

Assumptions and given information:

- The load is moderate shock and the power is smooth
- The gears are quality level 9
- The gears have uncrowned teeth, are straddle-mounted with bearings immediately adjacent, and are commercial enclosed gear units
- The gears have a backup ratio $m_B = 1.5$
- The reliability level is 99%
- The operating temperature is 200°F
- The pinion life is to be 10^8 revolutions
- Use $Y_N = 1.6831\, N^{-0.0323}$ and $Z_N = 2.466\, N^{-0.056}$

Determine the following.

(a) The diameters of the pinion and of the gear.

(b) Complete the table on the following page with the variables needed to analyze the gearset for bending and wear using the AGMA equations. Include dimensions, where applicable.

(c) Considering failure in the pinion due to bending, determine the transmitted load (W^t) in lbf for factor of safety $S_H = 1$.

Variable	**Pinion**	**Gear**
K_o		
K_v		
K_s		
P_d		
F		
K_m	1.184	1.184
K_B		
J		
S_t	40 kpsi	13 kpsi
Y_N		
K_T		
K_R		
C_p		
d_P		
C_f		
I		
S_c	150 ksi	75 ksi
Z_N		
C_H		1.012

PROBLEM No. 4 (continued)

PROBLEM No. 4 (continued)