

**МНННСТЕРСТВО ОБРАЗОБАНА И НАУКИ РОСНННСКОИ
ОЕ^ЕРАТТНН**

**ОНННА^ ОЕ^ЕРА^bНОrО rОСУ^АРСТБЕННОrО ВМ^ЕТНОrО
ОбРАЗОБАТЕ^bНОrО УМРЕА/IEmm BbICmErO ОБРАЗОБАНА
«НА^ОНА.НбНбИИ НСС^Е^ОБАТЕ^bСКНН УННБЕРЧТЕТ «М^Н»
В r. СМО^ЕНСКЕ**

Ка^егра «TexHonorHneckKHx MamHH И
оборуроБаННА»

nOtfCHHTEnEHAH 3AnHCKA
K KypcoBon pa6oTe no gn^HnnHHe «npHKnagHaa MexaHHKa»
Ha TeMy: «PacneTbi Ha nponocTb MexaHHneckKHx
KoHcTpy^HH»

HaHpaBneHHe noгpOTOBKH: 13.03.02. ^eKTpo^ep^eTHKa И
3.neKTpoTexHHKa npo^Hnb noгpOTOBKH: По6oTOTexHHKa B
3^eKTpoMexaHHHeckKHx cHCTeMax

r пynна PT-20 АВТОР паОотби

АТaKHmneB ^.A.

PyKoBогHTenb
паОотби

(nogнucb)



ЕорncoB A.B.

ПаОотa гоуrnpHa K 3арн,HTe 27.12.21

(nogнucb)



ЕорncoB A.B.

ПаОотa 3a^H^eHa 28.12.21

(гаТа)

(nogнucb)

О^HKa xopomo

(гаТа)

^neHbi
KOMHCCHH

KoHHHHa
.H.B.

(nogнucb)



ЕорncoB A.B.

(nogнucb)

**OH^HA^ OE^EPA^bHOrO rOCY^APCTBEHHOrO BM^ETHOrO
OBPA3OBATE^BHOrO YHPE^EHHfl BBICmErO OBPA3OBAHHH
«HA^HOHA.HbHBIIH HCC^E^OBATE^bCKHH YHHBEPCHTET «M^H»
B r. CMO^EHCKE**

Ka^epra «TexHoaopHHeckHe MamHHbi H
HanpaBaeHne nogroTOBKH 13.03.02 «pyKOBO, n, nTea Hep^eTHKa H ^.aeKTopTexHHKa»

3A^AHHE

Ha KypcoBym pa6oTy CTygeHTa ATaKHueBa. ^.A. (rpyнна PT-20)
TeMa: PacHeTbi Ha npoHHOCTT MexaHHeckHX KOHcpy^HH Cogep^aHHe
pacHeTHo-noacHHTeabHoH 3anHCKH:

1. BBegeHHe.
2. 3agana N°1: nocTpoHTb ^^mpbl npogoabHbix cna, Hanpa^eHHH H nepememyHHH nonepenHMx ceneHHH 6pyca.
3. 3agana N°2: nocTpoHTb ^^mpy KacaTeabHbix Hanpa^eHHH.
4. 3agana N°3: nocTpoHTb ^^mpy nonepenHbix CHH H H3py6a.mmHx MOMeHTOB.
5. 3agana N°4: nogopaTb nonepenHoe ceneHHe 6aHKH.
6. 3agana N°5: nog6op gnaMeTpa Bana npH H3pH6e c KpyneHHeM.
7. 3aKamneHHe.

nepeneHb rpa^nneckKoro MaTepnana:

1. 3nmpbi K 3agane N°1
2. 3nmpbi K 3agane N°2
3. 3nmpbi K 3agane N°3
4. 3nmpbi K 3agane N°4
5. 3nmpbi K 3agane N°5 ^ara Bbigann 3agaHHa: 8.09.2021

Eopncob A.B.

3agaHHe npHHaaa K BbmoaHeHHM:

ATaKHmeB ^.A.

CTygeHT

^ara 3amHTbi KypcoBon pa6oTbi 28.12.2021

CMoaeHCK
2021

AHHOTaUHH

В КypcoBOH пa6oTe пaccMarpнBaroTca MexaHнecKне KOHCTpy^nn, гна KOTopbix BbmonHamTca нпoHHOCTHTиe пaчнeTbi нпн cнeгымрнux Bнгax ге\$opMa^HH: пaчTa^eHHH (c^арнн), KпынeHHH, ropnde, ropnde c KпынeHнeM.

ПaчeTHO-нoачHHTenbHaa 3аннcKa KypcoBOH пaдoTbi COCTOHT H3 28 cрпaHH^ 5 нпннo^eHHH, BKаннammux пнcyHKH K 3aганаM, 7 ннTepapыпHbix HCTOHHHKOB. KнмнeBbie cнoBa: danKa, ^^ropa, пaчpa^eHнe, KпынeHнe, ropnd, нпouHOCTb.

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.

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И.И.И.	И.И.И.	И.И.И.	И.И.И.	И.И.И.
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И.И.И.	И.И.И.	И.И.И.	И.И.И.	И.И.И.
И.И.И.	И.И.И.	И.И.И.	И.И.И.	И.И.И.

18. КР. 13. 03. 02. нМ. н3

Рассчитать на по высоте
 Механические
 КОМПОНЕНТЫ

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©УИИИИИ 01 'HO V «HHY «M^H» e e. CMomHCKe		

BBegeHue

^aHHaa pacaerao-rpa^uaecKaa, KypcoBaa pa6oTa aBaaeTca uToroM caMocToaTeabHoro u3yaeHua yae6Hbix MaTepuaaob, noayaeHHbix npy KoHTaKTHoa pa6oTe c npenoBaTeaeM, u pemeHua 3agaa no gu^unauHe «npyKaagHaa MexaHHKa» Ha TeMy «PacaeT Ha npoaHocTb MexaHuaecKux KOHCTpy^HH».

^abro BbmoaHeHua pa6oTbi aBaaeTca ocBoeHue MeToroB pacaeTa Ha npoaHocTb KOHCTpy^HH npy pa3Hbix cayaaax ge\$opMa^HH: pacTa^eHHy(c^aTHy), KpyaeHyy, u3py6e, u3py6e c KpyaeHueM. B xoge BbmoaHeHua pacaeTHo-rpa^uaecKoa pa6oTbi, 6biau BbmoaHeHbi pacaeTbi, gaa nocpoeHua ^^rop BHypeHHux cuaoBbix ^aKTopoB gaa npyBegeHHbix Bbime BugoB ge\$opMa^HH. A TaK^e cgeaHbi aepTe^y, Heo6xoguMbie gaa pacaeTOB, B KoTopbix npegcTaBaeHbi ^^ropbi gaa Ka^goro Buga ge^opMaguu. Ebiau onpegeaeHbi npoaHocTHbie xapaKTepycTUKy KoHcTpy^ua, nogo6paHbi onTHMaabHbie ceaeHua u cgeaH aHaay3 npoaHocry KoHcTpy^ua.

KawaeBbie caoBa npn BbmoaHeHyy KypcoBoa pa6oTbi:

EaaKa - 6puc, raxogamyaca nog geacTBueM rоруSarorngx ycuaua, B aacTHocTy, nonepeaHbix cua, MoMeHToB u pacnpegeaeHHbix Harpy3oK.

3npa - oco6in Bug rpa^yKa, noKa3ibiBaromyH pacnpegeaeHue BeauauHbi Harpy3Ky Ha o6eKT.

PacTa^eHue - Bug npogoabHoa ge\$opMa^HH cTep^Ha uau 6puca, Bo3HHKapom,uH B TOM cayaae, ecau Harpy3Ka K HeMy npyKaagbiBaeTca no ero npogoabHoa ocu (paBHogencTBymaa cua, Bo3gencTBymux Ha Hero, HopMaabHa nonepeaHoMy ceaeHuw cTep^Ha u npoxoyT aepex ero ^mp Macc).

KpyaeHue - ogyH u3 BugoB ge^opMaguu Teaa. Bo3HHKaeT B TOM cayaae, ecau Harpy3Ka npyKaagbiBaeTca K Teay B Buge napbi cua (MoMeHTa) B ero nonepeaHoa naocKocTy. npy ^TOM B nonepeaHbix ceaeHuax Teaa Bo3HHKaeT ToabKo ogyH BHyTpeHHHH cuaoBoa ^aKTop — KpyamuH MoMeHT.

H3py6 - TaKoa Bug ge\$opMa^HH, Korga nog geacTBueM BHeMHux cua B nonepeaHbix ceaeHuax cTep^Ha(6puca) Bo3HHKaeT rоруSaromua MoMeHT.

npoaHocTb - ^TO cnocoHocTb KoHcTpy^uu Bbigep^HBaTb 3agaHHyw Harpy3Ky, He pa3pumaacb.

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						5
<i>H.3M.flucm</i>	<i>NB doKyM.</i>	<i>nodnucb</i>	<i>ffama</i>			

Задана №1

а) Ho:

$$a = 0; b = 9; B =$$

$$E = 210^5 \text{ Mna}$$

$$[G] = 160 \text{ Mna} = 1,6 \cdot 10^8 \text{ na}$$

CxeMa

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

$$A_1 = 2,0 \text{ CM}^I, A_2 = 2,9 \text{ CM}^I, A_3 = 2,7$$

$$\text{CM}^I; a = 0,8 \text{ M}, b = 0,7 \text{ M}, c = 0,6 \text{ M}.$$

Решение

Условие 1: неопределенные условия

$$\text{Условие 1 } AB: N_{AB} = P_1 = 17 \text{ KH}$$

$$\text{Условие 2 } BC: N_{BC} = P_2 = 19$$

$$\text{Условие 3 } CD: N_{CD} = P_1 - P_2 = 17 \text{ KH} - 19 \text{ KH} = -2 \text{ KH}$$

$$\text{Условие 4 } DE: N_{DE} = P_1 - P_2 = 17 \text{ KH} - 19 \text{ KH} = -2 \text{ KH}$$

Условие 2: неопределенные условия

$$\text{Условие 1 } AB: G_{AB} = \frac{N_{AB}}{A_{AB}} = \frac{1710^3}{2,0 \cdot 10^{-4}} = 8,5 \cdot 10^6 \text{ na} = 85 \text{ Mna}$$

$$\text{Условие 2 } BC: G_{BC} = \frac{N_{BC}}{A_{BC}} = \frac{1710^3}{2,9 \cdot 10^{-4}} = 5,8640 \cdot 10^6 \text{ na} = 58,6 \text{ Mna}$$

$$\text{Условие 3 } CD: G_{CD} = \frac{N_{CD}}{A_{CD}} = \frac{-2 \cdot 10^3}{2,9 \cdot 10^{-4}} = -6,9 \cdot 10^6 \text{ na} = -6,9 \text{ Mna}$$

$$\text{Условие 4 } DE: G_{DE} = \frac{N_{DE}}{A_{DE}} = \frac{-2 \cdot 10^3}{2,7 \cdot 10^{-4}} = -7,4 \cdot 10^6 \text{ na} = -7,4 \text{ Mna}$$

Условие 3: неопределенные условия неопределенные условия

$$U_{E+D}$$

$$M_E = 0;$$

$$\text{Условие 4 } DE: U_{D+E} = A_{D+E} \cdot M_E = 0 + (-7,4 \cdot 10^6) = -2,2240 \cdot 10^5 \text{ M}$$

$$\text{Условие 3 } CD: A_{C+D} \cdot M_D = -2,2240 \cdot 10^5 + (-6,9 \cdot 10^6) = -3,427540 \cdot 10^5 \text{ M}$$

H.3M.	Guam	N doKyM.	nodnucb	ffama

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YnacTOK 2 BC: $M_{BC} = M_C + \frac{M_B}{2 \cdot 10^5} = -3,4275 \cdot 10^{15} + \frac{58,6 \cdot 10^{15}}{2} = 6,840^{15} M$

YnacTOK 1 AB: $bd_{AB} = M_B + \frac{M_A}{2 \cdot 10^5} = 6,840^{15} + \frac{85 \cdot 10^{15}}{2} = 40,8 \cdot 10^{15} M$

Bbreog: TaK KaK $|6_{\max}| < [5]^{85} < 160$, TO cpeп^eHt Btигeп^HT npнno^eHHbie Harпy3KH.

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<i>H.3M.flucm</i>	<i>N doKyM.</i>	<i>nodnucb</i>	<i>ffama</i>			

K CTantHOMy Baay nprno^eHbi Tpn H3BecTHbix MOMeHTa: T_1, T_2, T_3 . Mogyab cgbHra $G = 0,8 \cdot 10^5$ Mna

ТребыеТса:

- 1) CgeaaTb nepTe^; Baaa no 3agaHHbiM pa3MepaM **B** MacmTa6e;
- 2) CocTaBHTt gaa Ka^goro ynacTKa Baaa **B** ceneHHH aHanHTHHeCKHe Bbipa«:eHHa H3MeHeHHa KpyTarn,Hx MOMeHTOB T, KacaTenbHbix Hanpa^eHHH **T H** ypaOB 3aKpyHHBaHHa 9;
- 3) nocTpoHTb ^^wpM npogonbHbix ycnHHH T, KacaTenbHbix Hanpa^eHHH **T H** ypaOB 3aKpyHHBaHHa 9;
- 4) CgeaaTb BbiBog o nponocpa cTep^Ha nprn **[T]=50** Mna

HcxogHbie

gaHHbie	$T_2,$	$T_3,$	a,	b,	c,	d1,	d2,	d3,	[T],	G, Mna
KH- M	KH> M	KH> M	M M	MM	M M	MM	MM	MM	Mna	
0,19	0,17	0,29	600	500	700	60	50	30	50	$0,8 \cdot 10^5$

CxeMa no nncyHKy: 7 PemeHHe:

1) CocTaBHM gaa Ka^goro ynacraa Baaa aHanHTHHeCKHe Bbipa^mna H3MeHeHHa KpyTam.Hx MoMeHTOB T H nocTpoHM ^^ropy Kpyramux MoMeHTOB.

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

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

$$M_z = T_3 - T_2 = 0,12 \text{ KH} \cdot \text{M};$$

M/CocTaBHM Taa Ka^goro ynacraa Baaa aHanHTHHeCKHe Bbipa^mna H3MeHeHHa KacaTenbHbix Hanpa^eHHH **T H** nocTpoHM ^^ropy KacaTenbHbix Hanpa^eHHH.

$$W_{pi}^1$$

rge x_i - KacaTeabHoe Hanpa^eHHe Ha ynacrae i;

M - KpyTamHH MoMeHT Ha ynacrae i;

W_p - MoMeHT conoTHBneHHa ceneHHa ynacTKa i, KoTopoe onpegeaaeTca

$$W_{pi} = \frac{B M_{pa}^{\wedge} d_i^3}{16 \wedge 0,2 d_i}$$

rge d_i - gnaMeTp ceneHHa ynacraa i;

						<i>flucm</i>
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<i>H.3M.flucm</i>	<i>NB doKyM.</i>	<i>nodnucb</i>	<i>ffama</i>			8

$$\begin{aligned}
& M, \quad 0,29 \cdot 10^3 \\
^1AB - W_{PR} & \quad 0,2 - (3 \cdot 10^{-2})^2 \quad 0,0537 \cdot 10^9 \text{ na} - 53,7 \text{ Mna}; \\
& M, B \quad j^3 \cdot 0,12 \cdot 10^3 \\
^xBC & \quad W_{PC} \quad 0,2 - (5 \cdot 10^{-2})^2 \cdot j^3 \quad 0,0048 \cdot 10^9 \text{ na} - 4,8 \text{ Mna}; \\
& M, B \quad 0,12 \cdot 10^3 \cdot 0,2 \\
^xCD & \quad W_{PD} \quad -(6 \cdot 10^{-2})^2 \cdot j^3 \quad 0,0028 \cdot 10^9 \text{ na} - 2,8 \text{ Mna}; \\
& M, C \quad 0,31 \cdot 10^3 \\
^LD & \quad W_{PDE} \quad 0,2 - (6 \cdot 10^{-2})^2 \quad 0,0072 \cdot 10^9 \text{ na} - 7,2 \text{ Mna}. \\
E & \quad j^3
\end{aligned}$$

3) CocTaBHM gaa Ka^goro ynacraa Baaa aHaaHTHneckKHe BbipmeHHa yraoB 3aKpyHHBaHHa Θ H nocpoHM ^^ropy yraoB 3aKpyHHBaHHa. Yroa 3aKpyHHBaHHa onpegeaaeTca no ^opMyae:

$$Mz_i - li \ 9 \ -i-,$$

$$^G - Jp_i$$

rge l_i - gaHHa ynacraa i, M;

G - Mogyat cgBHra, Mna;

$J_{p,i}$ - MOMeHT HHep^HH yaacraa i, KoTopaa onpegeaaeTca no ^opMyae: $J_{p,i} =$

$$0,1d^4;$$

$\Theta_E - O$ (T.K. ^TOT Kpan

$$3aKpenaeH); \quad MZED - \quad 0,31 \cdot 10^3 - 0,18 \quad 1A-3 \quad 0,54 \cdot 10^3 \text{ pag};$$

$$9D - 9E + 9ED - O + \quad EDJ PED \quad 0,8 \cdot 10^{11} - 0,1 - (6 \cdot 10^{-2})^2 \cdot j^4$$

$$9_C - 9_D + 9_{DC} - 0,54 \cdot 10^{-3} + \dots \quad M-1 \quad 0,12 \cdot 10^3 - 0,42$$

$$G - P \quad 0,8 \cdot 10^{11} - 0,1 - (6 \cdot 10^{-2})^2$$

$$J \quad D \quad j^4$$

$$-1,03 \cdot 10^3 \text{ pag};$$

$$M - l_{TM} \quad 0,12 \cdot 10^3 \wedge 0,5$$

$$9_B - 9_C + 9_{CB} - 1,03 \cdot 10^{-3} + \dots$$

$$G - J_P \quad 0,8 \cdot 10^{11} - 0,1 - (5 \cdot 10^{-2})$$

$$C \quad -^2)$$

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

$$M - l_{RA} \quad 0,29 \cdot 10^3 \wedge 0,7$$

$$9_A - 9_B + 9_{BA} - 2,23 \cdot 10^{-3} + \dots$$

$$G - J_P \quad 0,8 \cdot 10^{11} - 0,1 - (3 \cdot 10^{-2})$$

$$B \quad -^2)$$

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

4) M3 ^^ropbl KacaTeatHoro Hanpa^eHHa MaKCHMaatHoe Hanpa^eHHe x_{max} $x_{AB}^{-53,7}$, MMB;

npoBepHM npoHHocTt CTep^Ha npn gonycKaeMoM Hanpa^eHHH [x] - 50

Mna $x_{max} - 53,7 \text{ Mna} > [x] - 50 \text{ Mna};$

H.3M.flucm	NB doKyM.	nodnucb	ffama	

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fluc
m₉

Снегова TentHO, ycnobHe noHHoern He BbrnonHaeTca (cTep^eHt pa6oTaeT B ycnobHH nepepy3KH).

$$\% \quad \frac{\text{max} - \text{min}}{\text{max}} \cdot 100\% = \frac{50 - 53,7}{50} \cdot 100\% = 7,4\%$$

H.3M.	Rucm	NB doKyM.	nodnucb	ffama

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Ruc
m₁₀

Задача N°3

ночт роєнне \wedge роп ВHyтpeHHHx ycнaHH B cTapaecKH onпeгeaHMbix

6aaKax. тpeбyeтca:

1) Hаnнcaтb Bбpa«:eHHa noneпeaHoft cнaби Q_y H H3pH6apom,epo MOMeHTa M_x гaa

Ka^goro yaacTKa B o6^eM BHге;

2) ИocтpoHTb \wedge wpM noneпeHHOH cнaби Q_y H H3pH6apom,epo MOMeHTa

ИeкoгHbie гaHнбie:

M_x ; P, KH	M_y ; KH	a, M	b, M	c, M	d, M	q, T
10	19	1,0	2,9	2,7	1,0	7

CxeMa no пncyHKy: 7 пemeHHe:

1) OnпeгeaHM пea^HH onop. ^aa onпeгeaeHHa пea^HH cocTaBaaeM ypaBHeHHa cyMMM MoMeHToB Bcex cнa opaoHTeabHo ToaeK A H B.

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

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

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

$$R_A = \frac{P \cdot (a + b + c) + m + q \cdot (c + d) \cdot \frac{c + d}{2}}{b + c} = \frac{10 \cdot (1,0 + 2,9 + 2,7) + 19 + 7 \cdot (2,7 + 1,0) \cdot \frac{2,7 + 1,0}{2}}{2,9 + 2,7} = 19,11 \text{ KH}.$$

3HaK нapoc y пea^HH R_A H R_B нoKa3биBaeT, HTO HаnpaBaeHHe пea^HH бbiao Bби́paHo бepHo.

пoBepKa no ycaoBHW пeHHeBcнa: $R_A + R_B - q \cdot (c + d) = 0;$

$$10 + 19,11 + 16,79 - 7 \cdot (2,7 + 1,0) = 0;$$

$$0 = 0.$$

2) OnпeгeaHM noneпeaHbie cнaби Q_y H nocтpoHM \wedge ropy noneпeaHbix cнa.

нepBHH yqacTOK:
 $0 < z_1 < a = 1,0 \text{ M } Q_y = -P = -10 \text{ KH};$

H.3M.	aucm	NB doKyM.	nodnuch	ffama

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БТОРОН ыгачТОК:

$$0 < z_2 < b = 2,9 \text{ M } Q_{Y2} = -P + R_A = -10 + 19,11 = 9,11 \text{ KH};$$

ТреТНН ыгачТОК:

$$0 < z_3 < d = 1,0 \text{ M } Q_{Y3} = q \cdot z_3;$$

$$\text{npu } z_3 = 0: Q_{Y3} = 0 \text{ KH};$$

$$\text{npu } z_3 = d = 1,0 \text{ M} : Q_{Y3} = q \cdot z_3 = 7 \cdot 1,0 = 7 \text{ KH}.$$

РеТБепТНН ыгачТОК:

$$0 < z_4 < c = 2,7 \text{ M } Q_{Y4} = -R_B + q \cdot (d + z_4);$$

$$\text{npu } z_4 = 0: Q_{Y4} = -R_B + q \cdot d = -16,79 + 7 \cdot 1,0 = -9,79 \text{ KH};$$

$$\text{npu } z_4 = c = 2,7 \text{ M} : Q_{Y4} = -R_B + q \cdot (d + z_4) = -16,79 + 7 \cdot (1,0 + 2,7) = 9,11 \text{ KH}.$$

3) OnpegenHM roruGammue MOMeHTti M_x u nocTpouM ^{^^}mpy H3rH6a.mmHx

MOMeHTOB. непБНН ыгачТОК:

$$0 < z_1 < a = 1,0 \text{ M } M_{X1} = -P \cdot z_1;$$

$$\text{npn } z_1 = 0: M_{X1} = 0 \text{ KH} \cdot \text{M};$$

$$\text{npn } z_1 = 1,0: M_{X1} = -10 \cdot 1,0 = -10 \text{ KH} \cdot \text{M};$$

БТОРОН ыгачТОК:

$$0 < z_2 < b = 2,9 \text{ M } M_{X2} = -P \cdot (a + z_2) + R_A \cdot z_2; \text{ npn } z_2 = 0: M_{X2} = -P \cdot a = -10 \text{ KH} \cdot \text{M};$$

$$\text{npu } z_2 = b = 2,9 \text{ M} : M_{X2} = -P \cdot (a + z_2) + R_A \cdot z_2 = -10 \cdot (1,0 + 2,9) + 19,11 \cdot 2,9 = 16,42 \text{ KH} \cdot \text{M};$$

ТреТНН ыгачТОК:

z

$$0 < z_3 < d = 1,0 \text{ M } M_{X3} = m - q \cdot z_3; \text{ npn } z_3 = 0: M_{X3} = 19 \text{ KH} \cdot \text{M};$$

7 1 0 M MeТБепТНН ыгачТОК:

$$\text{npn } z_4 = c = 2,7 \text{ M} : M_{X4} = m + R_B \cdot z_4 - q \cdot (z_4 + d) = 19 + 16,79 \cdot 2,7 - 7 \cdot (2,7 + 1,0) = 15,5 \text{ KH} \cdot \text{M};$$

$$\text{npu } z_4 = 0: M_{X4} = m - q \cdot d = 15,5 \text{ KH} \cdot \text{M};$$

$$\text{npH } z_4 = c = 2,7 \text{ M} : M_{X4} = m + R_B \cdot z_4 - q \cdot (z_4 + d) = 19 + 16,79 \cdot 2,7 - 7 \cdot (2,7 + 1,0) = 15,5 \text{ KH} \cdot \text{M};$$

3nmpa 6ygeT aBnaTca napaGonofi BrnnyKnocTtm BBepx c MaKcuMyMOM B TogKe,

rge Q_{y4} = 0. HaHgeM ^Ty TogKy:

$$Q_{y4} = -R_B + q \cdot (d + z_4) = 0 \Rightarrow z_4 = \frac{R_B - q \cdot d}{q} = \frac{16,79 - 7 \cdot 1,0}{7} = 1,398 \text{ M};$$

H.3M.	ucm	NB doKyM.	nodnucb	ffama

ногсраBHM $z_4 = 1,398$ M B aHanHTHneCKoe ypaBHeHHe gna H3rH6arom,ero MOMeHTa Ha neTBepTOM yнаCTKe:

$$M_{x\max} = m + R_B \cdot 1,398 - 9 \cdot \frac{(1,398 + d)^2}{2} + 16,79 \cdot 1,398 - 7 \cdot \frac{(1,398 + 1,0)^2}{2}$$

= 22,34 KH ■
M.

H.3M.	Rucm	NB doKyM.	nodnucb	ffama

18. KP. 13. 03. 02. nM. n3

3аgааа N4

^аа 3аgаHН0H GааKu u3 3аgааu N 3 TpeGyeTca:

1. BbinepTHTb B MacmTa6e 3аgаHHoe ceaeHue GааKu c yKa3аHueM aucaeHHbix 3HaneHHH pa3MepoB. OnpeгeаyTb noa^eHue ^HTpa Ta^ecTu ceaeHua u BbiaucauTb MOMeHT HHep^HH ceaeHua OTHOCHTenbHO HeHTpanbHOH ocu.
2. nocTpoHTb ^^ropbl HopMaabHbix Hаnpа^eHun, pacnpeгeaeHHbix no BbicoTe ceaeHua gaa ceaeHua c MaKcyMaabHbiM rоруGarоrнуM MOMeHTOM M_x , B3aTbiM H3 3аgааu N 3.
3. Hcноab3ya ^^ropbl rоруGarоrнуx MOMeHTOB M_x , nocTpoeHHbix B 3аgаae N 3, onpeгeаyTb u3 pacaeTa Ha npoHHOCTb HOMep npo^uaa gBypaBпоBon (npu 3HанHTeabHOH Hегорпы3Ke npуHaTb gaa GааKu ceaeHue B Bугe mBeaepa) npoKpaOH GааKu. Mareпуaa GааKu - cTaab CT.3, [a] = 160 Mna.
4. npu TOM ®:e 3HaneHHH gonyCKaeMoro Hаnpа^muа onpeгeаyTb no ycaoBuro npoHHocTи Ha3MepиeHHoro ceaeHua B cлyчae $\beta = 0,6$
 a) Kпыra guaMeTpa d; $\beta = 1,9$
 B) nпaMoypoabHHKa c oTHomeHHem cToпoH b
5. CocTaBHTb TaGaH^y opaomeHun naom,agen yKa3аHHbix ceaeHun K naom,agu gBypaBпоBopo npo^uaa.

HcxoйHbie gaHHbe:

[a], Mna	$M_{xmax} \cdot KH \cdot M$	B, MM	C, MM
160	22,34	22	26

HoMep ceaeHua: 7

1) OnpeгeаyM ^HTp Ta^ecra oTHocuTeabHo HeHTpaabHon ocu Ox:

$$y_c = \frac{\sum A_i \cdot y_{Ci}}{\sum A_i}$$

где A_i - naom, agb i - Toro ceaeHHa, MM^2 ;

y_c - pacToaHHe oT OCH Ox го i - Toro ^npа Ta^ecra, MM.

$$y_c = \frac{A_1 \cdot y_{C1} + A_2 \cdot y_{C2} + A_3 \cdot y_{C3}}{A_1 + A_2 + A_3}$$

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

$A_2 = 3B \cdot 2C = 3 \cdot 22 \cdot 2 \cdot 26 = 3168$

$A_3 = \frac{3,14 \cdot (1,5 \cdot 22)^2}{4} = 855 \text{ MM}^2$;

$x_{c1} = \frac{B^2}{2} = \frac{22^2}{2} = 11 \text{ M}$;

					<i>flucm</i>
					1A
H.3M. flucm	NB doKyM.	nodnucb	ffama		14

18. KP. 13. 03. 02. nM. n3

$$EC_9 - h B - 3B - 3 \cdot 22 y p - f 22 = 55$$

$$J_{C_2} \cdot 2 \cdot 2 \quad MM;$$

$$y^{\wedge} - EC_3 - 3B - 3 \cdot 22 - 66 MM;$$

$$y_c \quad A_1 \cdot y_c + A_2 \cdot y_c - A_3 \cdot y_c \quad 2288 - 11 + 3168 \cdot 55 - 855 \cdot 66 \quad 31,1MM$$

$$2288 + 3168 - 855 \quad ;$$

2) OnpegenHM MOMeHT HHep^HH ceneHHa OTHOCHTeatHo OCH

Ox: 2 0 0

$$J_{x_c} - J_{x_{C1}} + A_1 \cdot a_1 + J_{x_{C2}} + A_2 \cdot a_2 + J_{x_{C3}} + A_3 \cdot a_3,$$

rge $a_1 - CC_1 - y_c - y_{Cj} - 31,1 - 11 - 20,1 MM; a_2 - CC_2 - y_c - y_c$
 $- 55 - 31,1 - 23,9 MM; a_3 - CC_3 - y_c - y_c -$
 $66 - 31,1 - 34,9 MM;$

$$K - \frac{b_1 \cdot h^3 4C \cdot B^3 4 \cdot 26 \cdot 22^3}{J_{x^2} \cdot 12 \cdot 12 \cdot 12} \quad 1245816 MM^4 - 124,58 CM^4;$$

$$b_2 \cdot h^2 2C \cdot (3B)^3 \cdot 2 \cdot 26 \cdot (3 \cdot 22)^3 \quad 58184 MM^4 - 5,82 CM^4;$$

$$J_{x^2} \cdot 12 \cdot 12 \cdot 12 \quad 1245816 MM^4 - 124,58 CM^4;$$

$$J_{x^2} \cdot 12 \cdot 12 \cdot 12 \quad 58184 MM^4 - 5,82 CM^4;$$

$$J_{x^2} \cdot 12 \cdot 12 \cdot 12 \quad 58184 MM^4 - 5,82 CM^4;$$

$$J_{x^2} \cdot 12 \cdot 12 \cdot 12 \quad 58184 MM^4 - 5,82 CM^4;$$

3) HopManbHbie Hanpa^eHHa npn H3rn6e no BbicoTe ceneHHa pacnpegeaeHbi no HHHeHHOMy 3aKoHy H B HM6OH Towe ceneHHa onpegeaaroTca no ^opMyae:

$$a \quad M_{b,zmax} \cdot y^{\wedge}$$

$$J_{x_c}$$

rge $M_z - H3FH6arom, HH MOMCHT B ceneHHH, KH \cdot M;$

J - MOMeHT HHep^HH CeHCHHfl OTHOCHTeabHO HeHTpaabHOH OCH, CM;

y_i - pacToaHHe OT HeHTpaabHOH OCH go pacMaTpHB aeMOH TOHKH i, MM. CTPOHM ^ropy HopMaabHbix Hanpa^eHHH gga onachoro ceneHHa: y_D
 $- CD - 56,9 MM; y_E - CE - 31,1 MM;$

$$a_D^{M_{zmax}} \quad 22,34 \cdot 40^3 \cdot 0,0311 A \quad 297,25 \cdot 40^{-8}$$

$$J_c$$

$$a_E^{M_{zmax}} \quad 22,34 \cdot 40^3 \cdot 0,0311 A \quad 297,25 \cdot 40^{-8}$$

$$J_c$$

4) OnpegeaHM MoMeHT conpoTHBaeHHa ceneHHa W_x

$$6aaKH: M_{b,zmax} < [4$$

$$a_{max} \quad W_{,,}$$

H.3M.flucm	NB doKyM.	nodnucb	ffama

18. KP. 13. 03. 02. nM. n3

$$W = \frac{M_{zmx}}{r \cdot i} = \frac{22,34 \cdot 10^3}{160 \cdot 10^6} = 139,6^3 \text{ CM}^3$$

Bbi6epeM coraachHoe OCT 8239-89 gByTaBp N18: $W_x = 143 \text{ CM}^3, A = 23,4 \text{ CM}^2$.

Hanna^eHHe B ^TOM cnynae 6ygeT paBHo:

$$a = \frac{M_{zmax}}{W_v} = \frac{22,34 \cdot 10^3}{143 \cdot 10^6} = 156,22 \text{ Mna.}$$

Hegorpy3 B ^TOM cnynae 6ygeT paBHo: $100\% = \frac{143 - 156,22}{143} \cdot 100\% = 2,4\% < 20\%$

[a] 160

ran

Hanp^eHHe B ^TOM cnynae 6ygeT paBHo: $a = \frac{M_{zmax}}{W_x} = \frac{22,34}{143} = 0,15622$

$$a = \frac{M_{zmax}}{W_x} = \frac{22,34}{143} = 0,15622$$

Hegorpy3 B ^TOM cnynae 6ygeT paBHo: $100\% = \frac{143 - 156,22}{143} \cdot 100\% = 2,4\% < 20\%$

paBHo: $100\% = \frac{143 - 156,22}{143} \cdot 100\% = 2,4\% < 20\%$ ^ y mBe^^ep Hegorpy300^ bme,

[a] 160

neM y gByraBpa, ^o^TOMy 6epeM gByTaBp N18.

5) OnpegenHM nonepenHoe ceneHHe 6anKH B \$opMe Kpyra:

$$W = \frac{n \cdot d^3}{12} = \frac{32 - 22,34}{3,14 \cdot 160} = 112,5 \text{ MM};$$

$$\frac{n \cdot d^2}{4} = \frac{3,14 \cdot 11,25^2}{4} = 99,35 \text{ CM}^2;$$

OnpegenHM nonepenHoe ceneHHe 6anKH B \$opMe Konb:

$W = 0,87, \text{ T.e.}$

$$W = \frac{n \cdot d^3 - 0,87}{32} = \frac{32 - 22,34 \cdot 10^3}{3,14 \cdot 160 \cdot 10^6 - 0,87} = 117,8 \text{ MM};$$

$$A = \frac{n \cdot d^2 - (1 - c_0^2)}{4} = \frac{0,87 \cdot 0,87 - 3,14 \cdot 11,78^2}{44} = 94,77 \text{ CM}^2;$$

nog6epeM ceneHHe B \$opMe npaMoyronbHHKa (h = 1,9-b):

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

$$h = 1,9 - b = 1,9 - 61,5 = 116,8$$

MM;

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

H.3M.	Rucm	NB doKyM.	nodnucb	ffama

18. KP. 13. 03. 02. nM. n3

	ОопМа сенеННА	9 A _b CM	СпаВHeHHe A pe3yntTaTa A
1	#	99,35	4,24
2	©	94,77	4,05
3	W	71,83	3,07

						<i>flucm</i>
						17
<i>H.3M.flucm</i>	<i>M doKyM.</i>	<i>nodnuch</i>	<i>ffama</i>			1/

18. KP. 13. 03. 02. nM. n3

3agana N5

CTanbHOH Ban BpamaeTcn c nOcTOnHHOH nactOTOH n u nepegaeT

MO^HOCTB N. Tpe6yeTca:

- 1) OnpegenuTb Harpy3Ku, geftcTByromue Ha Ban, nocTpoHTt ^^wpM KpyTnm, Hx MOMeHTOB, ^^ropbI u3ru6arom, ux MOMeHTOB B gByx nnocKocTnx (BepTUKanbHOH u rOpy3OHTanbHOH);
- 3) nogo6paTb guaMeTp Bana, ncnonb3yw TpeTbw Teopnro nponHocTH, ecnu H3BecTHO gonycKaeMoe HanpneHue [a] = 170 Mna

HcxonHbie

TeOpun npOHOC TH	a, MM	b, MM	D ₁ , MM	D ₂ , MM	06 n, — MUH	[a], Mna
17	190	170	80	220	600	170

CxeMa no pycyHKy: N7 PemeHHe:

1) OnpegenuM BenunuHy Kpyrnm, ero MOMeHTa:

$$r_{r-A/r} = N_{nn} \cdot T_{Mkp} ; Q ; Q_{30}$$

$$T = \frac{30 \cdot N_{30-17-10}}{3,14 \cdot 600} = 271H \cdot M = 0,271 KH \cdot M;$$

OnpegenuM BenunuHbi OKpy^Hbix u paguanbHbix can Ha 3y6naTbix Konecax:

$$T_{2T} = 0,5D D$$

$$2T \cdot 271$$

$$F_t = \frac{2T}{D_1} = 6775 H = 6,775 KH;$$

$$F_{t2} = \frac{2T}{D_2} = 2464 H = 2,464 KH;$$

$$F_r = F_t \cdot tga = F_t \cdot 0,364, \text{ rge } a = 20^\circ$$

$$F_r = F_{ti} \cdot 0,364 = 6,775 \cdot 0,364 = 2,466 KH; F_{rz}$$

$$= F_{tz} \cdot 0,364 = 2,464 \cdot 0,364 = 0,897 KH;$$

2) nOcTpoHM ^^ropbI u3ru6a.roinux MOMeHTOB B nnocKocTnx xOz u yOz. ^nn ^TO^o HafigeM OnOpHbie pea^uu: a) PaccMOTpuM BepTUKanbHyro nnocKocTb:

$$\sum_{k=1}^n F_{yk} = 0; -R \quad A_y \quad R_{By} \quad F_{tr} + F_t = 0; \quad '2$$

$$\sum_{k=1}^n M = 0; -F^ \cdot 3a + F_2^ \cdot a - R_{By} \cdot (3a + b) = 0;$$

H.3M.	flucm	NB doKyM.	nodnucb	ffama

18. KP. 13. 03. 02. nM. n3

$$R_{By} = -R_{By} - F_{rz} + F_{ti} = -1,049 - 0,897 + 6,775 = 4,829 \text{ KH};$$

$$R_{Ay} = -R_{By} - F_{rz} + F_{ti} = -1,049 - 0,897 + 6,775 = 4,829 \text{ KH};$$

npoBepKa:

$$\sum_{k=1}^n M = 0; F_2 \cdot b - F_1 \cdot (2a + b) + R_{Ay} \cdot (3a + b) = 0;$$

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

6) PaccMOTpHM ropu3oHTaabHyro

naocKocTb:

$$\sum_{k=1}^n F_{xv} = 0; R_{Ax} + R_{Bx} - F_{t_9} = 0;$$

k=

$$\sum_{k=1}^n M_{y_A} = 0; F_r \cdot a + F_{t_2} \cdot 3a - R_{Bx} \cdot (3a + b) =$$

k=1

$$R_{Bx} = \frac{F_r \cdot a + F_{t_2} \cdot 3a - 2,466 \cdot 0,19 + 2,464 \cdot 3}{3a + b} = \frac{0,19 \cdot 2,466 + 2,464 \cdot 3}{3 \cdot 0,19 + 0,17} = 2,53 \text{ KH};$$

$$R_{Ax} = -R_{Bx} + F_r + F_{t_2} = -2,53 + 2,466 + 2,464 = 2,4 \text{ KH};$$

npoBepKa:

$$\sum_{k=1}^n M_{y_R} = 0; -F_r \cdot (2a + b) - F_{t_2} \cdot b + R_{Ax} \cdot (3a + b) = 0;$$

k=1

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

nocTpoHM ^ropy H3ru6arom,Hx MOMeHTOB B BepTHKaabhofT

naocKocTb:

$$\sum_{k=1}^n M_{x_{AC}} < a =$$

$$M_{x_{AC}} = R_{Ay} \cdot Z_1 \cdot \text{npH } Z_3$$

$$= 0 \wedge M_{x_{AC}} = 0;$$

$$\text{npH } Z_3 = 190 \text{ MM} \wedge M = -4,829 \cdot 0,19 = -0,917 \text{ KH} \cdot \text{M};$$

II

$$\sum_{k=1}^n M_{y_3} < b = 170$$

$$M_{y_3} = R_{By} \cdot Z_3$$

$$\text{npH } Z_3 = 0 \wedge M_{x_{DDB}} = 0;$$

$$\text{npH } Z_3 = 170 \text{ MM} \wedge M = -1,049 \cdot 0,17 = -0,178 \text{ KH} \cdot \text{M};$$

nocTpoHM ^ropy H3ru6arom,Hx MoMeHTOB B roppoomaabhofT

naocKocTb:

$$\sum_{k=1}^n M_{x_{AC}} < a = 190$$

$$M_{x_{AC}} = R_{Ax} \cdot Z_1$$

H.3M.	ucm	NB doKyM.	nodnucb	ffama

18. KP. 13. 03. 02. nM. n3

fluc
n9

$$n p_n z_3 = 0^{\wedge} = 0;$$

$$n p_H z_3 = 190 \text{ MM}^{\wedge} M^{\wedge} = 2,4 \cdot 0,19 = 0,456 \text{ KH} \cdot \text{M};$$

II

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

$$y_{DB} = \frac{J}{I_{DB}} \cdot z_3;$$

$$n p_H z_3 = 0^{\wedge} M_{y_{DB}} = 0;$$

$$n p_H z_3 = 170 \text{ MM}^{\wedge} M^{\wedge} = 2,53 \cdot 0,17 = 0,43 \text{ KH} \cdot \text{M};$$

3) OnpegenHM gnaMeTp Bana ncxoga H3 ycnobHa obecneneHHa nroHHocTH

no TpeTten Teopnn nroHHocTH:

$$M_{KB} = J M_A + M_{j_B} + 0,75 T^2;$$

$$M_{3K} = J M_A + M_{j_A} + 0,75 T^2 = y l (-0,917)^2 + 0,456^2 + 0,75 \cdot 0,271^2 = 1,051 \text{ KH} \cdot \text{M}$$

$$M_{3K^B} = J M_B + M_{j_B} + 0,75 T^2 = y j (-0,178)^2 + 0,43^2 + 0,75 \cdot 0,271^2 = 0,521 \text{ KH} \cdot \text{M}$$

$$M_{3KB}^A \wedge M_{3KB}$$

OnegoBaTentHo, pacneT Heo6xogHMo Becpa B ceneHHH A. 3KBHBanemHoe

Hanpa^eHHe n p n H3rn6e onpegenaetca Btipa^eHHeM:

$$a_{3K} = \frac{M_{3K}}{W_{B^A}^3}, \text{ rre } W_x = 0,1 d;$$

$$d >^3 \frac{M_{3K}}{0,1^3 \cdot 170^3} = \frac{1,051 \cdot 10^3}{0,1^3 \cdot 170^3} = 0,03954 \text{ M} = 39,54 \text{ MM};$$

OKpynraeM go GpHafiraero 6ontmero cTaHgapTHoro 3HaneHHH gnaMeTpa Bana:

$$d = 40 \text{ MM}.$$

H.3M.	Rucm	NB doKym.	nodnucb	ffama

18. KP. 13. 03. 02. nM. n3

Ruc
m₂₀

3aKaroaeHH

В хогe BbmoaHeHHa KypcoBOH па6oTbi ноāyaeHM caegyrornue pe3yabTaTbi:

В 3аgaae 1 pacчHTaHa нpoHHocTb 3aKpenaeHHopo cTep^Ha, Haxogam,eroca nog геHCTBHeM cна. нpoBepHB нpoHHocTb cTep^Ha npn гоньcKaeMOM Hanpa^eHHH, cgeaaH BMBog HTO, ycaoBHe нpoHHocTH BbmoaHaeTca.

В 3аgaae 2 pacчHTaHa нpoHHocTb 3aKpenaeHHopo cTaabHopo Baaa, Haxoga^eroca nog гeнcTBHeM Kпыра^nx MOMeHTOB. npn нpoBegeHHH нpoBepKH Ha нpoHHocTb CTep^Ha npn гоньcKaeMOM Hanpa^eHHH cgeaaH BMBog HTO, Baa He Bbigep^HT Harpy3KH.

В 3аgaae 3 nocTpoeHM ^^ropbl nonepeHHbix cна H H3pH6arom,Hx MoMeHToB H onпeгeaeHo onacHoe ceaeHHe.

В 3аgaae 4 gaa 3аgаHHon 6aaKH 3аgаan 3 onпeгeaeHM npn гоньcKaeMoM Hanpa^eHHH no ycaoBHW нpoHHocTH па3MepM nonepeHHopo ceaeHHa В \$opMe гBypaBпа H mBeaaepa. H cgeaaHa cpaBHHTeabHaa Та6ан^ oraomeHHH naom,agen па3aHHHbix ceaeHHH, gaa onпeгeaeHHa caMopo BbirogHopo нpo^naa ceaeHHa, KaKoBMM oKa3aaca mBeaaep.

В 3аgaae 5, ncноab3ya aeTBepTyw Teopнpo нpoHHocTH (Teopнpo HanSoabmnx KacaTeabHMx Hanpa^eHHH), MM pacчHTaan gнаMeTp Baaa no H3BecTHoMy гоньcKaeMoMy Hanpa^eHHW [6] = 160 Mna, KOTOPMH 6bia oKпыраeH go San^anmero 6oabнpo. 2021aeHHa H3 cTaHгарTHopo paga pOCTa.

(gaTa) (nogнучb)

						<i>flucm</i>
					18. KP. 13. 03. 02. nM. n3	97
<i>H.3M.</i>	<i>flucm</i>	<i>NB doKyM.</i>	<i>nodнучb</i>	<i>ffama</i>		21

Список литературы по теме

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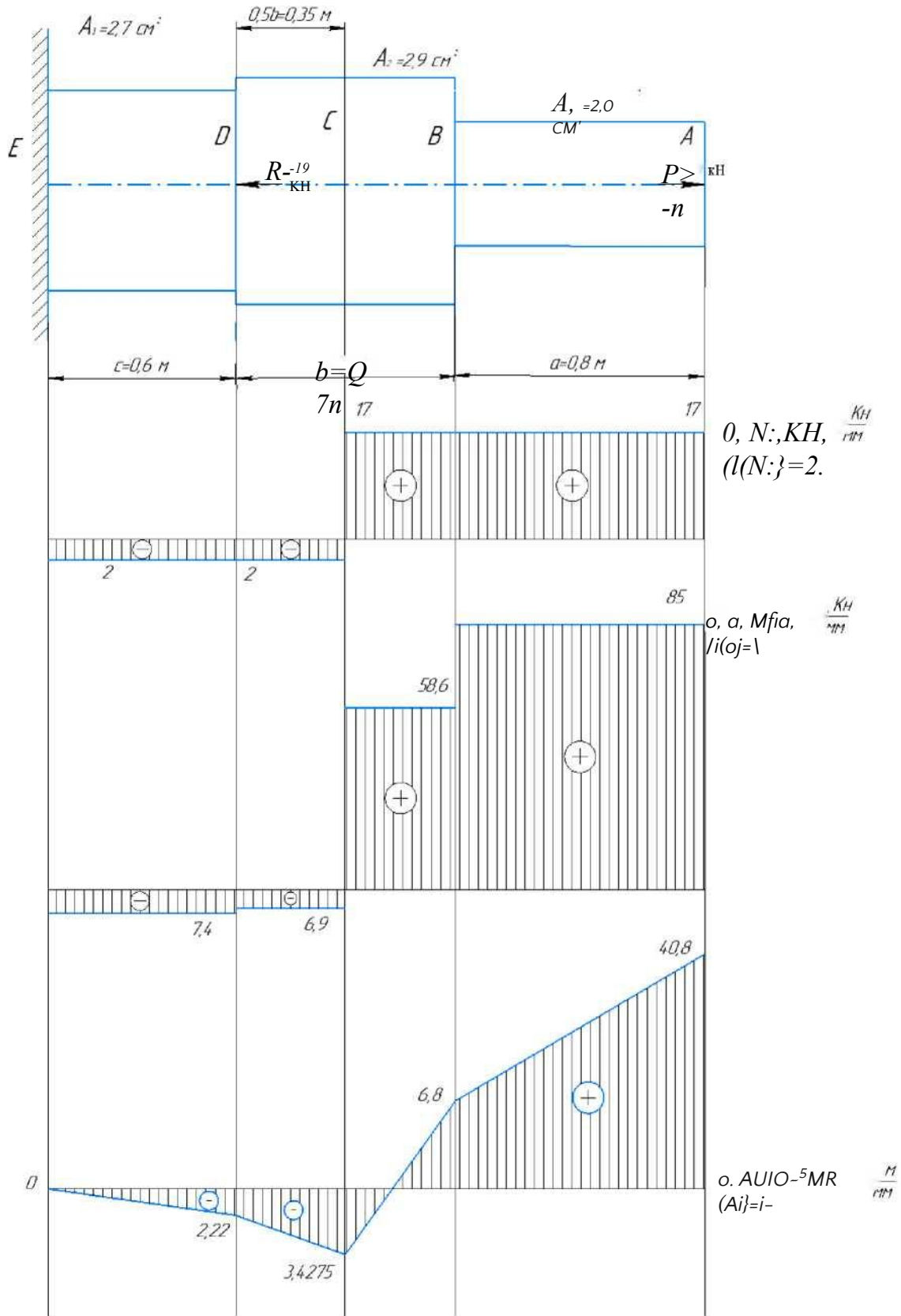
						<i>flucm</i>
					18. КР. 13. 03. 02. nM. n3	
<i>H.3M.flucm</i>	<i>M doKyM.</i>	<i>nodnucb</i>	<i>ffama</i>			22

Приложения

					18. КР. 13. 03. 02. ПМ. ПЗ	Лист
Изм.	Лист	№ докум.	Подпись	Дата		23

npHno^eHHe 1

^epTe^; K 3agane N°1



H.3M.Rucm	M doKyM.	nodnuch	ffama	

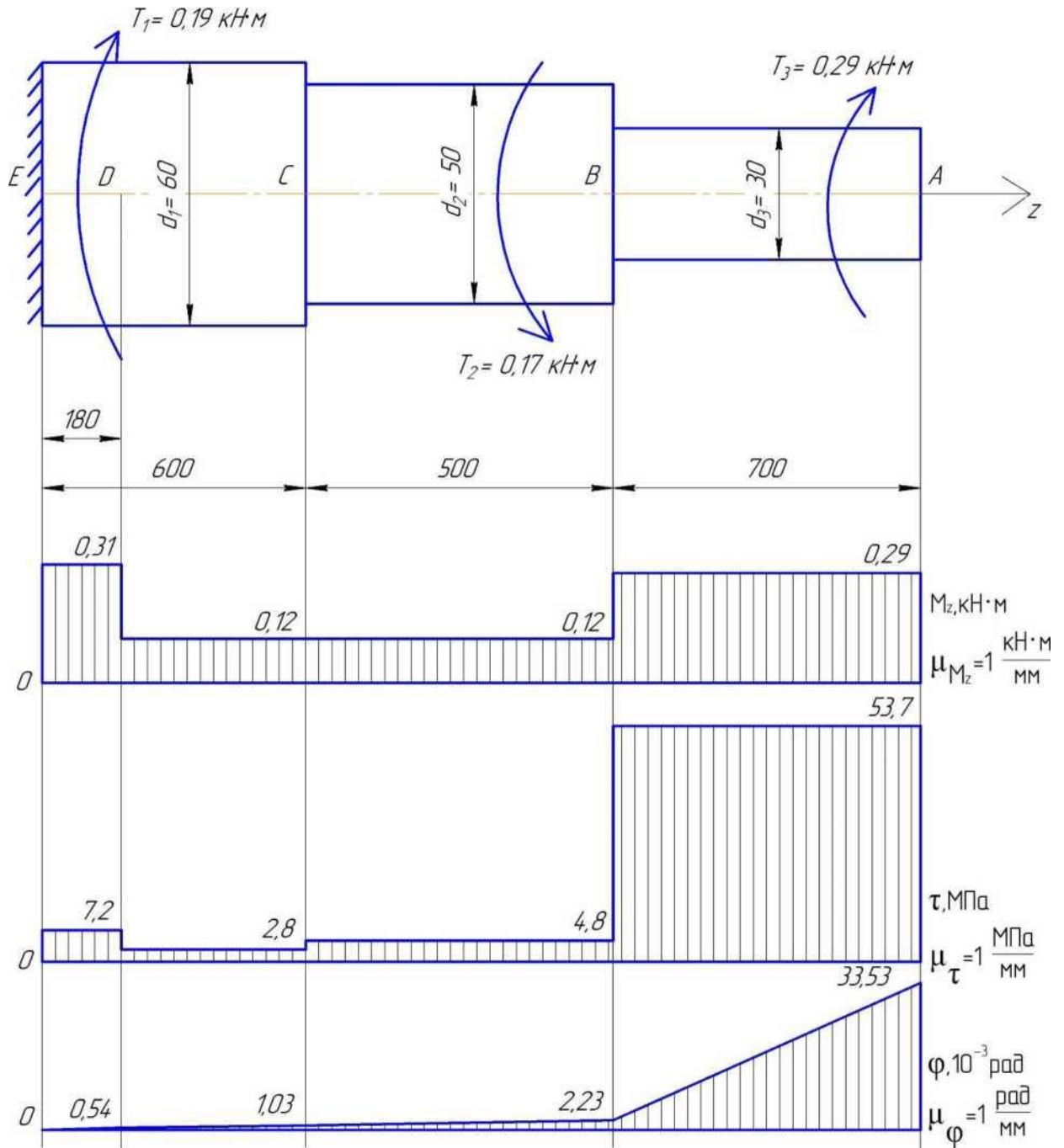
18. KP. 13. 03. 02. nM. n3

Ruc
m

npno^eHHe 2

^epTe^; K 3agane

N2

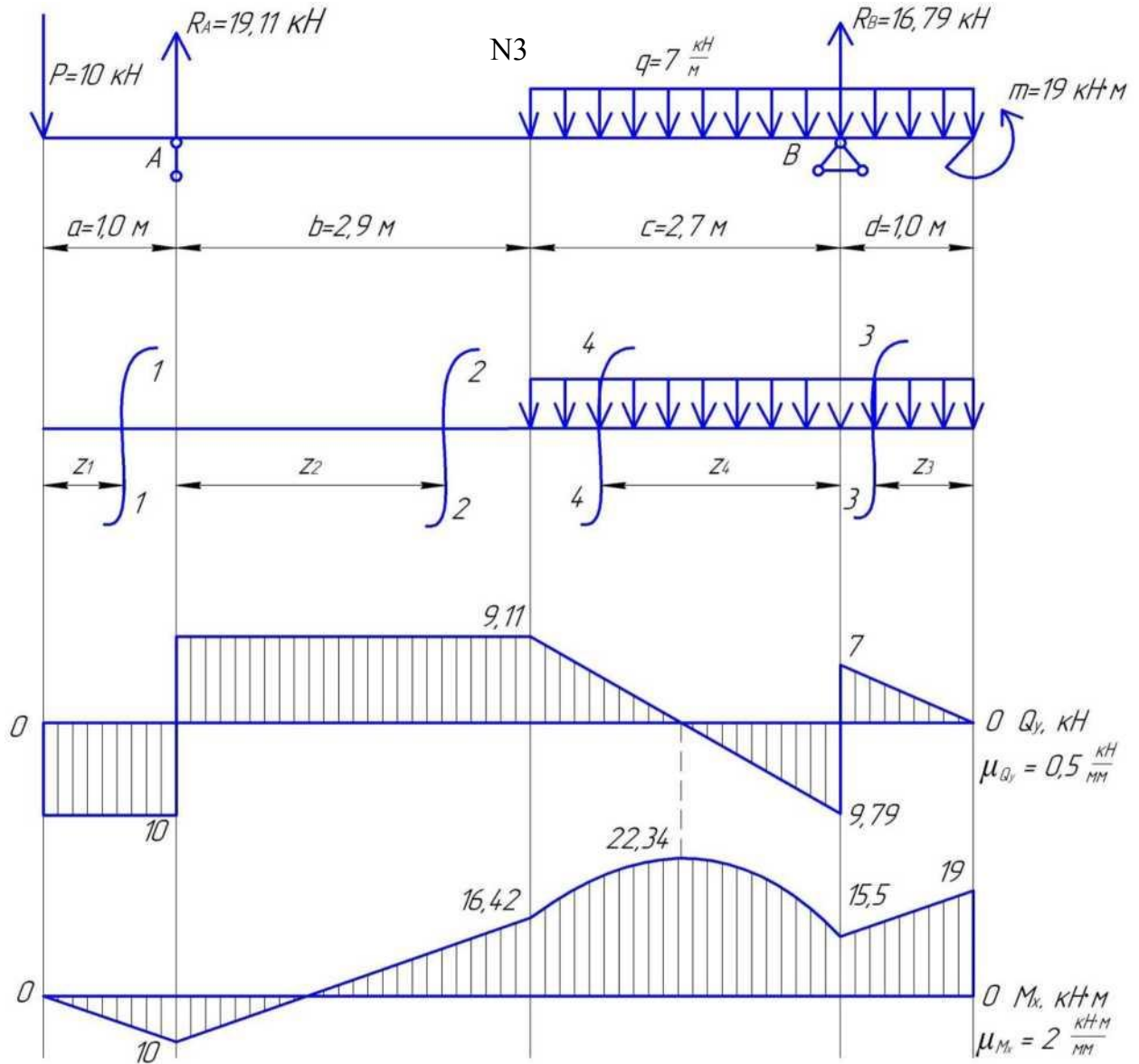


						<i>flucm</i>
						7S
<i>H.3M.flucm</i>	<i>M doKyM.</i>	<i>nodnuch</i>	<i>ffama</i>			

18. KP. 13. 03. 02. nM. n3

npno^eHHe 3

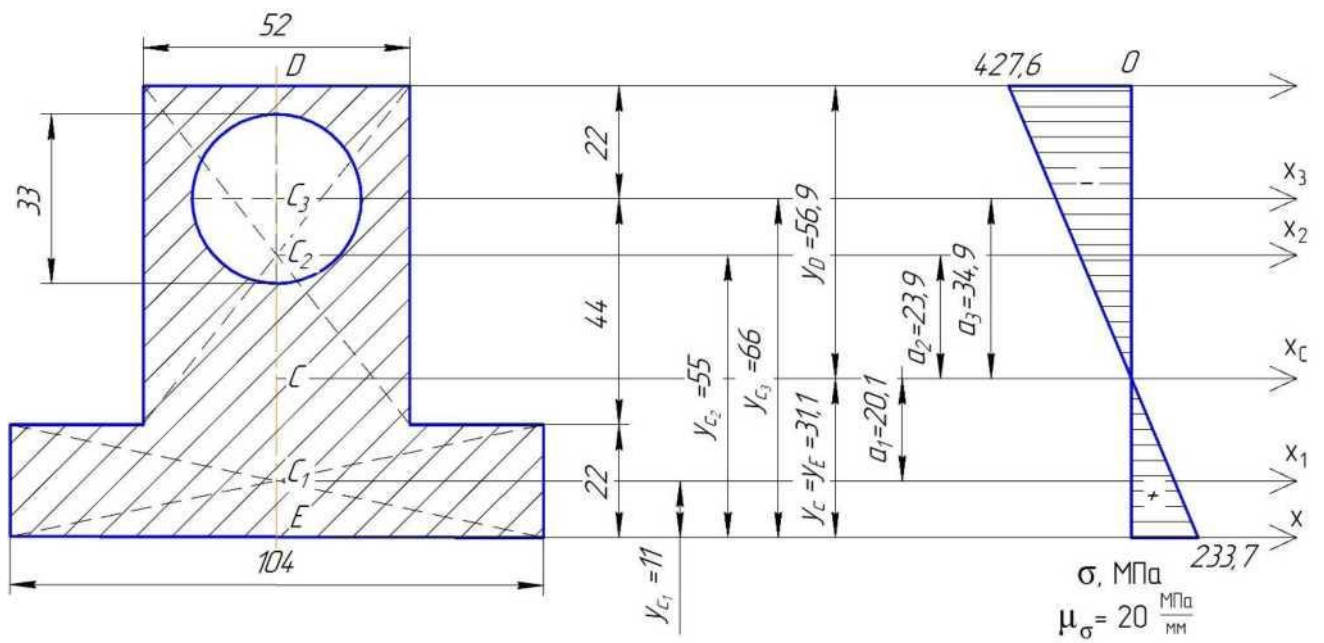
^epTe^; K 3agane



H.3	M	flucm	M doKyM	nodnych ffama

18. KP. 13. 03. 02. nM. n3

^ucm



H.3M.flucm	M doKyM.	nodnuch	ffama	

