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| 1.2      |            |          |
|          | -2000      | ----- 20 |
| 1.3.     |            | ----- 18 |
| 1.4.     | -          | ----- 20 |
| 15.      |            | ----- 29 |
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|          | ,          | ----- 31 |
| 2.2.     |            | ----- 35 |
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[12, 13, 27, 24].



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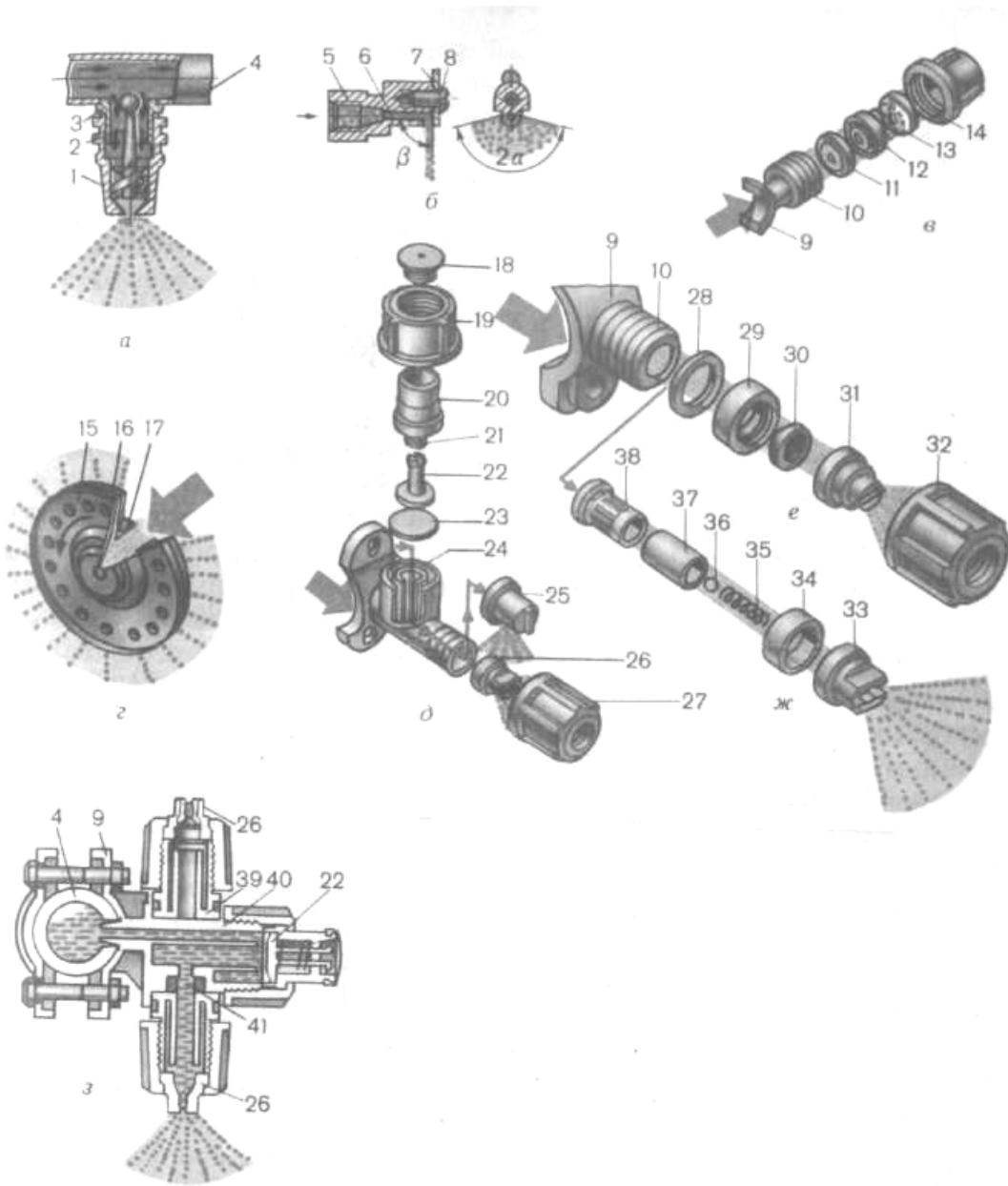
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- ; 12 - ; 13 18 - ; 14, 19, 27 32 - ; 15 16 -
- ; 17 - ; 20, 29, 38 39 - ; 21 35 - ; 22,
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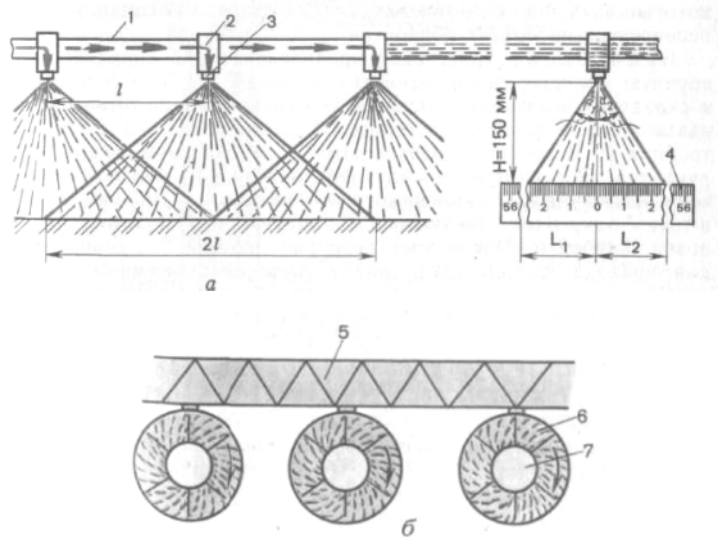
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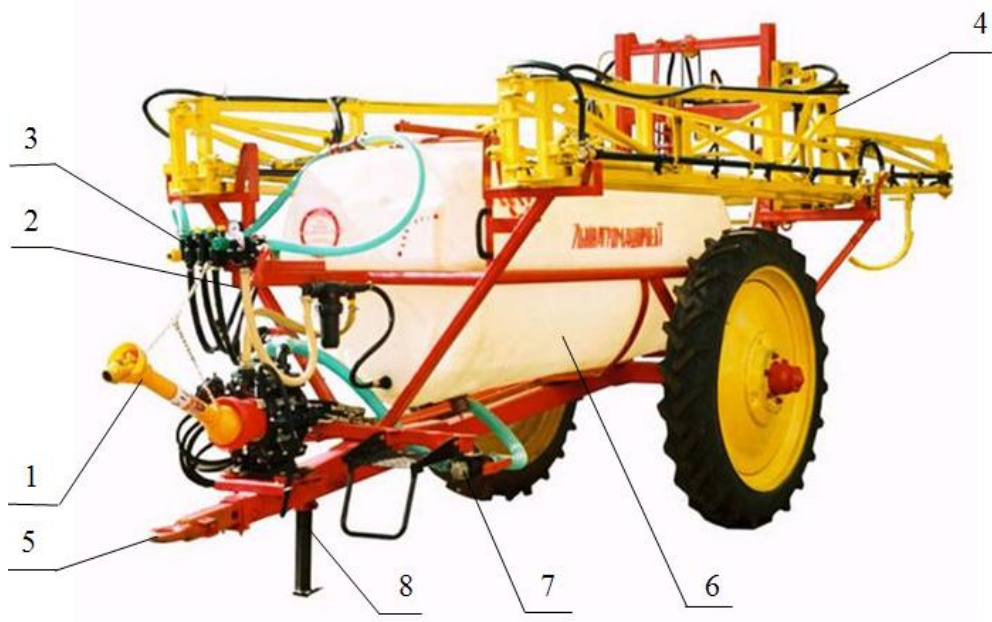
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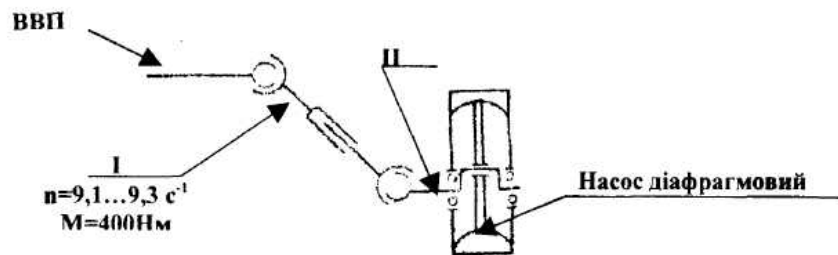
[36].

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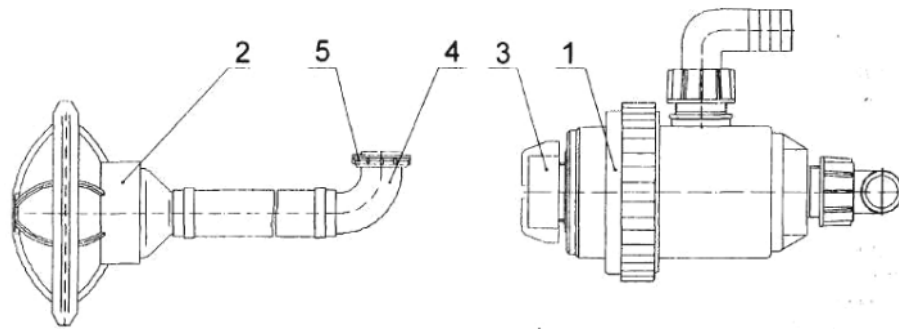


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$$V = \frac{600 \cdot Q}{L \cdot v},$$

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;  $v -$

/ .

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$Q$ .

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**1.4**

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1.8 – KRUZADOR JACTO

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1.9 –

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|      |     |     | 35 |     |     |      |      | -  |       |
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1.12 – Explorer B-36 Premium

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1.13 – Phoenix C-50

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1.14 –

Explorer A-28 AirPlus

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±10%.

(2.1)[ 26]

$$B = z \cdot l, \quad (2.1)$$

$z$  — ,  $z=36$ ,  
 $l$  — ,  $l=0.6$  .

$$B = 36 \cdot 0,6 = 21,6 \text{ .}$$

$d=1,0 \text{ } 1,2 \text{ } )$  (  $0,3 \dots 1,0$   
 $1,5; 2; 2,5 \text{ } )$ ,  
2,0

$q$  , /

[26, 35]

$$q_H = 600 \mu S_0 \sqrt{2gH} \quad (2.2)$$

$\mu$  — :  $\mu=0,37 \dots 0,43$  ;  
 $\mu=0,22 \dots 0,27$  — ;

$S = d^2/4$  — ,  $^2$ ;

$H$  — , ;

$g$  — ;

- 0,1 -2000-1

4

$$q_H = 0,06 \cdot 0,43 \cdot \frac{\pi \cdot 4^2}{4} \cdot \sqrt{200 \cdot 9,81 \cdot 0,1} = 4,54 \text{ /}$$

$$Q_{\max} = q_H \cdot z = 4,54 \cdot 36 = 163 \text{ /} \quad (2.3)$$

170 / ..

$Q$  ( / )

· ,

$W$  ( / )

$$W = \frac{B \cdot V}{10} \quad (2.4)$$

$V$  — ,  $V=10$  / .

$$W = \frac{21,6 \cdot 10}{10} = 21,6 \text{ / ,}$$

· ,  $q$  .

$$q = \frac{W \cdot Q}{60z} , \quad (2.5)$$

$Q -$  , ,  $Q=150 /$  .

$$q = \frac{21,6 \cdot 150}{60 \cdot 36} = 1,5 / .$$

$H ( )$

2

$$H = \frac{q^2}{0,72 \cdot \mu^2 \cdot S_0^2 \cdot g} . \quad (2.6)$$

(2.6) ,

(2.2, 2.5),

:

$$H = \frac{1,5^2}{0,72 \cdot 0,4^2 \cdot \left( \frac{\pi \cdot 2^2}{4} \right)^2 \cdot 9,81} = 0,2 .$$

,

$$N = \frac{6,36P}{450 \cdot \eta} Q_n \quad (2.7)$$

$P_n -$  ( , ),

$P_n=2$  ;

$Q_n -$  ( ),

$Q_n=170 /$  ;

-

(2.7)

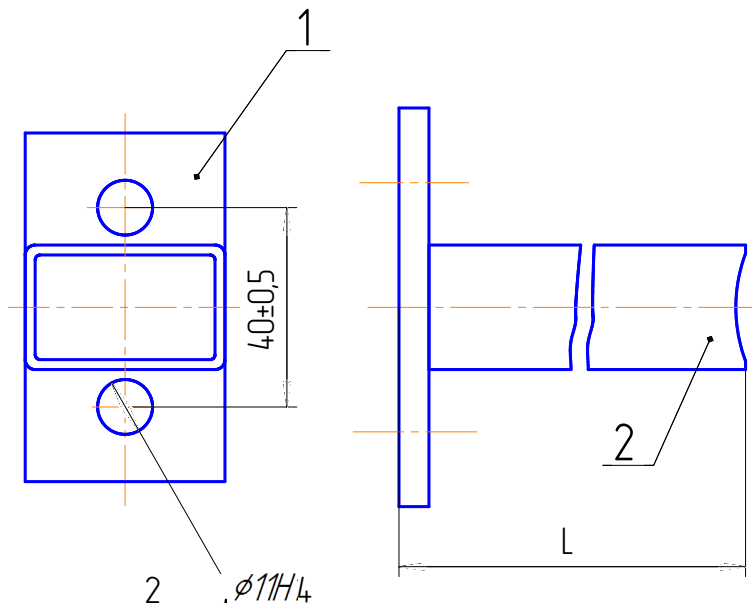
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$$N = \frac{6,36 \cdot 2}{450 \cdot 0,8} \cdot 170 = 6,007$$

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40 , 485 10, 400 .



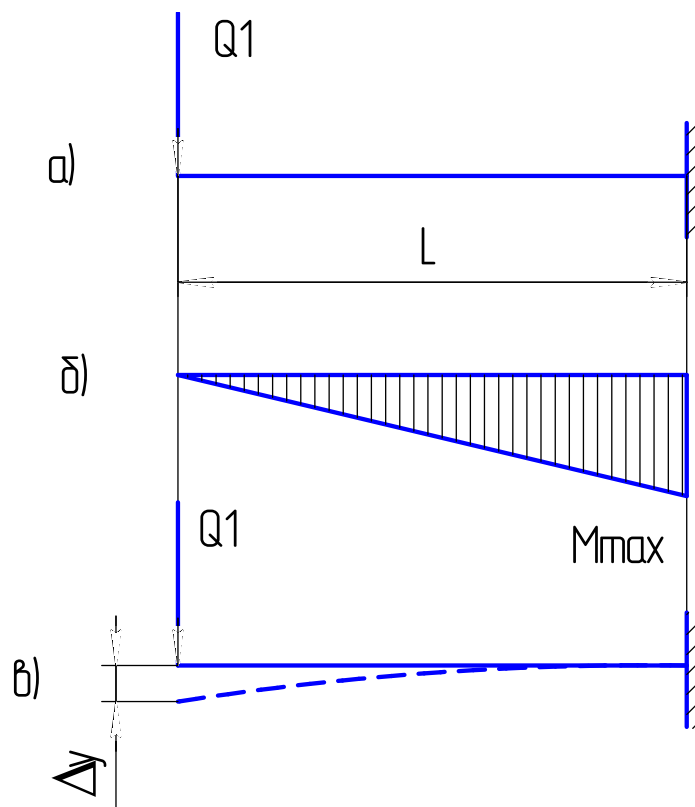
1 - ; 2 -  
 2.2 -

, . 2.2 [ 29, 31, 36].

$L = 204$  .

- 2 40 25 2

, . 2.3.



2.3 -

 $Q_1$ 

$$Q_1 = \eta \frac{Q}{2} = 2,5 \frac{400}{2} = 500 \quad , \quad (2.8)$$

 $\eta -$  $, \eta = 2.5.$ 

;

 $Q -$  $, Q = 400 .$

$$M(x) = -Q_1 x, \quad (2.9)$$

$x -$

$$, \quad x = L$$

$$M_{\max} = M(x) = M(L) = -Q_1 \cdot L = -500 \cdot 0.204 = -102 \quad . \quad (2.10)$$

, .2.3, .

[ 9, 10, 16, 37-40]

$$\sigma = \frac{M_{\max}}{W_0} \leq [\sigma], \quad (2.11)$$

$W_0 -$

. 2.2

$$W_0 = \frac{\delta B^2}{3} \left( 3 \frac{H}{B} + 1 \right), \quad (2.12)$$

$B -$  ,  $B = 40$  ;

$H -$  ,  $H = 25$  ;

$\delta -$  ,  $\delta = 2$  ,

$$W_0 = \frac{0.002 \cdot 0.04^2}{3} \left( 3 \frac{0.025}{0.04} + 1 \right) = 3.067 \cdot 10^{-6} \quad ^3,$$

$[\sigma] -$

$$[\sigma] = \frac{\sigma}{1,5} = \frac{250}{1,5} = 166,7 \quad , \quad (2.13)$$

$\sigma$  –  $3 \cdot 10^2$ ,  $\sigma = 250$  ;  
 $n$  –  $1,5$ .

$$\sigma = \frac{102}{3,067 \cdot 10^{-6}} = 33,7 \cdot 10^6 \quad .$$

$\Delta y$ , . 2.3, [39-40] .

$$\Delta y = -\frac{Q_1 L^3}{3EJ}, \quad (2.14)$$

$E$  –  $2,1 \cdot 10^5$  ;  
 $J$  –

$$J = \frac{\delta B^3}{6} \left( 3 \frac{H}{B} + 1 \right), \quad (2.15)$$

$$J = \frac{0,002 \cdot 0,04^3}{6} \left( 3 \frac{0,025}{0,04} + 1 \right) = 6,133 \cdot 10^{-8} \quad .$$

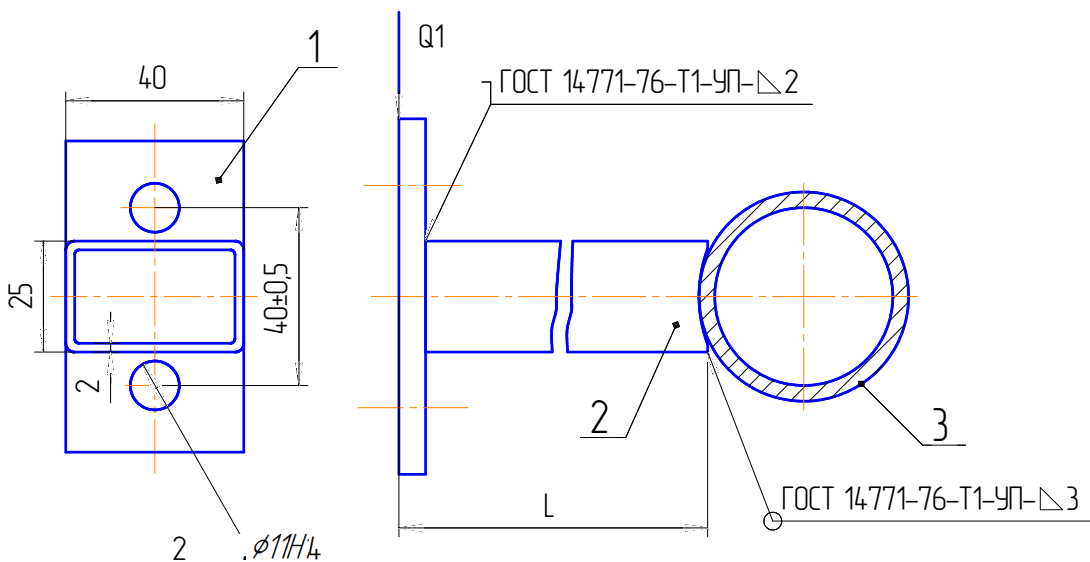
$$\Delta y = -\frac{500 \cdot 0,204^3}{3 \cdot 2,1 \cdot 10^{11} \cdot 6,133 \cdot 10^{-8}} = 1,648 \cdot 10^{-4} \quad .$$



0.25 .

2.3

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 2 3.  
 1 - 2.  
 . 2.4.



1 - ; 2 - ; 3 -  
 2.4 -

$$Q_1 = 500$$

[31]

$$\tau_{Q_1} = \frac{Q_1}{0.7k \cdot l} \leq [\tau], \quad (2.16)$$

$k$  – ;

$l$  – ,

$[\tau]$  –

, [11],

$$[\tau] = 0,6 \cdot \frac{\sigma}{n \cdot \beta}, \quad (2.17)$$

$\sigma$  – ,  $\sigma = 250$  ;

$n$  – . [9, 14, 15, 23, 31]  $n = 1.5$ ;

$\beta$  –

[31],  $\beta = 2.4$



$$k = 2$$

(2.16)

$$\tau_{Q_1} = \frac{500}{0,7 \cdot 2 \cdot 50} = 7,143 < [\tau].$$

$$Q_1 = 500$$

$$M = Q_1 \cdot L = 500 \cdot 0,204 = 102$$

$$\tau_{\max} = \sqrt{\tau_M^2 + \tau'_{Q_1}{}^2} \leq [\tau], \quad (2.22)$$

$$\tau_M - \quad ;$$

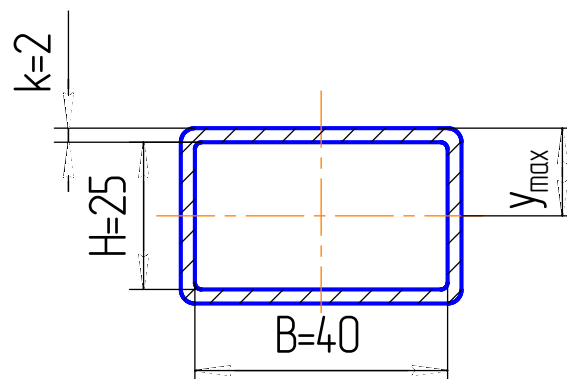
$$\tau'_{Q_1} - \quad Q_1$$

$$\tau_M$$

$$\tau_M = \frac{M}{W}, \quad (2.23)$$

$W$  –

$$B=40, H=25 \quad (2.5)$$



2.5 –

[37-40],

$$W = \frac{j}{y_{\max}}, \quad (2.24)$$

$j$  –

, 4,

$$j = \frac{(B + 2 \cdot 0,7 \cdot k)(H + 2 \cdot 0,7 \cdot k)^3}{12} - \frac{B \cdot H^3}{12},$$

$k$  –

,  $k=2$  (

);

$y_{\max}$  —

,

$$y_{\max} = \frac{H}{2} + k = \frac{25}{2} + 2 = 14,5 \quad , \quad (2.25)$$

,

$$j = \frac{(40 + 2 \cdot 0,7 \cdot 2)(25 + 2 \cdot 0,7 \cdot 2)^3}{12} - \frac{40 \cdot 25^3}{12} = 5539 \quad , \quad 4,$$

$$W = \frac{5539}{14,5} = 382 \quad 3.$$

,

$\tau_M$

$$\tau_M = \frac{102 \cdot 10^3}{382} = 267 \quad .$$

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$$j' = \frac{(40 + 2 \cdot 0,7 \cdot 3)(25 + 2 \cdot 0,7 \cdot 3)^3}{12} - \frac{40 \cdot 25^3}{12} = 39620 \quad , \quad 4,$$

$$W' = \frac{39620}{14.5} = 2732 \text{ }^3.$$

$$, \quad \tau_M \quad 3$$

$$\tau_M = \frac{102 \cdot 10^3}{2732} = 37.3 \text{ }.$$

$Q_1$

$$\tau'_{Q1} = \frac{Q_1}{0.7k \cdot l} = \frac{500}{0.7 \cdot 3 \cdot 130} = 1.8 \text{ } , \quad (2.26)$$

$$k - , k = 3;$$

$$l - , l \approx 130 \text{ } .$$

$$\tau_{\max} = \sqrt{37.3^2 + 1.8^2} = 37.34 \text{ } , \quad (2.27)$$

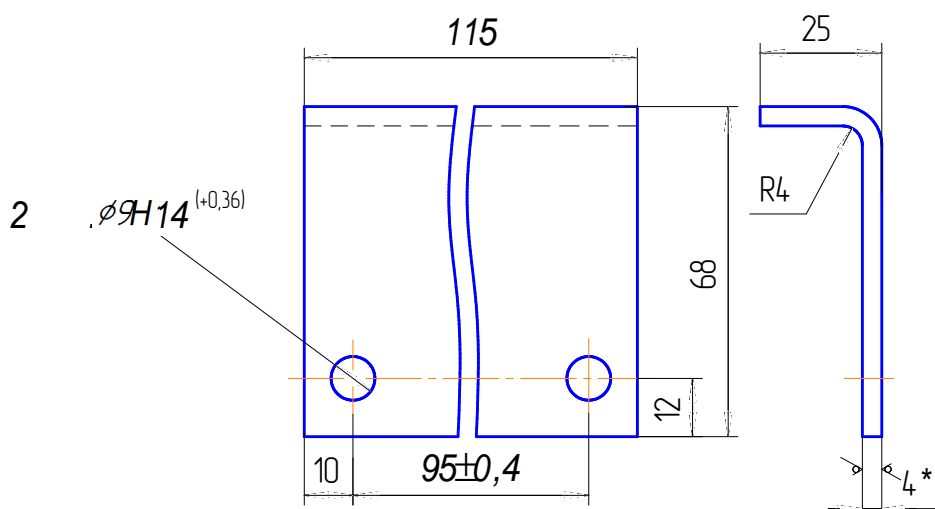
$$\tau_{\max} = 37.34 < [\tau] = 41.7$$

$$k = 3.$$

3

3.1

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3.1.



3.1 –

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105 ,

$$q = \eta q' = 2.5 \cdot 105 = 262.5 \quad , \quad (3.1)$$

$\eta$  –

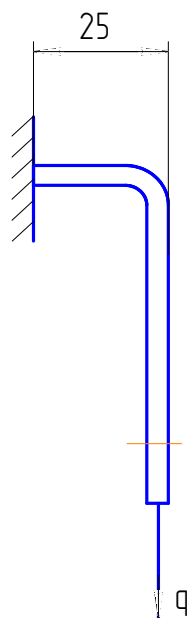
,  
 $\eta = 2.5;$



$q'$  –

,  $q'=105$  .

, . 3.2.



3.2 –

[ 29]

$$M'_{\max} = q \cdot 0,025 = 262,5 \cdot 0,025 = 6,6 \quad . \quad (3.2)$$

$$\sigma = \frac{M'_{\max}}{W'_0} \leq [\sigma], \quad (3.3)$$

$W'_0$  –

$$W'_0 = \frac{bh^2}{6}, \quad (3.4)$$

$b$  – ,  $b = 115$  ;  
 $h$  – ,  $h = 4$  ( ).

$$W'_0 = \frac{0.115 \cdot 0.004^2}{6} = 3.067 \cdot 10^{-7} \text{ }^3.$$

$[\sigma]$  –

$$[\sigma] = \frac{\sigma}{n} \quad (3.5)$$

$\sigma$  – .2 2,  $\sigma = 240$  ;  
 $n$  – ,  $n = 1,5$ .

$$[\sigma] = \frac{240}{1,5} = 160 \text{ } ,$$

$$\sigma = \frac{6,6}{3,067 \cdot 10^{-7}} = 21,5 \cdot 10^6 \text{ } .$$

$\Delta y'$ , . 3.2 [37].

$$\Delta y' = -\frac{q \cdot 0.025^3}{3EJ'}, \quad (3.6)$$

$E$  – ,  $E = 2,1 \cdot 10^5$  ;  
 $J'$  –

$$J' = \frac{bh^3}{12}. \quad (3.7)$$

$$J' = \frac{0,115 \cdot 0,004^3}{12} = 6,133 \cdot 10^{-10} \text{ }^4.$$

$$\Delta y' = -\frac{262.5 \cdot 0.025^3}{3 \cdot 2.1 \cdot 10^{11} \cdot 6.133 \cdot 10^{-10}} = 1.162 \cdot 10^{-5} \text{ }.$$

$$q = 2625$$

$$M'_{\max} = 6,6 \text{ }.$$

[20-22]

$$\tau''_{\max} = \sqrt{\tau''_M{}^2 + \tau''_{q1}{}^2} \leq [\tau], \quad (3.8)$$

$$\tau''_M = \frac{M''_{\max}}{W''}, \quad \tau''_q = \frac{q}{W''}.$$

$$\tau''_M = \frac{M''_{\max}}{W''}, \quad (3.9)$$

$$W'' =$$

$$B=115, \quad H=4.$$

, [19, 40],

$$W'' = \frac{j''}{y''_{\max}}, \quad (3.10)$$

$$j'' = \frac{B+2 \cdot 0,7 \cdot k}{12} (H+2 \cdot 0,7 \cdot k)^3 - \frac{B \cdot H^3}{12},$$

$$k = 2 \quad ($$

$$y''_{\max} -$$

,

$$y''_{\max} = \frac{H}{2} + k, \quad (3.11)$$

$$y''_{\max} = \frac{4}{2} + 2 = 4,$$

,

$$j'' = \frac{(115 + 2 \cdot 0,7 \cdot 2)(4 + 2 \cdot 0,7 \cdot 2)^3}{12} - \frac{115 \cdot 4^3}{12} = 2473,$$

$$W'' = \frac{2473}{4} = 618,3.$$

,

$$\tau''_M$$

$$\tau''_M = \frac{6,6 \cdot 10^3}{618,3} = 10,7.$$

.

.

$$q.$$

,

$$\tau''_q = \frac{q}{2 \cdot 0.7k \cdot l}, \quad (3.12)$$

$k = 2$ ;  
 $l \approx 115$ .

$$\tau''_q = \frac{262.5}{2 \cdot 0.7 \cdot 2 \cdot 115} = 0.82,$$

$$\tau''_{\max} = \sqrt{10.7^2 + 0.82^2} = 10.7,$$

$$\tau''_{\max} = 10.7 < [\tau] = 41.7$$

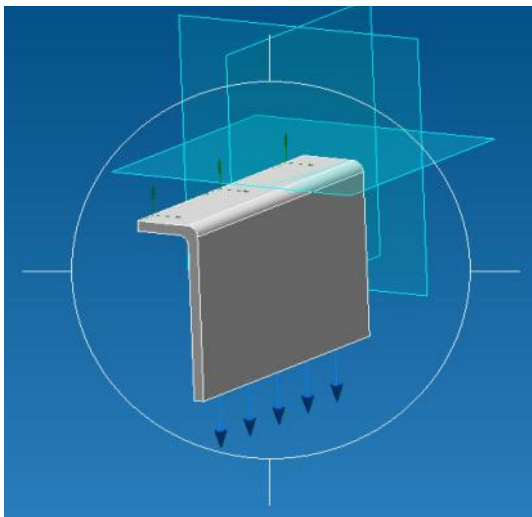
$k = 2$ .

### 3.2

### APM Studio

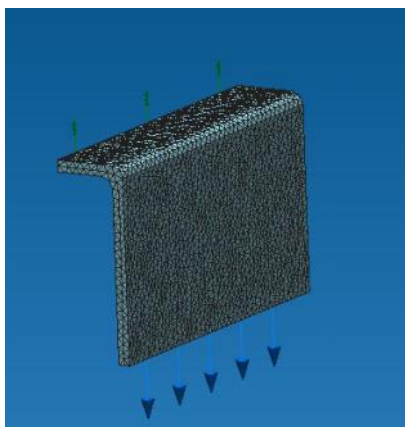
APM Studio

., .3.3.



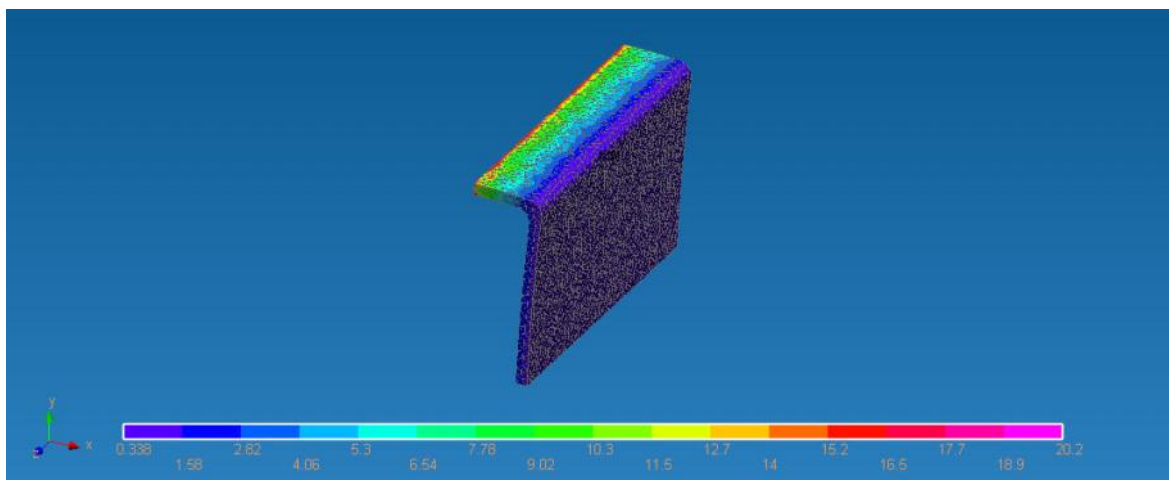
3.3 –

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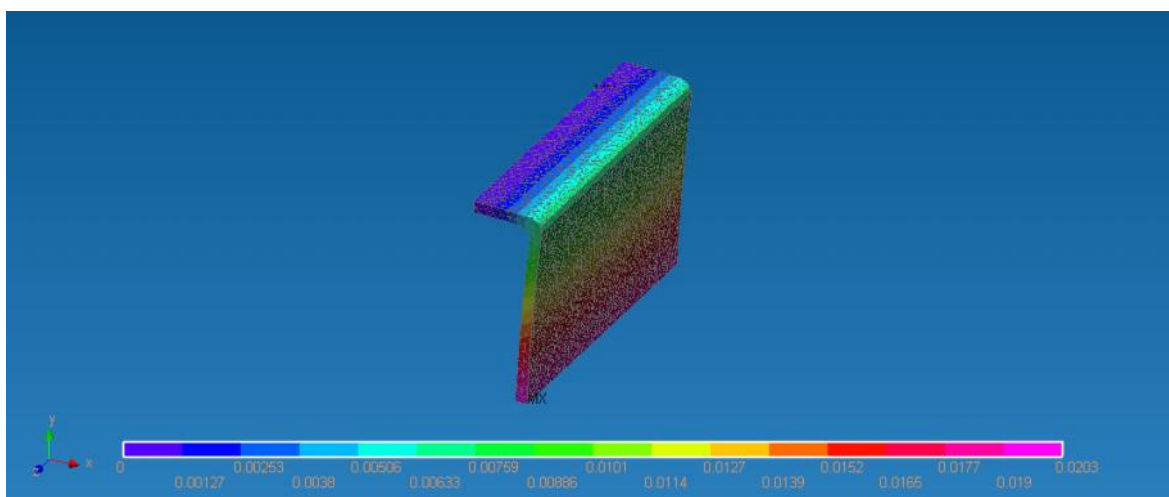
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3.5 –

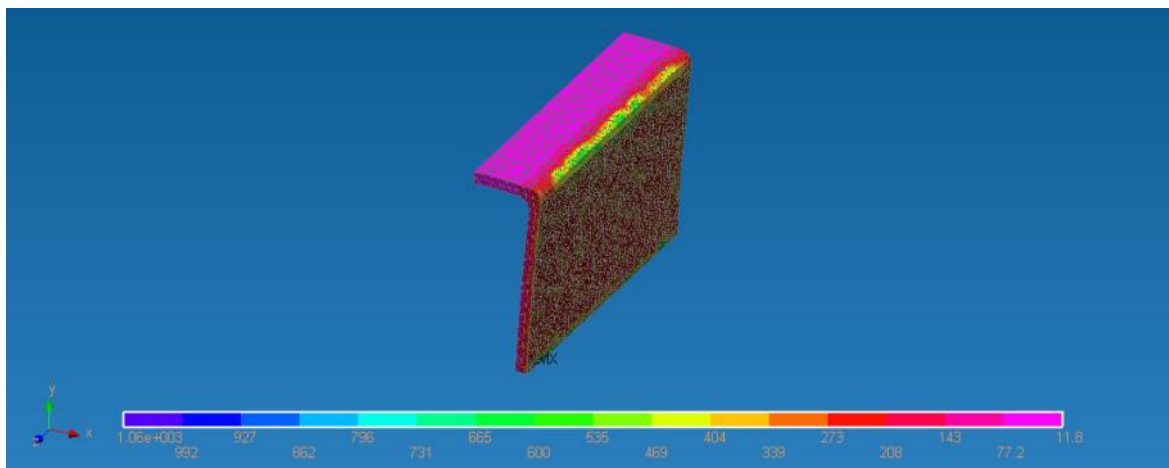
20,2 . , ,  
 , 21,5 ,  
 6 % , .



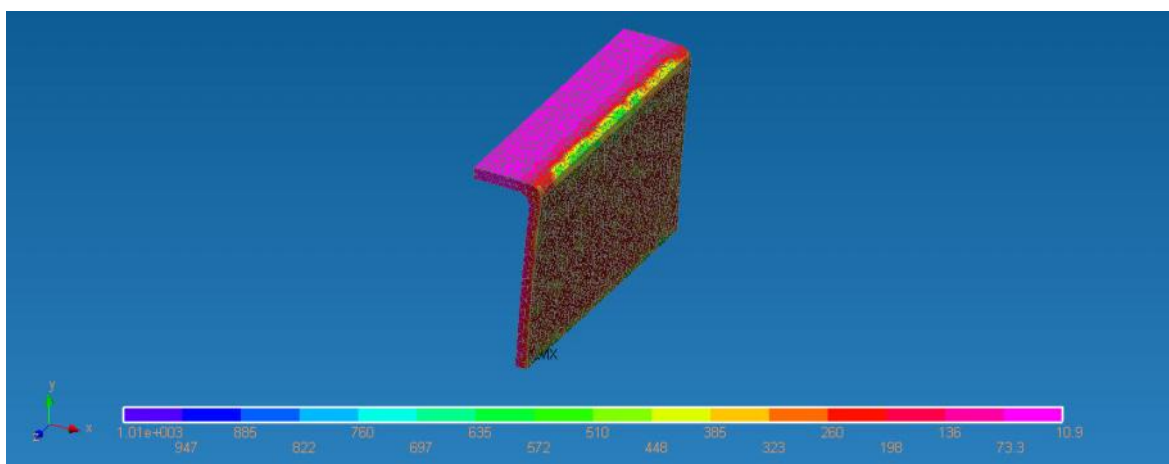
3.6 –



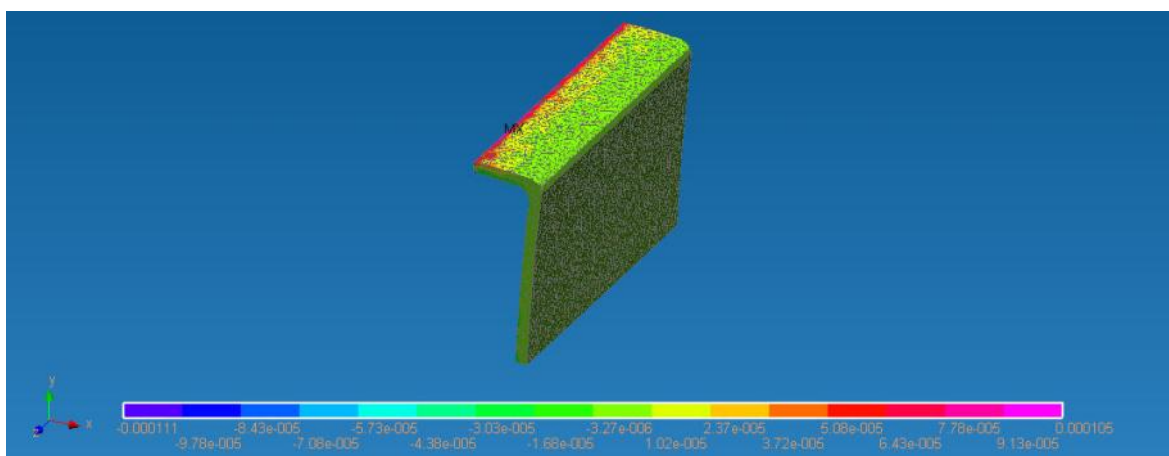
.3.7



3.7 –



3.7 –



3.8 –

## 3.3

$$\tau_{Q_1} = \frac{Q_1}{0.7k \cdot l} \leq [\tau], \quad (3.13)$$

$Q_1$  – ,  $Q_1 = 500H$  ;  
 $k$  – ;  
 $l$  – ,  
 $[\tau]$  -

$$[\tau] = 0,6 \cdot \frac{\sigma}{n \cdot \beta}, \quad (3.14)$$

$\sigma$  – ,  $\sigma = 250$  ;  
 $n$  – .  $n = 1.5$ ;

$\beta -$

[31],  $\beta = 2.4$ .

Mathcad.

:

$$\sigma_m := 250 \cdot 10^6 \cdot Pa$$

$$n := 1.5$$

$$\beta := 2.4$$

:

$$\tau_d := 0.6 \cdot \frac{\sigma_m}{n \cdot \beta}$$

$$\tau_d = 4.167 \times 10^7 Pa$$

$$k = \frac{Q_1}{0.7 \cdot [\tau] \cdot l} \quad (3.15)$$

Mathcad:

$$Q_1 := 500 \cdot N$$

$$l := 0.13 \cdot m$$

$$k := \frac{Q_1}{0.7 \cdot \tau_d \cdot l}$$

$$k = 1.319 \times 10^{-4} m$$

$$l1 = 50$$

$$l1 := 0.05 \cdot m$$

$$k1 := \frac{Q1}{0.7 \cdot \tau d \cdot l1}$$

$$k1 = 3.429 \times 10^{-4} \text{ m}$$

$$k1 = 2$$

:

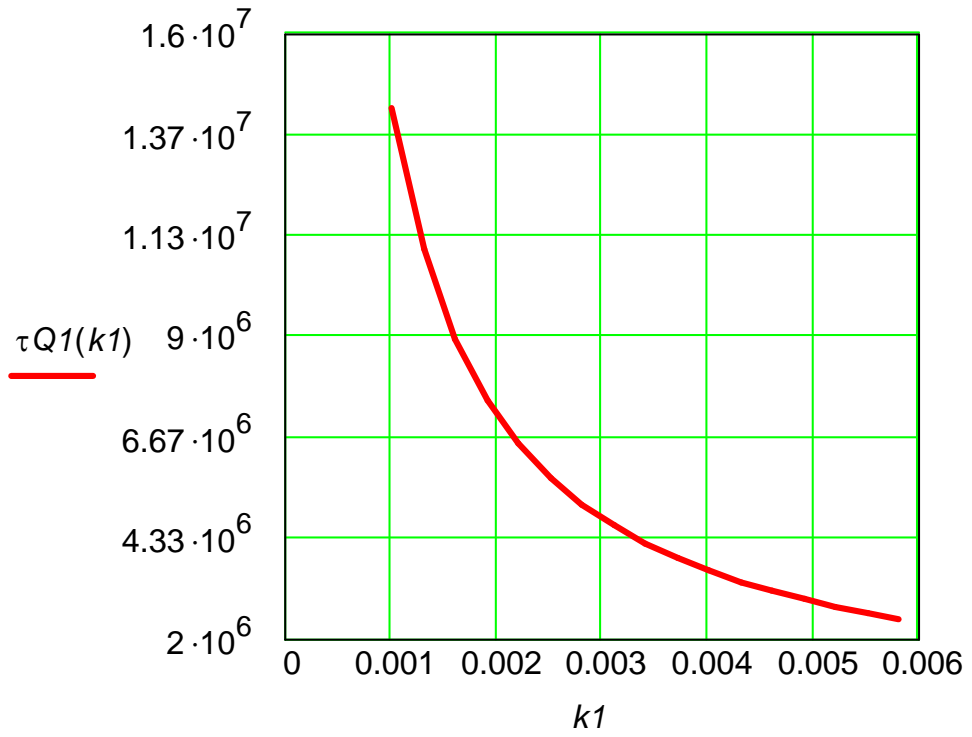
$$k1 := 0.002 \cdot m$$

$$\tau Q1 := \frac{Q1}{0.7 \cdot k1 \cdot l1}$$

$$\tau Q1 = 7.143 \times 10^6 \text{ Pa}$$

$$k1 := 0.001 \cdot m, 0.0013 \cdot m.. 0.006 \cdot m$$

$$\tau Q1(k1) := \frac{Q1}{0.7 \cdot k1 \cdot l1}$$



3.9 -

## 4

## 4.1

$$0,38 \quad 0,77 \quad ,$$

$$1 \quad ( \quad ) .$$

$$E = \frac{F}{S}, \quad . \quad (4.1)$$

$$B = \frac{E \cdot \rho}{\pi \cdot 10^4}, \quad , \quad (4.2)$$

[11, 25, 30]:

$$F = \frac{E \cdot S \cdot K}{n \cdot \eta \cdot z}, \quad (4.3)$$

$F$  — , ( . 7.1);  
 $E$  — , ;  
 — ;  
 $S$  — , ;  
 — (1,3 — 1,5),  
 ;  
 — ;  
 $z$  — ( 0,75 —  
 0,87).

$$n = \frac{E \cdot S \cdot K}{F \cdot \eta \cdot z}. \quad (4.4)$$

. 4.1

[11]:

$$\varphi = \frac{a \cdot b}{h(a + b)}, \quad (4.5)$$

$b$  —

;

$h -$

, .

4.1 -

|  |     |      |      |      |      |      |      |      |
|--|-----|------|------|------|------|------|------|------|
|  | 0,5 | 0,6  | 0,8  | 1,0  | 1,5  | 2,0  | 3,0  | 5,0  |
|  | 0,2 | 0,25 | 0,32 | 0,37 | 0,42 | 0,46 | 0,51 | 0,54 |

- 80

, ,

5

.

, ,

40

$F=380$  [33].

(4.5)

: -4 .. -8 ..

-2 .

$$\varphi = \frac{4 \cdot 8}{2(4+8)} = 1.33.$$

4.1

0,4.

(4.4)



$$n = \frac{5 \cdot (4 \cdot 8) \cdot 1.5}{380 \cdot 0.4 \cdot 0.8} = 1.97,$$

$$n=2 \quad .$$

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**4.2**

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10-15%).

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$z=36$  ,  
 $l=0,6$  .  
 $d=1,0 \quad 1,2$  ) (  $0,3 \dots 1,0$  )  
 $2,0$  (  $1,5; 2; 2,5$  ) ,  
 $L=204$  ,  
 $40 \quad 25 \quad 2$  ,  
 $-\sigma = 33,7 \cdot 10^6$  .  
 $-0,2$  ,  
 $0,25$  .  
 $3$  ,  
 $\tau_{\max} = 37,34 < [\tau] = 41,7$  .  
 $\sigma = 21,5 \cdot 10^6$  .  
 $\Delta y' = 1,162 \cdot 10^{-5}$  .

$$\tau''_{\max} = 10,7$$

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