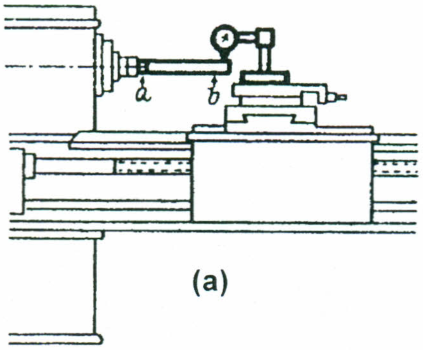
Question 1: (30 marks)

a) A machine tool has a bed length of 7.5 m and connected to the concrete by 14 bolts. This machine tool has been designed with a target stiffness of 672 MN/m, with m = 1500 m^{-1}, σ_B = $2x10^8$ N/m^2, S_B = 22.2 MN/m, and S_c = 24 MN/m. Suppose that with infinite joint stiffness, this machine tool has an overall stiffness of $1.91x10^3$ MN/m and equivalent vertical deflection 'Δ' of 0.156 mm. For the actual machine tool find the subsoil stiffness, the joint stiffness, the bolt size, and the vertical deflection 'Δ'. Note that the available bolt cross-sectional areas are 113.10 mm^2, 153.94 mm^2, and 254.47 mm^2 for M14, M16, and M20 respectively. **(15 marks)**

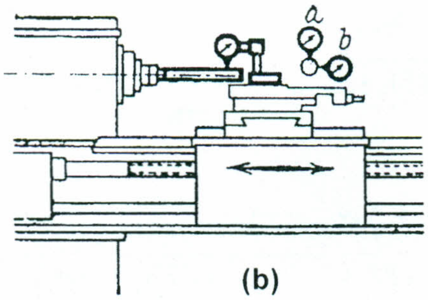
b) A machine tool with a metallic bed was used for certain cutting condition. The starting cutting point was at e_X = 50 mm, e_y = 1000 mm and e_Z = 120 mm. The measured cutting force components were 1.0 K.N, 2.0 K.N. and 0.6 K.N. in X, Y and Z direction respectively. Given are: $E_2 = 24x10^9$ N.m^{-2}, ν_2 =0.16, b/d=1.5, k_1 = 0.196, E_1 = $2.1x10^9$ KN.m^{-2}, ν_1 = 0.27. Also, given that $(EI)_1$ = 0.4 $(EI)_2$, $(GA)_1$ = $2.5(GA)_2$, $(GK)_1$ = 0.4 $(GK)_2$, and the beam length is 1000 mm. Assume any required data if necessary. Calculate the concrete depth to fulfill target stiffness in X-dir $\geq$ $2x10^4$ KN/m. **(15 marks)**

Question 2: (30 marks)

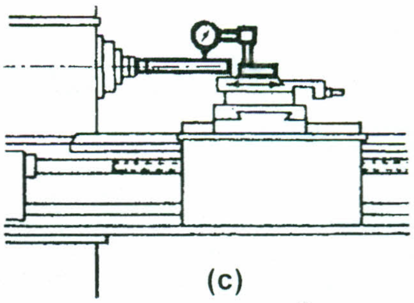
Re-draw the figures a, b, and c then determine the suitable acceptance test for each figure. **(10 marks each)**



(a)



(b)



(c)

Question 3: (30 marks)

When designing two jointed structures, one of cantilever with end point load and the other of fixed beam with central load. Assume for both structures, that I_s / I_j = 4/9, E = 210000 N/mm^2, P_m = 20 N/mm^2, cantilever beam length = 200 mm, the surface finish for both joints m = 100 mm^{-1}, and the fixed to cantilever beam length ratio is 1.5. The joint bending deflections required to be the same for both structures. Find the ratio of the solid diameters **(14 marks)**. If the solid diameters ratio greater than 1.8, find the mathematical relationship between the surface finish of the two jointed structures that can fulfill the above requirements **(16 marks)**.

Question 4: (30 marks)

a) When a certain machine tool was used to manufacture a certain workpiece at 300 r.p.m., it was found that the cutting mode was a wave removing one. At certain position during cutting, the instantaneous shear angle was 35°, the instantaneous undeformed chip thickness was 1.5 mm, and the resultant chip taper angle δ_o was -15°. If the tool has a normal rake angle of +10°, clearance angle of +6° with an average undeformed chip thickness of 1.3 mm and chip width of 2.5 mm. Graphically find the instantaneous slope angle **(10 marks)**. Also, calculate the average shear angle **(5 marks)**.

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b) Prove analytically that the chip taper angle can be obtained by:

$$\cot \delta_0 = \tan(\phi - \gamma_n)\left[\frac{2\sin\phi\sin(\phi-\delta_c)}{\sin 2(\phi-\gamma_n)\sin\delta_c} - 1\right]$$

Given are:

$sin(\alpha+\beta) = sin\alpha\ cos\beta + cos\alpha\ sin\beta$ $\quad$ $sin(\alpha-\beta) = sin\alpha\ cos\beta - cos\alpha\ sin\beta$

$cos(\alpha+\beta) = cos\alpha\ cos\beta - sin\alpha\ sin\beta$ $\quad$ $cos(\alpha-\beta) = cos\alpha\ cos\beta + sin\alpha\ sin\beta$

$sin2\alpha = 2\ sin\alpha\ cos\alpha$ **(15 marks)**

Useful Relations

For jointed cantilever with end point load; $\frac{\delta_J}{\delta_b} = \frac{3E}{mP_m}\cdot\frac{I_s}{I_J}\cdot\frac{1}{L}$

For jointed fixed beam with central load; $\frac{\delta_J}{\delta_b} = \frac{6EI_s}{mP_m I_J[L+(2EI_s/mP_m I_J)]}$ and $\delta_b = \frac{WL^3}{192EI_s}$

The component deflections at the cutting point due to the effect of the cutting forces are:

$$\Delta_x = Pl^3\left[\frac{L(\frac{1}{3}-\gamma+\gamma^2)+N\alpha(\frac{1}{2}-\gamma)}{(EI_y)_1+(EI_y)_2} + \frac{\beta(L\beta - M\alpha)}{(GK)_1+(GK)_2}\right] + Pl\left[\frac{L}{\left(\frac{GA}{F_x}\right)_1+\left(\frac{GA}{F_x}\right)_2}\right]$$

$$\Delta_y = Pl^3\left[\frac{M(\frac{1}{3}-\gamma+\gamma^2)+N\beta(\frac{1}{2}-\gamma)}{(EI_x)_1+(EI_x)_2} + \frac{\alpha(M\alpha - L\beta)}{(GK)_1+(GK)_2}\right] + Pl\left[\frac{M}{\left(\frac{GA}{F_y}\right)_1+\left(\frac{GA}{F_y}\right)_2}\right]$$

$$\Delta_z = Pl^3\left[\frac{N\alpha^2+L\alpha(\frac{1}{2}-\gamma)}{(EI_y)_1+(EI_y)_2} + \frac{N\beta^2+M\beta(\frac{1}{2}-\gamma)}{(EI_x)_1+(EI_x)_2}\right] + Pl\left[\frac{N}{(AE)_1+(AE)_2}\right]$$

$$R = \frac{I_x}{K},\ T = \frac{I_y}{K},\ and\ \psi = \frac{K}{l^2 A}$$

Notice: for second order equation $(ax^2+bx+c=0)$ the solving roots are given as:

$$x_{1,2} = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$$

Good Luck

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