Version JMC/8

EGT2
ENGINEERING TRIPOS PART IIA
EGT3
ENGINEERING TRIPOS PART IIB

Friday 7 May 2021   1.30 to 3.10

Module 4C4

DESIGN METHODS

Answer not more than ***three*** *questions.*

All questions carry the same number of marks.

The ***approximate*** *percentage of marks allocated to each part of a question is indicated in the right margin.*

Write your candidate number ***not*** *your name on the cover sheet and at the top of each answer sheet.*

STATIONERY REQUIREMENTS
Write on single-sided paper.

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed.
You are allowed access to the electronic version of the Engineering Data Books.

10 minutes reading time is allowed for this paper at the start of the exam.

The time taken for scanning/uploading answers is 15 minutes.

Your script is to be uploaded as a single consolidated pdf containing all answers.

1 Literate nonspeaking individuals with motor disabilities rely on augmentative and alternative communication (AAC) devices to communicate. Users type their communications using a built-in keyboard and push a designated `Speak` button to trigger the system to output the response to the conversational partner using speech synthesis.

A major bottleneck for AAC device users is the slow typing speed. Your company is designing a word prediction functionality that allows an AAC device to predict the word the user is typing and display such word predictions in the vicinity of the keyboard. The word predictions are produced by a word prediction algorithm that uses three signals to inform a prediction: 1) the user's keystrokes; 2) a list of words the system can predict; and 3) the user's context, such as time-of-day and current location.

(a) Identify the overall function of the word prediction system and its system boundary. Briefly motivate the system boundary. [10%]

(b) Identify and draw the overall function structures, including their functional elements and the flow of signals. Briefly explain the role of the function structures. [30%]

(c) It is later discovered that users demand functionality for updating the list of words the system can predict. Propose a mechanism for doing so and update the function structures derived and drawn in (b) to reflect this requirement. Briefly motivate your design. [20%]

(d) Identify the critical controllable and uncontrollable parameters that govern the word prediction performance of the system derived in (b) and (c). [20%]

(e) Briefly describe how an understanding of the controllable and uncontrollable parameters in (d) can inform the design of word prediction. [20%]

2 Your company is planning to develop a bicycle navigation aid that provides egocentric directional instructions (i.e. “turn left”) to cyclists given a route.

(a) Derive a solution-neutral problem statement for the proposed system. [10%]

(b) Identify the key functions that must be realised by the system. Briefly motivate each function’s relevance to the design. [20%]

(c) Use a morphological chart to explore alternative function carriers for the functions identified in (b) and motivate a preferred conceptual design. [30%]

(d) Write a requirements specification with eight key requirements for the conceptual design identified in (c). [20%]

(e) Devise a verification cross-reference matrix for the requirements specification identified in (d). [20%]

3 A community in the foothills of the Himalayas is at risk of flash floods during the monsoon season, due to heavy rain fall in the mountains above the village. The changing climate means floods are becoming more frequent, causing damage to homes, livestock, crops and livelihoods. An appropriately designed early flood warning system has the potential to improve flood warning times from a few minutes up to several hours.

(a) List key requirements for the early flood warning system. [20%]

(b) Sketch a fault tree highlighting events that may lead to the unsuccessful operation of the early flood warning system. [30%]

(c) Outline the six principles for integrated system design and describe in detail how each principle relates to the delivery of the system in the Himalayan context. [30%]

(d) A risk review affords an assessment of the nature and extent of potential risks within a system. Discuss key factors of good risk management practice that will enable the successful delivery of this project. [20%]

(TURN OVER

4 A designer is tasked with specifying a brass bush for a bushed bearing assembly, as shown in Fig. 1, to house a shaft. The bush is machined to the precise size to allow the shaft to rotate, but the bush is to remain stationary within the bearing assembly.

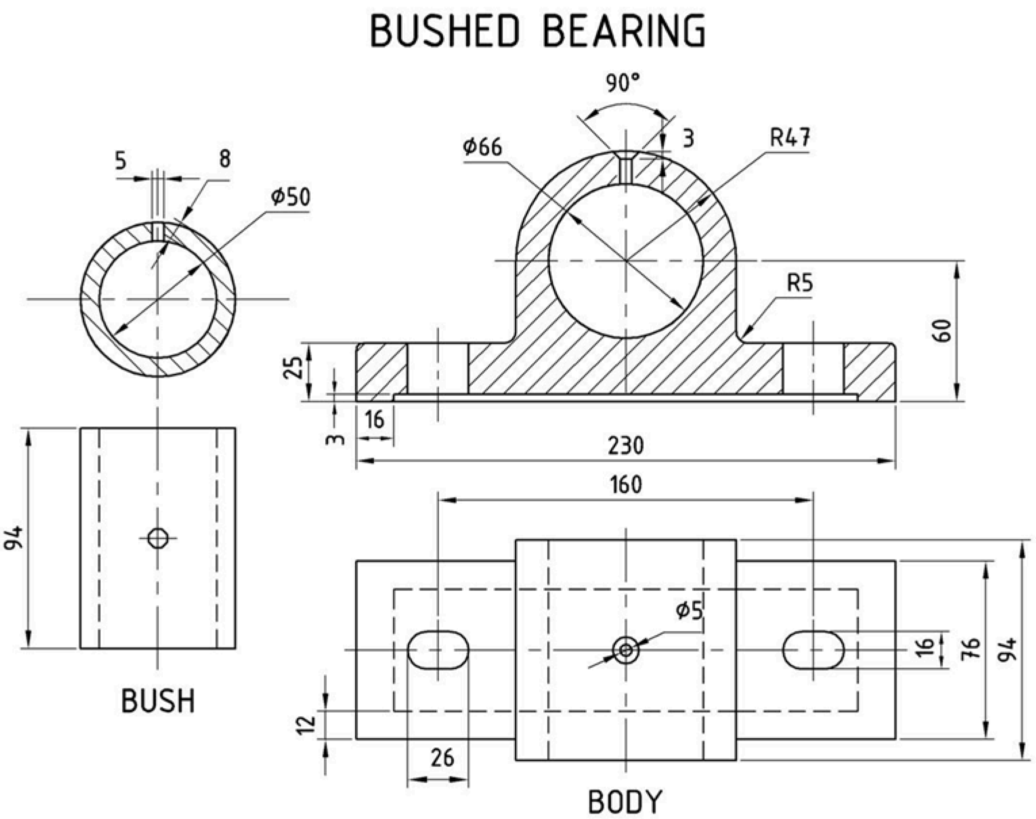


Fig. 1: Bushed bearing assembly (all dimensions are in mm)

British Standard BS4500 describes tolerances required for fitting a shaft into a hole. An extract of BS4500 for holes ranging from 50 mm to 80 mm is shown in Fig. 2.

Assume that all probability distributions are normal and independent, and that the range from minimum to maximum is equivalent to six standard deviations. Table 1 shows equations for combining probabilities.

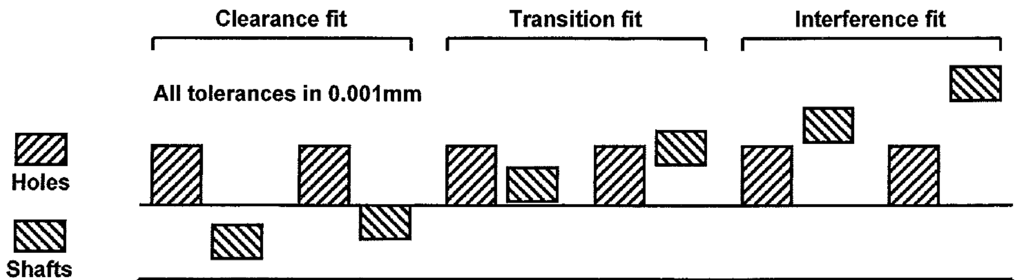
(a) A clearance fit H7 - h6 is specified between the shaft and the inside diameter of the bush. Calculate the mean shaft diameter and show that the probability of *not* obtaining a clearance fit is zero. [20%]

(b) A transition fit H7 - n6 is specified between the outside diameter of the bush and the bearing housing. Calculate the probability of *not* obtaining an interference fit between the bush and housing (allowing the bush to rotate.) [20%]

 (cont.

(c) A new manufacturing process is proposed for the bush, whereby a flat sheet of brass is formed into a tube, welded along the seam and then cut to length. The sheet rolling process has a thickness tolerance of ±0.030 mm. Calculate the thickness of the brass sheet that maintains the clearance fit between the shaft and bush, but relaxes the probability of *not* obtaining an interference fit between the bush and the housing to 20%. Comment on the accuracy of this tube forming manufacturing process to achieve the appropriate fits. [30%]

(d) Discuss how any variability in interference fit might affect the assembly and operation of the bearing, and what design options might be employed to address these issues. [30%]



H7	g6	H7	h6	H7	k6	H7	n6	H7	p6	H7	s6
+30	-10	+30	0	+30	+21	+30	+39	+30	+51	+30	+72
0	-29	0	-19	0	+2	0	+20	0	+32	0	+53

Fig. 2: British Standard BS4500 extract for 50 mm to 80 mm holes

y	μ_y	σ_y^2
$x + a$	$\mu_y + a$	σ_x^2
ax	$a\mu_x$	$a^2\sigma_x^2$
$a_1x_1 + a_2x_2$	$a_1\mu_1 + a_2\mu_2$	$a_1^2\sigma_1^2 + a_2^2\sigma_2^2$
x_1x_2	$\mu_1\mu_2$	$\mu_2^2\sigma_1^2 + \mu_1^2\sigma_2^2$
x_1/x_2	μ_1/μ_2	$(\mu_2^2\sigma_1^2 + \mu_1^2\sigma_2^2)/\mu_2^4$

Table 1: Equations for combining probabilities, where y is a function of independent variables x_n, a is a constant, μ is the mean and σ is the standard deviation.

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