

МНННСТЕРСТВО ОЕРАЗОВАНИИ И НАУКИ РОССИИ
ОЕ, ^ЕРА^НН

ОНННАИ ОЕ^ЕРА^ВНОРО РОСЬ^АПСТБЕНОРО ЕВ^ЕНОРО
ОЕРАЗОБАТЕНОРО Я^РЕ^ЕННИ ВВСМЕРО ОЕРАЗОБАНИИ
«НА^НОНАИВНИИ НСЧЕ^ОВАТЕНСКИИ УННБЕРЧТЕТ «М^Н»
В г. СМОЕНСКЕ

Ка^егпа «Техно.ноуэекс МамуИ и оорыгоВанун»

НОЧНТЕ^ВНАИ ЗАНСКА К КупсОВОИ паОоте но гуцгунуе
«нуКнаган МехануКа» На ТеМь: «ПаОтеТМ На нро^Нотб
Механу^екс КоНсТрыКгифи»

НапаБаеНие нороТОВКу: 13.03.02. ^^екТпо^Нер^еТНКа и
анекТпоТехННКа нро^уаб нороТОВКу: ПоПоТОТехНУКа В
анекТпоМехануэекс цсТеМах

рпына РТ-20 АВТОР паОотМ

АТакумеВ ^.А.

(ногнуб)

РыКобогутеаб паОотМ

ЕорусоВ А.В.

(ногнуб)

ПаОота гонь^еНа К За^уТе 27.12.21

ЕорусоВ А.В.

(гаТа)

(ногнуб)

ПаОота За^у^еНа 28.12.21

ОгеНКа хоромо.

(гаТа)

^аеНМ КОМУССУ

КоН^уНа .Н.В.

(ногнуб)

ЕорусоВ А.В.

(ногнуб)

СМоаеНск
2021

ОНННАИ ОЕ^ЕРАИbHOrO rOCy^APCTBEHHOrO BW^ETHOrO
ОБРАЗОБАТЕ^bHOrO y^PE^EHHИ BWCmErO ОБРАЗОБАHHH
«НА^HOHAИbHBIH HCCHE^OBATEHbCKHH yHHBEPCTET «M^H»
B r. CMOHEHCKE

Ка^егра «TexHoaopuaeckue MamuHM u o6opyгobahue»

HанпаBaeHue nogroToBKy 13.03.02 «^aeKTpo^Hep^eTUKa u
aneKTpoTexHHKa»

3A^AHHE

Ha KypcoBypo паOoTy cTyгеHTa ATaKumueBa ^.A. (rpynna PT-20)

TeMa: PacaeTM Ha npoaHocTL MexaHuaeckux

KoHcTpyKгуи Cogep^aHue pacaepao-noaHuTeaLHofi

3anucku:

2. 3агааа N1: nocTpoуTL ^^ropM npogoaLHtix cya, Hanpa^eHufи u nepeMe^eHufи
BBeгeHue.

noneпeaHtix ceaeHufи бpыca.

3. 3агааа N2: nocTpoуTL ^^Mpy KacaTeaLHtix Hanpa^eHufи.

4. 3агааа N3: nocTpoуTL ^^ropy noneпeaHtix cya u u3py6apo^ux MOMeHTOB.

5. 3агааа N4: nogoOpaTL noneпeaHoe ceaeHue 6aaKu.

6. 3агааа N5: nog6op гuaMeTpa Baaa npy u3py6e c KpuaeHueM.

7.

3aKapoaeHue.
neпeaHL rpa^uaeckopo MaTepuaaa:

1. ^^MpM K 3агааe N1

2. ^^MpM K 3агааe N2

3. ^^MpM K 3агааe N3

4. ^^MpM K 3агааe N4

5. ^^MpM K 3агааe N5 ^aTa

Btigaau 3агаHua: 8.09.2021

PyKOBOfIHTeHb ---

/<T
)

- EopucoB A.B.

3агаHue npyHaaa K

CTyгеHT
BтuгoаHeHuro:

ATaKumueB ^.A.

^aTa 3a^uTM KypcoBofi паOoTM 28.12.2021

CMoaeHCK
2021

AHHOTa^H

В КypcoBOH pa6oTe пaccMaTpHBaMTcn MexaHH^eckHe KOHCTpyKцHH, gnn KOTOPMX BMnoaHHMTCH нпo^HOcratie паOTeTM нпу cneyро^Hx Bugax ge^opMagHH: пacTH^eHHH (c^aTHH), Kpy^eHHH, H3pH6e, H3pa6e c Kpy^eHHeM.

Пac^eTHO-ноHCHHTenLHaH 3ануcKa KypcoBOH pa6oTM COCTOHT H3 28 CTpaHHг, 5 нпHно^eHHH, BKнM^aM^Hx пучыHKH K 3ага^aM, 7 нHTeпаTypHMx HCTO^HHKOB.

Knpo^eBLie cноBa: 6анKa, ^^Mpa, pacpa^eHHe, Kpy^eHHe, H3pH6, нпo^HOcrt.

Annotation

The coursework discusses mechanical structures for which toughness calculations are performed assuming that the following types of deformation occur: tension (compression), torsion, bending, bending and torsion.

The explanatory note on the calculations of this coursework comprises 28 pages, 5 applications, which include drawings for the tasks, and 7 literary sources.

Keywords: beam, diagram, tension, torsion, bending, strength.

O»DH0I/OIAI3 J a « GIAl » AI/1H » A09JO i/em/MO			mitixAd-LDHOx XMxDdhMHeXdW qiDOHhOdU > . 6H NldhDBd		gv aoDMdog	■tfdaaiA
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						■EHahad
V					■g'V aoDMc p^.	■daaodu
ao±DMi/	J-DML /	■±MI/ (aanrTiMXB±v	■gedeed
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 PIp°bl eMi/ee
 IT8⁵N ehei/ee
 8^ehetfee
 9T⁵NBhBtfe£
 c;9HH9b·9ag
 :9HHPM<d9'D

BBegeHue

^aHHaa pacaerao-rpa^uaecKaa, KypcoBaa paSoTa aBaaTca uroroM caMOCTOHTealHoro u3yaeHua yaeSHwx MaTepuaaoB, noyaeHHwx npy KoHTaKTHofi pa6oTe c npenoBaTeaem, u pemeHua 3agaa no gucgunauHe «npyKaagHaa MexaHHKa» Ha TeMy «PacaeT Ha npoaHocTL MexaHuaecKux KoHcTpyKcufi».

^atro BtmoaHeHua paSoTw aBaaTca ocBoeHue MeToroB pacaeTa Ha npoaHocTL KOHCTpyKcHH npy pa3HMx cayaaax ge^opMaguu: pacTa^eHHu(c^aTHu), KpyaeHuu, H3pH6e, H3pH6e c KpyaeHueM. B xoge BtmoaHeHua pacaerao-rpa^uaecKofi pa6oTM, 6LMH BtinoaHeHTu pacaeTtu, gaa nocTpoeHua ^^Mp BHyTpeHHux cuaoBtux ^aKTopoB gaa npyBegeHHMx BMme BugoB ge^opMaguu. A TaK^e cgeaaHTu aepTe^u, HeoXoguMte gaa pacaeToB, B KOTOPMX npegcraBaeHn ^^ropM gaa Ka^goro Buga ge^opMaguu. Etiau onpegaeHTu npoaHocraTe xapaKTepecTUKy KoHcTpyKcufu, nogoCpaHM onTUMaaLHTe ceaeHua u cgeaaH aHaa3 npoaHocTu KoHcTpyKcufu.

KaroaeBte caoBa npy BtinoaHeHuu KypcoBofi paSoTtu:

EaaKa - 6puc, Haxoga^ufica nog geficTBueM H3pH6apo^ux ycaufu, B aacraocpa, nonepeaHTux cu, MoMeHToB u pacnpegaeHHtux Harpy3oK.

^^ropa - ocoTufu Bug rpa^uka, noKa3tuBaro^HH pacnpegaeHue BeauauHTu Harpy3Ku Ha o6eKT.

PacTa^eHue - Bug npogoaLHofi ge^opMaguu cTep^Ha uau Spyca, Bo3HUKaM^ufu B TOM cayaae, ecau Harpy3Ka K HeMy npyKaagtuBaeTca no ero npogoaLHofi ocu (paBHogeficTByro^aa cu, Bo3geficTByro^ux Ha Hero, HopMaalha nonepeaHoMy ceaeHHM cTep^Ha u npoxoguT aepe3 ero geHTp Macc).

KpyaeHue - oguH H3 BugoB ge^opMaguu Teaa. Bo3HHKaeT B TOM cayaae, ecau Harpy3Ka npyKaagtuBaeTca K Teay B Buge naptu cu (MoMeHTa) B ero nonepeaHofi naocKocTu. npy ^TOM B nonepeaHwx ceaeHuax Teaa Bo3HHKaeT ToaLKO oguH BHyTpeHHufu cuaoBofi ^aKTop — KpyTa^ufu MoMeHT.

H3pH6 - TaKofi Bug ge^opMaguu, Korga nog geficTBueM BHeMHux cu B nonepeaHwx ceaeHuax cTep^Ha(fipyca) Bo3HHKaeT u3pH6aM^ufu MoMeHT.

npoaHocTL - ^TO OTOCOSHocTL KoHcTpyKcuy Bwgep^uBaTL 3agaHHyro Harpy3Ky, He pa3pumaacL.

						aMC
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M3MaMC		N°	nognM			5

Задание 1

Исходные:

$a = 0; b = 9; e = 7$

$E = 240 \text{ МПа}$

$[\sigma] = 160 \text{ МПа} = 1,6 \cdot 10^8 \text{ Па}$

Схема 7;

$P_1 = 17 \text{ кН}, P_2 = 19 \text{ кН};$

$A_1 = 2,0 \text{ см}^2, A_2 = 2,9 \text{ см}^2, A_3 = 2,7 \text{ см}^2; a$

$a = 0,8 \text{ м}, b = 0,7 \text{ м}, c = 0,6 \text{ м}.$

Решение

Рис. 1: Схема конструкции с нагрузками.

Сила в стержне 1 AB: $N_{AB} = P_1 = 17 \text{ кН}$

Сила в стержне 2 BC: $N_{BC} = P_1 = 17 \text{ кН}$

Сила в стержне 3 CD: $N_{CD} = P_1 - P_2 = 17 \text{ кН} - 19 \text{ кН} = -2 \text{ кН}$

Сила в стержне 4 DE: $N_{DE} = P_1 - P_2 = 17 \text{ кН} - 19 \text{ кН} = -2 \text{ кН}$

Рис. 2: Схема конструкции с реакциями.

Сила в стержне 1 AB:

Сила в стержне 2 BC:

Сила в стержне 3 CD:

Сила в стержне 4 DE:

Сила в стержне 4 DE:

Рис. 3: Схема конструкции с реакциями.

N_{AB}	$17 \cdot 10^3$	$8,5 \cdot 10^7$	Па	85 МПа
A_{AB}	$2,0 \cdot 10^{-4}$			
N_{BC}	$17 \cdot 10^3$	$5,86 \cdot 10^7$	Па	58,6 МПа
A_{BC}	$2,9 \cdot 10^{-4}$			
N_{CD}	$2 \cdot 10^3$	$-6,9 \cdot 10^6$	Па	-6,9 МПа
A_{CD}	$2,9 \cdot 10^{-4}$			
N_{DE}	$2 \cdot 10^3$	$-7,4 \cdot 10^6$	Па	-7,4 МПа
A_{DE}				

$$A_{1E} = 0$$

$$A_{1E} = 0$$

$$\text{Сила в стержне 4 DE: } A_{1D} = A_{1E} + \frac{0,6 \cdot 19 \cdot 10^3}{2 \cdot 10^5} = -2,22 \cdot 10^5 \text{ М}$$

$$\text{Сила в стержне 3 CD: } A_{1C} = A_{1D} + \frac{0,8 \cdot 17 \cdot 10^3}{2 \cdot 10^5} = -3,4275 \cdot 10^5 \text{ М}$$

М3М	МС	№	ногнМ	лаТ

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М
С

$$y^{\text{acroK 2 BC}}: Al_B = Al_C + \frac{0,35}{2-1} \cdot 10^{-5} = 6,8 \cdot 10^{-5} \text{ M}$$

$$y^{\text{acTOK 1 AB}}: Al_A = Al_B + \frac{0,85}{2-1} \cdot 10^{-5} = 40,8 \cdot 10^{-5} \text{ M}$$

BMBog: TaK KaK |6_{max}| < 10⁸⁵ < 10¹⁶, TO CTep^eHL Btipep^HT npHao^eHHLie Harpy3KH.

M3M	^MC	N°	nognM	flaT
T		roKvM	C	

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-R3-

3аgааа N2

K CTaaLHOMy Baay npuao^eHM Tpu u3BecTHMx MOMeHTa: T₁, T₂, T₃. Mogyat cgBura
 G = 0,8 • 10⁵ Mna

TpeOBeTca:

- 1) CgeaaTL qepTe^ Baaa no 3аgаHHMM pa3MepaM B MacmTaOe;
- 2) CocTaBHTL gaa Ka^goro yaacTKa Baaa B ceaeHuu aHaauTuaeckue Btipa^eHua H3MeHeHHH KpyTHigux MOMeHTOB T, KacaTeaHTix Hanpn^eHHH T u ypaOB 3aKpy^HBaHHH 9;
- 3) nocTpoHTL ^^MpM npogoatHix ycauH T, KacaTeaHTix Hanpa^eHufi T u ypaOB 3aKpy^HBaHHH 9;
- 4) CgeaaTL BLiBog o npoaHocpa cTep^HH npu [T]=50 Mna

T ₁ , KH^ gaHMe	T ₂ , KH^ M	T ₃ , KH^ M	a, MM	b, MM	c, MM	d ₁ , MM	d ₂ , MM	d ₃ , MM	[T], Mna	G, Mna
0,19	0,17	0,29	600	500	700	60	50	30	50	0,8 • 10 ⁵

CxeMa no пycыHKy: 7 PemeHue:

- 1) CocTaBHM gaa Ka^goro yaacTKa Baaa aHaauraaeckue BLipa^eHua u3MeHeHua KpyTH^ux MoMeHTOB T u nocTpoUM ^^Mpy KpyTHigux MoMeHTOB.

$$M_z = T_3 = 0,29 \text{ KH-M};$$

$$M = T_3 - T_2 = 0,29 - 0,17 = 0,12 \text{ KH-M};$$

$$M_{z'CD} = T_3 - T_2 = 0,12 \text{ KH-M};$$

$$M = T_3 - T_2 + T_1 = 0,29 - 0,17 + 0,19 = 0,31 \text{ KH-M}.$$

- 2) CocTaBUM gaa Ka^goro yaacTKa Baaa aHaauTuaeckue BLipa^eHua u3MeHeHua KacaTeaLHMx Hanpa^eHua T u nocTpoUM ^^Mpy KacaTeaLHLix Hanpa^eHua.

$M_i = W_{pi}$
 rge $i = 1$ KacaTeaLHoe Hanpa^eHue Ha yaacTKe 1;
 $M_{zi} = K_{pi} \cdot W_{pi}$ KpyTH^uH MoMeHT Ha yaacTKe 1;
 $W_{pi} = p_i \cdot d_i$ - MoMeHT conoTyaehua ceaeHua yaacTKa 1, KoToпoe onпeгeaaeTca

BMpa^eHueM

$$W_{pi} = \frac{nd}{3 \cdot 2 \cdot d}$$

-rge d гuaMeTp ce юHHH aaeTKa

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M3 aMC N° nogH fla

M. T goKyM. MC T -R3-

$$Z_{AB} = \frac{0,29 \cdot 10^3}{3} = 0,0537 \cdot 10^9 \text{ na} = 53,7 \text{ Mm};$$

$$W_{PAB} = 0,2 \cdot (3 \cdot 10^{-2})^3 = 0,0048 \cdot 10^9 \text{ na} = 4,8 \text{ Mna};$$

$$W_{PBC} = 0,2 \cdot (5 \cdot 10^{-2})^3 = 0,0025 \cdot 10^9 \text{ na} = 2,5 \text{ Mna};$$

$$W_{PDE} = 0,2 \cdot (6 \cdot 10^{-2})^3 = 0,0072 \cdot 10^9 \text{ na} = 7,2 \text{ Mna}.$$

3) Сочта БНМ гаН Ка^goro yaacTKa Baaa aHaauTuaecKue Btipa^eHua yraoB 3aKpy^HBaHHH ^ u nocTpyM ^^ropy yraoB 3aKpyauBaHHH. yroa 3aKpy^HBaHHH onpegeaaeTCH no ^opMyae:

$M \cdot /.$

z. i

$$O = 1,$$

rge li - gauHa yaacTKa i, M;

G - Mogyal cgBura, Mna;

Jpi - MoMeHT HHepgyu yaacTKa i, KoTopaH onpegeaaeTCH no ^opMyae:

$$J_{OE} = 0,1 d, \text{ (T.K. ^TOT Kpafi 3aKpenaeH);}$$

$$M_{zED} = \frac{0,31 \cdot 10^3 \cdot 60,18}{0,8 \cdot 10^{11} \cdot 0,1 \cdot 6 \cdot 10^{-2}} = 0,54 \cdot 10^3 \text{ pad};$$

$$M^{\wedge} = 0,54 \cdot 10^{-3} + 0,12 : 10! \cdot 60,42.$$

$$OC = OD + ODC = 0,54 \cdot 10$$

J +

$$GJ_{DC} = 0,8 \cdot 10^u \cdot 6 \cdot 0,1 \cdot (6 \cdot 10^{-2})^4$$

$$O_B = 1,03 \cdot 10^{-3} \text{ pad}; \quad O_C = 0,3 \cdot 10^{-3} + \Delta z_{CB} = 1,03 \cdot 10^{-3} + 0,12 \cdot 10 \cdot 60,5$$

$$GJ_{CB} = 0,8 \cdot 10^u \cdot 6 \cdot 0,1 \cdot (5 \cdot 10^{-2})^4$$

$$= 2,23 \cdot 10^{-3} \text{ pad};$$

$$O_A = O_B + O_{BA} = 2,23 \cdot 10^{-3} + \frac{1}{7} \cdot \frac{1}{GJ_{BA}} = 2,23 \cdot 10^{-3} + 0,29 \cdot 10 \cdot 60,7$$

$$GJ_{BA} = 0,8 \cdot 10^u \cdot 6 \cdot 0,1 \cdot (3 \cdot 10^{-2})^4$$

$$= 33,53 \cdot 10^{-3} \text{ pad};$$

4) H3 ^^ropM KacaTeaLHoro Hanpa^eHHH MaKCHMaalHoe Hanpa^eHue paBHo:

$$T_{max} = T_{AB} = 53,7 \text{ Mna};$$

npobepuM npo^hocTL cpe^HH npy gonyCKaeMoM HanpaweHHy I^1_{50} Mna

M3Ma^cT	N°	nognM	flaT	
	goKyM.	C		

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m

СнегоBaTenLHO, ycноBue npo^HOcra He BLinonHaeTcn (cTep^eHL paOoTaeT

B ycноBHH nepery3KH).

$$I_{\text{max}}^T \cdot 100\% = \frac{150-53}{27} = 7,4\%$$

n_{T1}

50

M3M	^MC	N°	nognM	flaT

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^M
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90

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3aga^a N3

nocTpoeHue ^^Mp BHyTpeHHux ycaufi B cTara^ecku onpegeauMwx 6aaKax.

Tpe6veTca:

- 1) HanucaTL Bwpa^eHun nonepe^Hofi cuaw Q_y u roruSaro^ero MOMeHTa M gan Hanuca
Ka^goro y^acTKa B o6^eM Buge;
- 2) nocTpouTL ^^MpM nonepe^Hofi cuaw Q_y u u3ru6aro^ero MOMeHTa M_x ;

P, KH	M, KH^M	a, M	b, M	C, M	d, M	$\frac{KH}{M}$
10	19	1,0	2,9	2,7	1,0	7

CxeMa no pucyHKy: 7

PemeHue:

1) OnpegeauM peaKguu onop. ^an onpegeaeHun peaKgufi cocTaBaneM ypaBHeHun cyMMw MoMeHToB Bcex cua oraocuTeatHo To^eK A u B.

$$\sum_{i=1}^n M_i = 0: P a + R_B (b + c) + m - q - (c + d) \quad b + \frac{c+d}{2} = 0;$$

$$P a - m + q - (c + d) \cdot (b + \frac{c+d}{2})$$

$$R_B = - \frac{b+c}{2} \cdot \frac{2 \cdot 7 + 10}{2,9 + 2,7} = 16,79 \text{ KH};$$

$$R_A = \frac{P - (a+b+c) + m + q - (c+d)}{b+c} \cdot d$$

$$10 - (1,0 + 2,9 + 2,7) + 19 + 7 - (2,7 + 2,7 + 1,0) \cdot \frac{1,0}{2,9 + 2,7} = 19,11 \text{ KH}.$$

3HaK naroc y peaKgufi RA u RB noKa3MBaeT, ^TO HanpaBaeHue peaKgufi 6wao

BwSpaHo BepHo.

npobepKa no ycaoBuro

~~npaBHoBecun~~ $R_B - q - (c + d) = 0;$

$$\sum_{i=1}^n M_i = 0: -10 + 19,11 + 16,79 - 7 - 2,7 + 1,0 = 0.$$

0=0.

2) OnpegeauM nonepe^Htie cuaw Q_y u nocTpouM ^^Mpy nonepe^Htix cua.

nepBmfi ygacTQK:

M3M^MC	N°	nognM	gaT	
T	soKyM	C		

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$$0 < z_1 < a = 1,0 \text{ M } Q_{yt} = -P = -10 \text{ KH};$$

БТопоН ygacTQK:

$$0 < z_2 < b = 2,9 \text{ M } Q_{y2} = -P + R_A = -10 + 19,11 = 9,11 \text{ KH};$$

ТреТуН ygacTQK:

$$0 < z_3 < d = 1,0 \text{ M } Q_{y3} = q - z_3;$$

$$\text{npu } z_3 = 0: Q_{y3} = 0 \text{ KH};$$

$$\text{npu } z_3 = d = 1,0 \text{ M}: Q_{y3} = q - z_3 = 7 - 1,0 = 7 \text{ KH}.$$

^eTBepTfcrn ygacTQK:

$$0 < z_4 < c = 2,7 \text{ M } Q_{y4} = -R_b + q \cdot (d + z_4);$$

$$\text{npu } z_4 = 0: Q_{y4} = -R_b + q \cdot d = -16,79 + 7 \cdot 1,0 = -9,79 \text{ KH};$$

$$\text{npu } z_4 = c = 2,7 \text{ M}: Q_{y4} = -R_b + q \cdot (d + z_4) = -16,79 + 7 \cdot (1,0 + 2,7) = 9,11 \text{ KH}.$$

3) Onpege^HM H3ru6aM^ue MOMEHTM Mx u nocTpouM ^^Mpy H3ru6aM^ux

MOMEHTOB. nepBHH ygacTPK:

$$0 < z_x < a = 1,0 \text{ M } M_{x1} = -P \cdot z_1;$$

$$\text{npu } z_1 = 0: M_{x1} = 0 \text{ KH-M};$$

$$\text{npu } z_1 = 1,0: M_{x1} = -10 \cdot 1,0 = -10 \text{ KH-M};$$

БТопofi ygacTPK:

$$0 < z_2 < b = 2,9 \text{ M } M_{x2} = -P \cdot (a + z_2) + R_A \cdot z_2; \text{npu } z_2 = 0: M_{x2} = -P \cdot a = -10 \text{ KH-M};$$

$$\text{npu } z_2 = b = 2,9 \text{ M}: M_{x2} = -P \cdot (a + z_2) + R_A \cdot z_2 = -10 \cdot (1,0 + 2,9) + 19,11 \cdot 2,9 = 6,42 \text{ KH-M};$$

ТреТ

HH ygacTPK:

$$0 < z_3 < d = 1,0 \text{ M } M_{x3} = m - q \cdot z \text{ npu } z$$

$$z_3 = 0: M_{x3} = 19 \text{ KH-M};$$

$$\text{npu } z_3 = d = 1,0 \text{ M}: M_{x3} = m - q \cdot z_3 = 19 - 7 \cdot 1,0 = 12 \text{ KH-M};$$

^eTBepTHH ygacTPK:

$$0 < z_4 < c = 2,7 \text{ M } M_{x4} = m + R_B \cdot z_4 - q \cdot (z_4 + d) \cdot \text{npu } z_4 + d$$

$$z_4 = 0: M_{x4} = m - q \cdot d = 15,5 \text{ KH-M};$$

$$\text{npu } z_4 = c = 2,7 \text{ M}: M_{x4} = m + R_B \cdot z_4 - q \cdot (z_4 + d) = 19 + 19,11 \cdot 2,7 - 7 \cdot (2,7 + 1,0) = 16,42 \text{ KH-M};$$

$$= 16,42 \text{ KH-M};$$

2				
M3M^MC	N°	nognM	flaT	
T	гоKvM	с		

18. KP. 13. 03. 02. nM.

^M
CT

ne

^^ropa 6ygeT HB^HTLCH napaSoaos BLinyKnocrtM BBepx c MaKCHMyMOM B TO^Ke,

rge Q_y^{40} . HafigeM ^Ty Tomy:

$$Q_y^{40} = d \cdot R_b \cdot q \cdot (1 + Z_4) = 0 \cdot Z_4 = 1,398 \cdot 1,398 \cdot M;$$

Z_1 398

nogcTaBHM ^' B aHaaHTH^ecKoe ypaBHeHue gan H3rH6aro^ero MOMeHTa Ha

qeTBepTOM y^acTKe:

$$M_{x \max} = m + R_B \cdot l \cdot 1,398 \cdot q \cdot 1,398 \cdot 19 + 16,79 \cdot 1,398 \cdot 7^4 \cdot 1,398 + 1,01$$

2

=22,34 KH.M.

143	^MC	N°	nognM	flaT
M	T	goKvM	C	

18. KP. 13. 03. 02. nM.

-R3-

^M
16T

3aga^a N4

^nn 3agaHHofi 6anKu H3 3aga^H N 3

1) ~~Третье~~ ~~Третье~~ ТНТЛ В MacmTa6e 3agaHHoe ce^eHue 6anKH c yKa3aHueM qucneHHtix

3Ha^eHHH pa3MepoB. OnpegenuT nono^eHue geHTpa TH^ecru ce^eHun u BtiqucnuTt MOMeHT HHep^H Ce^eHHH OTHOCHTentHO HeHTpantHOH

3cнocTpouTL ^^MpM HopMantHtix Hanpn^eHHH, pacnpegeneHHtix no BticoTe ce^eHHH gnn ce^eHun c MaKcuMantHMM H3py6aM^uM MOMeHTOM M_x , B3HTMM H3

3aga^u N 3.

3. Hcnont3yn ^^MpM H3py6aro^ux MOMeHTOB M_x , nocpoeHHtix B 3aga^e N 3, onpegenuTt H3 pac^eTa Ha npo^hocTt HOMep npo^unn gByTaBpoBofi (npu 3Ha^HTentHOH Hegorpy3Ke nпуHHTt gnn 6anKH ce^eHue B Buge mBennepa) npoKaTHofi 6anKH. MaTepuan 6anKu - cTant CT.3, [a] = 160 Mna.

4. nпу TOM ^e 3Ha^eHuu gonyckaemopo Hanpa^eHun onpegenuTt nO ycноBuro npo^hocru pa3Mepm nonepe^Horo ce^eHun B \$opMe:

a) Kpyra guaMeTpa d;

6) Kontga c OTHomeHueM guaMeTpoB $c o = -J = \frac{d}{h} = 0,6$

$$k = \frac{1}{b} = 1,9$$

B) np^MoyrontHuKa c OTHomeHueM CTOPOH b

5. CocpaBurt Ta6nygy OTHomeHufi nno^agefi yKa3aHHtix ce^eHufi K nno^agu gByTaBpoBopo npo^unn.

[a], Mna	$M_x \max, \text{кНм}$	B, MM	C, MM
160	22,34	22	26

HoMep ce^eHun:

7

1) OnpegenuM geHTp TH^ecra OTHocuTentHO HefiTpantHofi ocu Ox:

$$y_c = \sum_{i=1}^n X_i^2 \cdot y_c \cdot n \quad \blacksquare A = X A_i$$

zde A, -nno^adb i- mozo ceueHun, MM; y_c - paccmoRHue om ocu Ox

do i-mozo yeumpa mnwecmu, MM .

$$A_1 = y_c c_1 + A_2 y_c c_2 + A_3 y_c c_3$$

$$y_c = \frac{A_1 + A_2 + A_3}{B - 4C}$$

$$\text{zde } A_1 = B - 4C = 22 - 4 \cdot 26 = 2288 \text{ MM}^2;$$

$$A_2 = 3B^2 C = 3 \cdot 22^2 \cdot 26 = 3168 \text{ MM}^2;$$

$$A_3 = n \cdot (1,5 B)^2 \cdot (3,14 - 1,5 \cdot 22)^2 = 855 \text{ MM}^2$$

M3M^MC	N°	nognM	flaT	

18. KP. 13. 03. 02. nM.

^M
CT
14

ne

$$y_c = EC_1 = \frac{B}{2} = 22 \text{ MM};$$

$$y_c = EC_2 = \frac{3B}{2} = 2 + 2 \cdot 22 = 55 \text{ MM};$$

$$y_c = EC_3 = 3B = 3 \cdot 22 = 66 \text{ MM};$$

$$A_1 y_c + A_2 y_c + A_3 y_c = 2288 \cdot 11 + 3168 \cdot 55 + 855 \cdot 66$$

$$y_c = 31,1 \text{ MM};$$

$$J_c = A_1 + A_2 + A_3 = 2288 + 3168 + 855$$

2) OnpegeauM MOMeHT HHepgHH ceaeHHa OTHOCHTeatHO OCH Ox:

$$222 J_x = J_x + A_1^2 + J_x + A_2^2 + J_x + A_3^2$$

$$a_1 = CC_1 = y_c - y_c = 31,1 - 11 = 20,1 \text{ MM};$$

$$a_2 = CC_2 = y_c - y_c = 55 - 31,1 = 23,9 \text{ MM}; a_3 =$$

$$CC_3 = y_c - y_c = 66 - 31,1 = 34,9 \text{ MM};$$

$$J_x = \frac{b^3 h}{12} = \frac{4 \cdot 26^3 \cdot 22}{12} = 92283 \text{ MM}^4 = 9,23 \text{ CM}^4,$$

$$J_x = \frac{b^3 h}{12} = \frac{26^3 \cdot 3}{12} = 1245816 \text{ MM}^4 = 124,58 \text{ CM}^4;$$

$$J_x = \frac{b^3 h}{12} = \frac{12^3 \cdot 12}{12} = 1728 \text{ MM}^4 = 1,728 \text{ CM}^4;$$

$$J_x = \frac{b^3 h}{12} = \frac{6^3 \cdot 6}{12} = 18 \text{ MM}^4 = 0,018 \text{ CM}^4;$$

$$= 9,23 + 22,88 - 2,01^2 + 124,58 +$$

$$31,68 - 2,39^2 - 5,82 - 8,55 - 3,49^2 = 297,25 \text{ CM}^4;$$

3) HopMaatHtie Hanpa^eHHa npu H3rH6e no BMCOTe

ceaeHHa pacnpegaeHM no aHHeHHOMy 3aKOHy u B aroSofi Tome ceaeHHa

onpegeaaroTca no ^opMyae:

$$M_z \text{ max}$$

ede M_z - u3eu6aK > w, uu MOMeHm e ceueHuu, KH-M;

$$a_D = J_x = \frac{M_z}{\sigma} = \frac{22,34 \cdot 10^4}{100} = 2234 \text{ MM};$$

$$J_x = \frac{M_z}{\sigma} = \frac{22,34 \cdot 10^4}{100} = 2234 \text{ MM}^4;$$

$$ceaeHHa: y_D = CD = 56,9 \text{ MM};$$

$$y_E = CE = 31,1 \text{ MM}$$

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aMC
T5

M3MaMC	N°	nognM	gaT
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n3

4) OnpegeauM MOMeHT conporaBaeHua ceaeHua W x 6aaKu:

M

$$a_{\max} = \frac{z \max}{W} < [a],$$

$$W_{\max} = \frac{z \max \cdot 22,34 \cdot 10^3}{[a] \cdot 160 \cdot 10^6} = 139,6 \text{ CM}$$

$$W = 143 \text{ CM}^3, A = 23,4 \text{ CM}^2.$$

Bbi6epeM coraacHo rOCT 8239-89 $g_{ByTaBp} \wedge 18$

Hanpa^eHue B ^TOM cayaae 6ygeT paBH0:

$$a = \frac{USSL}{W} = \frac{22,34 \cdot 10^3}{143 \cdot 10^{-6}} = 0,15622 \cdot 10^9 \text{ na} = 156,22$$

Hegorpy3 B ^TOM cayaae 6ygeT paBeH:

$$100\% = \frac{156,22}{160} \cdot 100\% = 2,4\% < 20\%$$

[a] 160

$$W = 152 \text{ CM}^3, A = 23,4 \text{ CM}^2.$$

ECHH nPUH^Tb 6aaKy B \$opMe mBeaaepa N°

20: Hanpa^eHue B ^TOM cayaae 6ygeT paBH0:

$$a = \frac{USSL}{W} = \frac{22,34 \cdot 10^3}{152 \cdot 10^{-6}} = 0,14697 \cdot 10^9 \text{ na} = 146,97 \text{ Mna.}$$

$$W, 152 \cdot 10^{-6}$$

Hegorpy3 B ^TOM cayaae 6ygeT paBeH:

$$100\% = \frac{146,97}{160} \cdot 100\% = 8,1\% < 20\% \wedge y \text{ meejnep nedocpy3 dojbwe, [a] 160}$$

m y gByTaBpa, ^o^TOMy 6epeM gByTaBp N°18.

ae

5) OnpegeauM nonepeaHoe ceaeHue 6aaKu B \$opMe Kpyra:

$$W_{\max} = \frac{z \max \cdot 32 \cdot 22,34 \cdot 10^3}{n \cdot [a] \cdot 160 \cdot 10^6} = 112,5 \text{ MM}$$

$$AKP = \frac{z \max \cdot 32 \cdot 22,34 \cdot 10^3}{n \cdot [a] \cdot 160 \cdot 10^6} = 99,35 \text{ CM}^2;$$

OnpegeauM nonepeaHoe ceaeHue 6aaKH B \$opMe Koabga:

$$W = \frac{nd^3 \cdot (1 - cQ)}{32}, \text{ ede } c_0 = d \cdot d \approx 0,6 \text{ u } (1 - cQ) = (1 - 0,6^4) = 0,87,$$

m. e.

$$W = \frac{nd \cdot 0,87}{32} \wedge d > 3^{32} \cdot z \max = \frac{332 \cdot 22,34 \cdot 10^3}{n \cdot [a] \cdot 160 \cdot 10^6 \cdot 0,87} = 117,8 \text{ MM};$$

$$K \cdot d \cdot (1 - c_0^2) = n \cdot d^2 \cdot 0,87 = 0,87 \cdot 3,14 \cdot 11,78^2 =$$

$$94,77 \text{ CM};$$

KOJI 4 4 4

nogSepeM ceaeHue B \$opMe npaMoyroabHUKa (h = 1,9/b):

M3M	aMC	N°	nognM	gaT
T		goKvM	C	

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T6

$$W_x = \frac{bh^2 - b(1,9b)}{6} = 0,6 \cdot b^3 \cdot \frac{1}{b} = 3 \frac{22,34 - 10}{160 - 10^6 - 0,6} = 61,5 \text{ MM};$$

$$h = 1,9 - b = 1,9 - 61,5 = 116,8 \text{ MM};$$

$$A_{np} = b \cdot h = 6,15 \cdot 11,68 = 71,83 \text{ CM}^2$$

CocTaBHM cpaBHHT&nbHyro Ta6.^H^y

№	Среднее значение	$A_{\text{г}} \text{ CM}^2$	$A_{\text{г}} \text{ CM}^2$
1	#	99,35	4,24
2	0	94,77	4,05
3	1	71,83	3,07

M3M	^MC	N°	nognM	flaT
.	T	goKyM.	C	

18. KP. 13. 03. 02. nM.

**^M
CT**

ne

3agaaa N5

CTaatHofi Baa Bpa^aeTca c nocToaHHofi aacTOTofi n u nepegaeT MO^HOCTL N.

TpeSveTca:

- 1) OnpegeauTL Harpy3KH, geficTByro^ue Ha Baa, nocTpOHTL ^^MpM KpyTR^HX MOMeHTOB, ^^MpM H3rH6aM^HX MOMeHTOB B gByx naocKocrax (BepTuKaatHofi u ropoohTaathofi);
- 3) nogoSpaTL guaMeTp Baaa, ucnoal3yro TpeTLro Teopuro npoaHocTu, ecau u3BecTHO gonycKaeMoe Hanpa^eHue [a] = 170 Mna

HcxogHLie

группа	Teopua npoaHocTu u TpeTLa	a, MM	b, MM	D1, MM	D2, MM	объём, МУН	[a], Mna
17	TpeTLa	190	170	80	220	600	170

CxeMa no пycьHKy: N7 PemeHue:

1) OnpegeauM BeauauHy KpyTa^ero MoMeHTa:

$N \quad nn$

$T = M = \dots ; a = \dots ;$

$Kp \quad a \quad 30$

$30-N \quad 301710^3$

$T = 30-N = 30 \cdot 17 = 271 \quad H-M=0, \quad 271 \quad KH-M; \quad nn \quad 3,14-600$

OnpegeauM BeauauHM oKpy^HMx u paguaatHix cua Ha 3y6aaTtix Koacax:

$F = T = 2T$

$t = 0,5 \quad D = D'$

$2 \quad T \quad 2-271$

$F = \dots = 6775 \quad H=6,775 \quad KH;$

$t \quad D_1 \quad 0,08$

$2 \quad T \quad 2-271$

$F_t = \dots = 2464 \quad H=2,464 \quad KH;$

${}^{12}D_2 \quad 0,22$
 $F_r = F - tga = F - 0,364, \quad ede$

$F_r = 200,364 = 6,775 - 0,364 = 2,466 \quad KH;$

$r_1 \quad 1_1$

$F_r = F_t + 0,364 = 2,464 + 0,364 = 0,897 \quad KH;$

$r_2 \quad 1_2$

2) nocrpouM ^^ropM u3py6aro^ux MoMeHToB B naocKocTax xOz u yOz. ^aa ^TO^o

HaHgeM onopHtie peaKgy: a) PaccMoTpyM BepTuKaalHyro naocKocTL:

n
 $Z^F y = 0; \quad -R A_y - R_{By} - F_r z + F_t = 0;$

k=1

M3MaMC	N°	nognM	gaT	

18. KP. 13. 03. 02. nM.

aMC
18T

ne

$$\sum_{k=1}^n X M_x = 0; -F_r \cdot 6 \cdot 3a + F_t \cdot 6a - R_{By} \cdot 6(3a+b) = 0;$$

$k=1$

$$R_{By} = - \frac{F - 3a + F_t \cdot 6a}{3a + b} = \frac{-0,897 - 3 \cdot 0,19 + 6,775 \cdot 0,19}{3 \cdot 0,19 + 0,17} = 1,049 \text{ KH};$$

$$R_{Ay} = -R_{By} - F_r + F_t \cdot 2 = -1,049 - 0,897 + 6,775 = 4,829 \text{ KH};$$

npobepKa:

$$\sum_{k=1}^n X M_x = 0; F_r \cdot 6b - F_t \cdot 6(2a+b) + R_{Ay} \cdot 6(3a+b) = 0;$$

$$0,897 \cdot 0,17 - 6,775 \cdot (2 \cdot 0,19 + 0,17) + 4,829 \cdot (3 \cdot 0,19 + 0,17) = 0; -0,001$$

$\ll 0;$

6) PaccMOTpuM ropH30HTa^LHyro nnockKOCTh:

$$\sum_{k=1}^n X F_x = 0; R_{Ax} + R_{Bx} - F_r - F = 0;$$

$k=1 \dots n$

$$\sum_{k=1}^n X M_y = 0; F_r \cdot 6a + F_t \cdot 6(3a) - R_{Bx} \cdot 6(3a+b) = 0;$$

$k=1 \dots n$

$$R_{Bx} = \frac{F - a + F_t \cdot 6 \cdot 3a}{3a + b} = \frac{2,466 - 0,19 + 2,464 \cdot 3 \cdot 0,19}{3 \cdot 0,19 + 0,17} = 2,53 \text{ KH};$$

$$R = -R_{Bx} + F_r + F = -2,53 + 2,466 + 2,464 = 2,4 \text{ KH};$$

npobepKa:

$$\sum_{k=1}^n X M_y = 0; -F \cdot 6(2a+b) - F_r \cdot 6b + R_{Bx} \cdot 6(3a+b) = 0;$$

$k=1 \dots n$

$$-2,466 \cdot (2 \cdot 0,19 + 0,17) - 2,464 \cdot 0,17 + 2,4 \cdot (3 \cdot 0,19 + 0,17) = 0;$$

$0,001 \approx 0;$

nocpohM ^Mpy H3ra6aM^Hx MOMeHTOB B BepTHKa^bHofi

nnockKOCTh: I ygacTQK:

$$0 < z_1 < a = 190 \text{ MM};$$

$M_{x,c} = -R_{Ay} \cdot z_1$

AC

$$\text{npu } z_1 = 0 \cdot M_x = 0;$$

v AC

$$\text{npu } z_1 = 190 \text{ MM} \cdot M = -4,829 \cdot 0,19 = -0,917 \text{ KH-M};$$

II ygacTQK:

$$0 < z_3 < b = 170 \text{ MM};$$

$$M = -R_{By} \cdot z_3$$

DB

$$\text{npu } z_3 = 0 \cdot M_x = 0;$$

DB

$$\text{npu } z_3 = 170 \text{ MM} \cdot M = -1,049 \cdot 0,17 = -0,178 \text{ KH-M};$$

M3M	BMC	N°	nognM	flaT
T		goKyM.	C	

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BMC
T 19

nocrhoHM ^^ropy H3rH6aro^Hx MOMeHTOB B ropooHTanLHoH

nnocKocTH:

I ygacTOK:

$$0 < z_1 < a = 190 \text{ MM};$$

$$M_{y_{AC}} = R_{AX} L_{Z1};$$

$$z = 0 \wedge M = 0; \text{ npu } 1 \wedge AC$$

$$z. = 190 \text{ MM} \wedge M = 2,4 \cdot 0,19 = 0,456 \text{ KH-M};$$

$$\text{npu } 1 \wedge AC$$

II ygacTOK:

$$0 < z_3 < b = 170 \text{ MM};$$

$$M_{y_{DB}} = R_{B} * L_{z3};$$

$$z_3 = 0 \wedge M = 0; \text{ npu } 3 \wedge DB$$

$$\text{npu } 3 \wedge DB$$

3) OnpegenHM gHaMeTp Bana HCxogH H3 ycnOBHH oOecneHeHHH npo^Hocpa

no

TpeTLeH TeopHH:

no TpeTLeH TeopHH, npo^Hocpa:

$$M_{KD} = JM^2 + M^2 + 0,75 T^2 = V(-0,917)^2 + 0,456^2 + 0,75 \cdot 0,271^2 = 1,051 \text{ KH-M};$$

$$M^A = JM^2 + M^2 + 0,75 T^2 = V(-0,178)^2 + 0,43^2 + 0,75 \cdot 0,271^2 = 0,521 \text{ KH-M};$$

$$M_A > M_B$$

CneBoBaTenBo, pacneT HeoXogHMo BecTH B ceneHHH A.

^KBHBaneHTHoe Hanpn^eHHe npu H3ry6e onpenenneTCH BMpa^eHueM:

$$\sigma = \frac{M}{W}, \text{ zde } W_x = 0,1 d^3;$$

$$d > A = \sqrt[3]{\frac{3 M_{3KB}}{0,1}} = 0,03954 M = 39,54 \text{ MM};$$

$$0,1 [o] \quad 0,1-170-10_$$

OKpyrHeM go Onu^anmero Oontmero CTaHgapTHoro 3HaneHHH guaMeTpa

Bana: d=40 MM.

M3M	^MC	N°	nognM	gaT
T		goKyM.	C	

18. KP. 13. 03. 02. nM.

ne

^M
96

3aKnro^eHue

B xoge BMinonHeHuH KypcoBofi paSoTMi nony^eHMi cnegyro^ue pe3ynLTaTMi:

B 3aga^e 1 pacOTuraHa nro^HocTt 3aKpenneHHoro cTep^HH, HaxogH^eroch nog geficTBueM cun. nroBepuB nro^HocTt cTep^HH nru gonyckaeMOM HanpH^eHuu, cgenaH BMiBog ^TO, ycnoBue nro^Hocra BtmonHHeTch.

B 3aga^e 2 pacOTuraHa nro^HocTt 3aKpenneHHoro cTantHoro Bana, HaxogH^eroch nog geficTBueM KpyTH^ux MOMeHTOB. nru nroBegeHuu nroBepKH Ha nro^HocTt cTep^HH nru gonyckaeMoM HanpH^eHuu cgenaH BMBog ^TO, Ban He BMigep^uT Harpy3KH.

B 3aga^e 3 nocTpoehM ^^ropM nonepe^HMix cun u roruSaro^ux MoMeHTOB u onpegeneHo onachoe ce^eHue.

B 3aga^e 4 gnH 3agaHHofi 6anku 3aga^u 3 onpegeneHM nru gonyckaeMoM HanpH^eHuu no ycnoBuro nro^Hocra pa3MepM nonepe^Horo ce^eHuH B \$opMe gByTaBpa u mBennepa. H cgenaHa cpaBHurentHaH TaSnuga oraomeHufi nno^agefi pa3nu^HMx ce^eHufi, gnH onpegeneHuH caMoro BMrogHoro nro^unH ce^eHuH, KaKoBMM oKa3anch mBennep.

B 3aga^e 5, ucnont3yH ^eTBepTyro Teopuro nro^Hocra (Teopuro HauSontmux KacaTenLHMx HanpH^eHufi), MM pacca^uTanu guaMeTp Bana no u3BecraoMy gonyckaeMoMy HanpH^eHuro [6] = 160 Mna, KoTopMfi Skin oKpyrneH go Snumfimero Sontmero 3Ha^eHuH u3 cTaHgapTHoro pHga pOCTa.

27.12.2021

(gaTa) (nognuh)

						^MC
					18. KP. 13. 03. 02. nM.	T
M3M	^MC	N°	nognM			21

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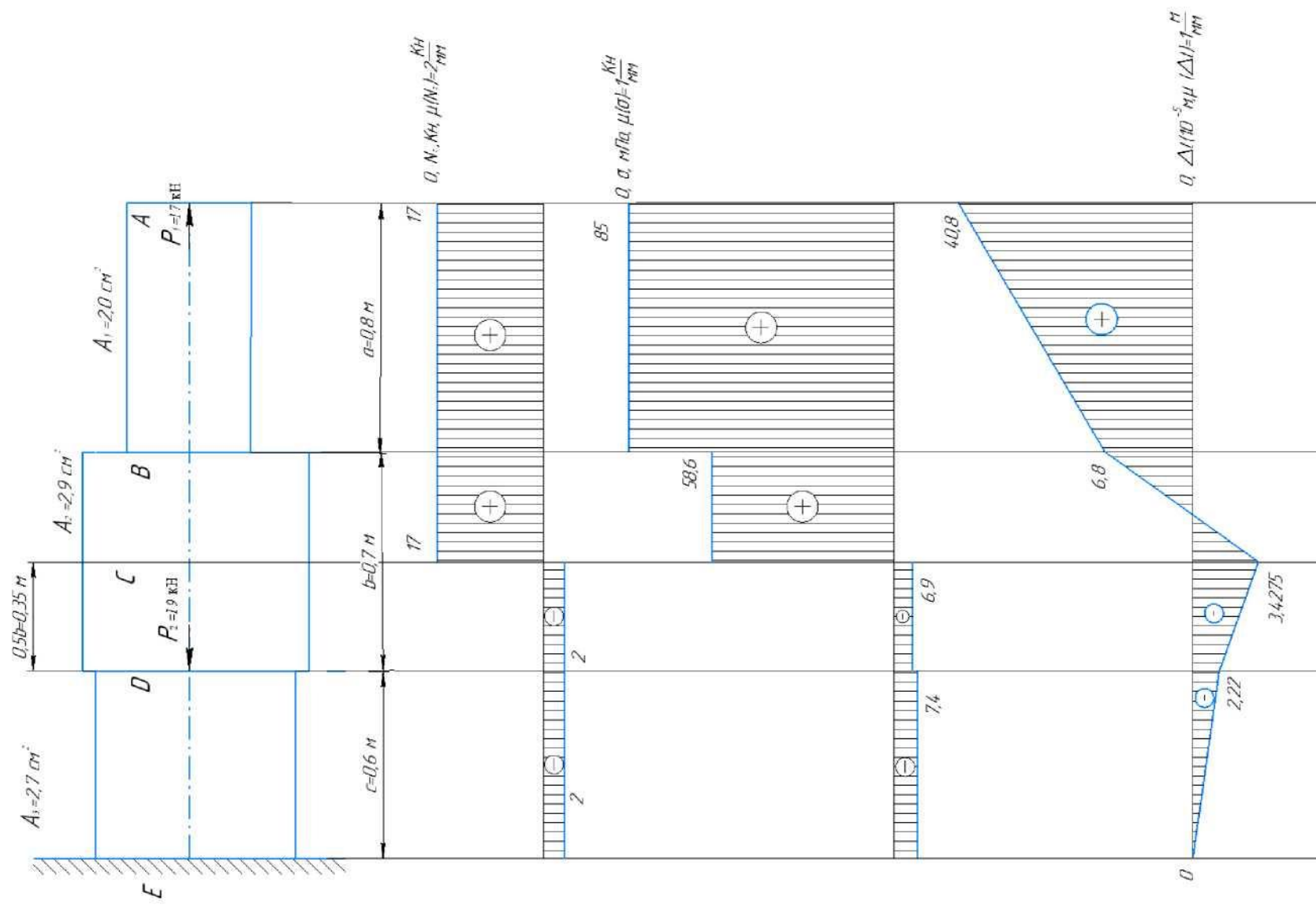
					18. КР. 13. 03. 02. нМ.	^MC T
M3M	^MC	N°	nognM			22

ripnn0>KeHHH

Изм.	Лист	№ докум.	Подпис	Дат

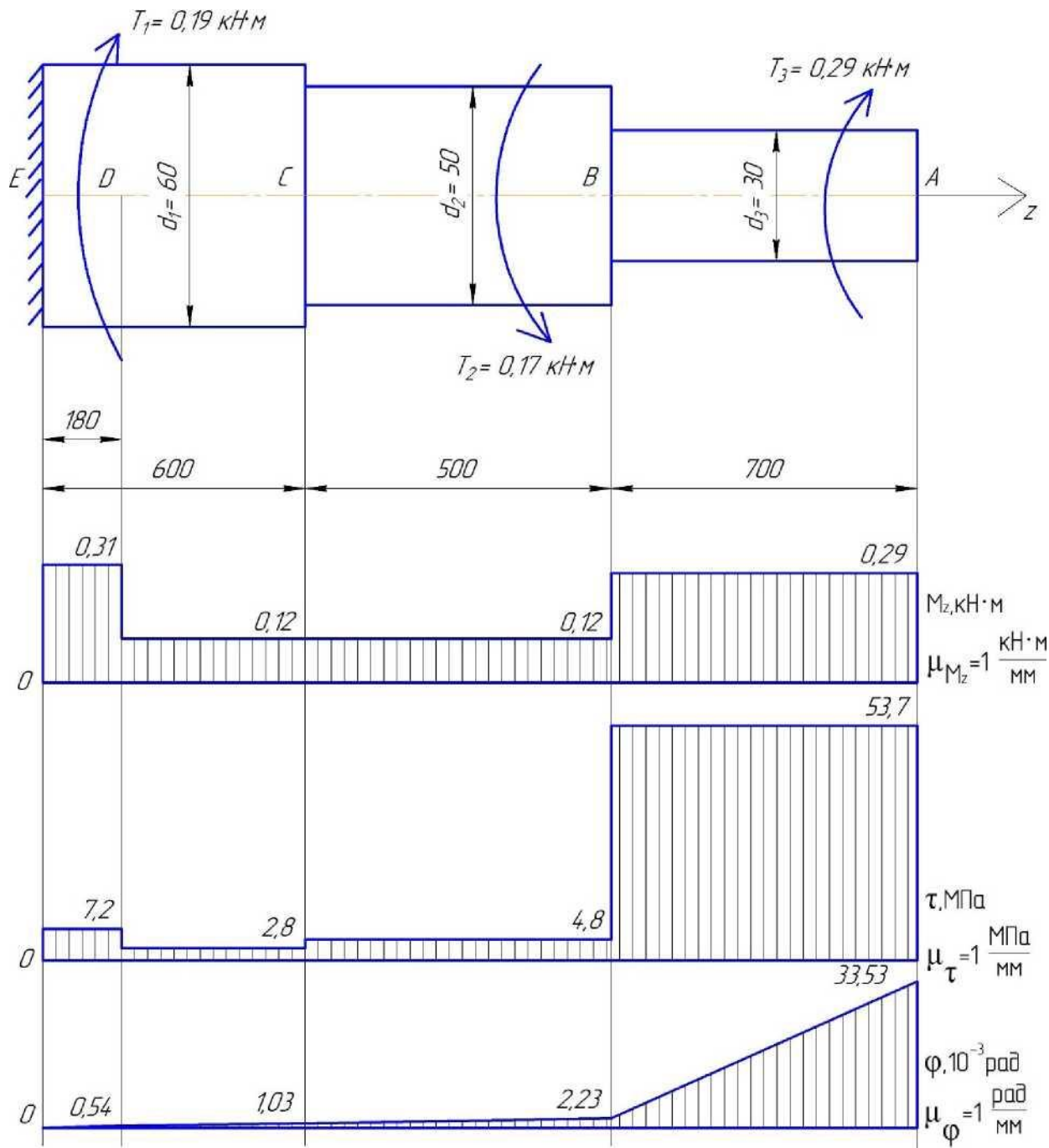
18. КР. 13. 03. 02. нМ.

Приложение 1
Чертеж к задаче №1



npHno^eHHe 2

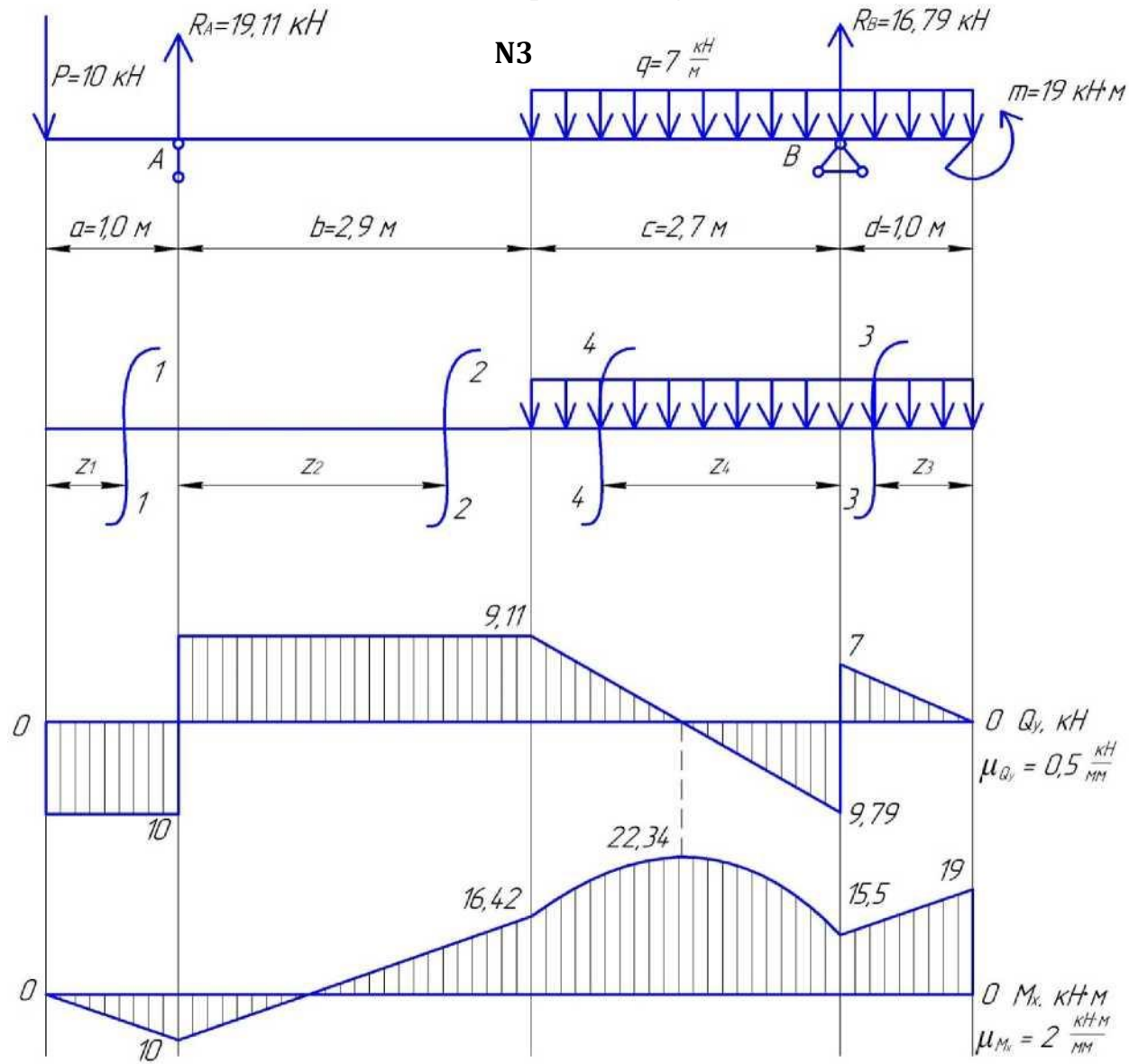
^epTe^ K 3aga^e N2



						^MC Г
18. KP. 13. 03. 02. nM.						
M3M	^MC T	N° гоKyM	nognM C	flaT		25

npHno^eHHe 3

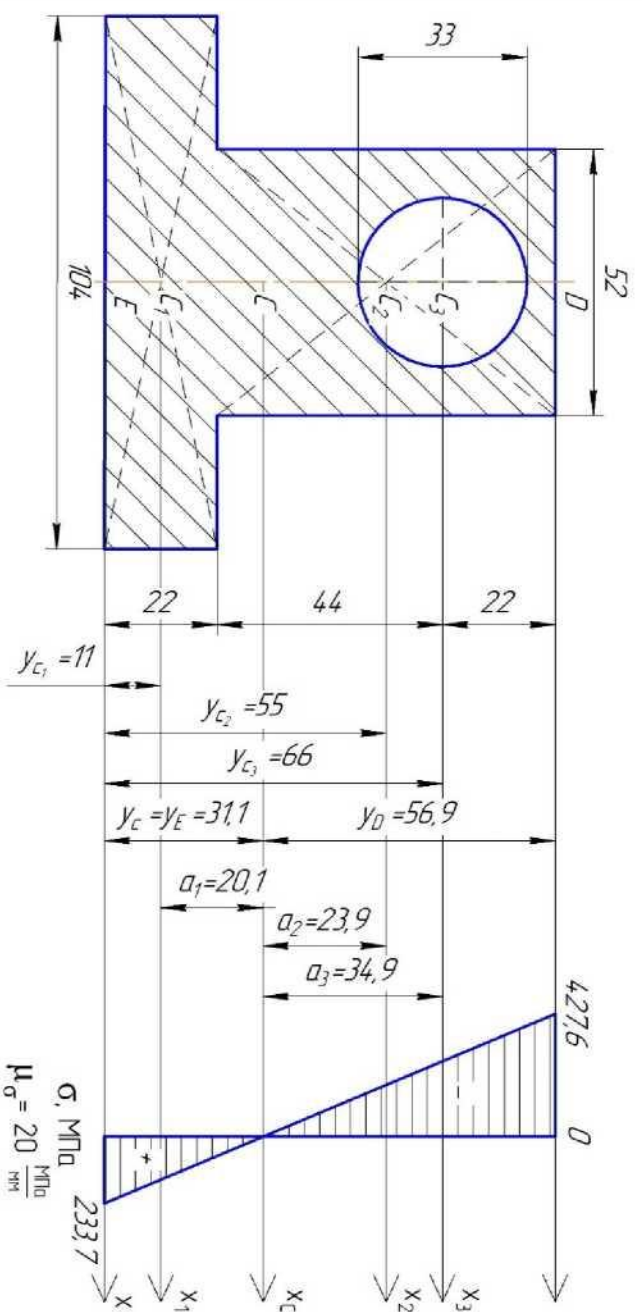
^epTe^ K 3aga^e



					18. KP. 13. 03. 02. nM.	^MC T
M3	^MC	N°	nognM	flaT		26

Приложение 4

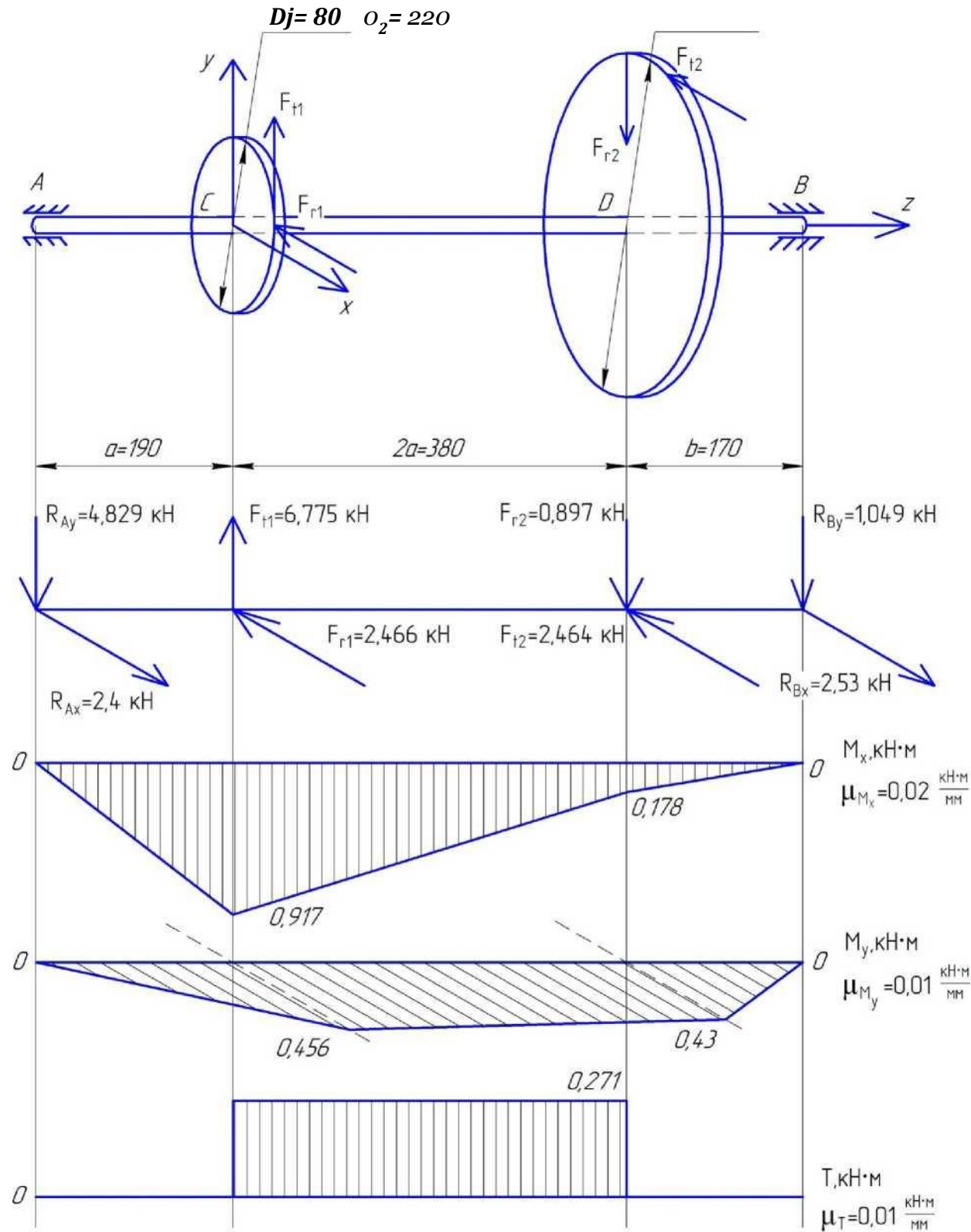
Чертеж к задаче №4



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						27

ПЗ

npHno^eHHe 5 ^epTe^ K 3aga^e N5



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						^MC Г
M3M	^MC T	N° гоКvM	ноgnM C	flaT		28