

## IMPROVED CLEANING DEVICE DETERMINATION OF PILE LENGTH, INFLUENCE OF LENGTH ON MASS AND INSPECTION OF SHAFT STRENGTH

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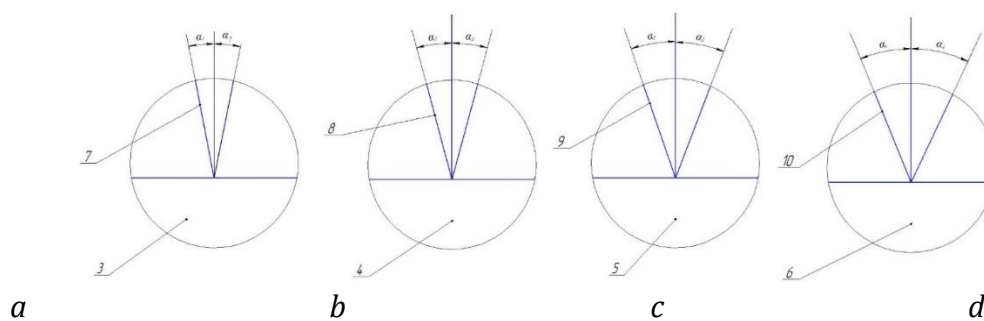
### Abstract

In this article, by finding the optimal lengths of inclined pile drum piles, the change in drum weight was determined, and finally, the strength state was studied as a result of increasing the drum deflection.

**Keywords:** Cotton cleaning, machine, pile drum, pile inclination angle, pile length, strength, amplitude, rotation speed.

### Introduction

For optimal operation of the cotton gin drum, the pile tip must reach a certain part of the web surface in each revolution in order for the piles to properly impact the web surface. However, in the drum design, the piles are installed at different angles ( $\alpha = 6^\circ, 10^\circ, 14^\circ, 18^\circ$ ), which directly affects their transverse displacement. If the pile length is not sufficient, the displacement displacement will be less than the distance of reaching the web surface, and the impact force on the cotton mass will be significantly reduced. Also, determining the optimal pile length for each drum is important in terms of ensuring the efficiency of the device. This study discusses a method for calculating the minimum length based on the angular displacement geometry of the pile.



**Scheme of drums with an enlarged slope angle**

a)  $\alpha_1=6^\circ$ , b)  $\alpha_2=10^\circ$ , c)  $\alpha_3=14^\circ$ , d)  $\alpha_4=18^\circ$

### Theoretical studies

The following specific technical data were taken for calculations. The drum with piles is diametric (without piles)  $D_{dr}=300$  mm, with piles  $D_{total}=400$  mm From this we can see that  $L_0=(400-300)/2=50$  mm. The drum length is 2000 mm, each drum has 300 piles, i.e. 8 rows  $N_{piles}= 4 \cdot 37+4 \cdot 38=300$ . The figure shows that the drum piles are equipped with piles with angles  $\alpha_1=6^\circ, \alpha_2=10^\circ, \alpha_3=14^\circ, \alpha_4=18^\circ$ , respectively. If the pile has a height of  $L_0=50$  mm in the vertical position, then when installed at an angle  $\alpha$ , its vertical component must be increased in order to cover the distance between the drum and the mesh surface;

$$L_0=L_q \cdot \cos(\alpha) \rightarrow L_q= L_0/ \cos(\alpha)=50/\cos(\alpha) \quad (1)$$

Using the formula, the pile lengths of all drums at angles of 6°, 10°, 14°, and 18°, respectively, are given in Table 1.

Table 1 Pile length depending on angle

Drum №	$\alpha(^{\circ})$	$\cos(\alpha)$	$L_q=50/\cos(\alpha)$ mm	Accepted $L_q$ (mm)
I ( $\alpha_1=6^{\circ}$ )	6°	0,9945	50/0,9945=50,28	51
II ( $\alpha_2=10^{\circ}$ )	10°	0,9848	50/0,9848=50,77	51
III ( $\alpha_3=14^{\circ}$ )	14°	0,9703	50/0,9703=51,53	52
IV ( $\alpha_4=18^{\circ}$ )	18°	0,9511	50/0,9511=52,57	53

The amplitude of transverse displacement, i.e. the amount of movement of the pile tip along the mesh surface:

$$\delta = L_q \cdot \sin(\alpha) \quad (2)$$

The values in Table 1 above and the motion of the pile tip on the string surface according to the angles using the 2 formulas are given in Table 1.

Table 2. Amplitude of transverse displacement depending on the angle

Drum №	$\alpha(^{\circ})$	$\sin(\alpha)$	$\delta = L_q \cdot \sin(\alpha)$ mm	Accepted $\delta$ (mm)
I ( $\alpha_1=6^{\circ}$ )	6°	0,1045	51/0,1045=5,33	5,3
II ( $\alpha_2=10^{\circ}$ )	10°	0,1736	51/0,1736=8,85	8,9
III ( $\alpha_3=14^{\circ}$ )	14°	0,2419	52/0,2419=12,58	12,6
IV ( $\alpha_4=18^{\circ}$ )	18°	0,3090	53/0,3090=16,38	16,4

As can be seen from Tables 1 and 2, with an increase in the angle  $\alpha$ , the difference in pile length from 51 mm to 53 mm increases by 2 mm, or 4%. At the same time, the amplitude of transverse displacement increases from 5.3 mm to 16.4 mm, or 3.1 times. This indicates that the intensity of the impact on the mesh surface is significantly higher.

Pile material - 40X grade steel (according to pile drum manufacturing technology), density  $\rho=7850$  kg/m<sup>3</sup>, diameter  $d_q=20$  mm. Cross-sectional area:

$$A_q=\pi \cdot d_q^2/4=\pi \cdot 0,020^2/4=3,1416 \cdot 10^{-4} \text{ m}^2 \quad (3)$$

Mass of one pile:

$$m_q=\rho \cdot A_q \cdot L_q=7850 \cdot 3,1416 \cdot 10^{-4} \cdot L_q=2,466 \cdot L_q \quad (4)$$

Total mass of piles per drum (n = 300 pieces):

$$M_{pile} = n \cdot m_q=300 \cdot m_q \quad (5)$$

Table 3. Pile length and mass ( $d_q=20$  mm,  $\rho=7850$  kg/m<sup>3</sup>,  $n=300$ )

Drum №	$L_q$ (mm)	$m_q = \rho \cdot (\pi \cdot d_q^2 / 4) \cdot L_q$ (kg)	$m_q$ (kg)	$M_{pile}=300 \cdot m_q$ (kg)
I	51	$7850 \times 3,1416 \times 10^{-4} \times 0,051$	0,1257	37,71
II	51	$7850 \times 3,1416 \times 10^{-4} \times 0,051$	0,1257	37,71
III	52	$7850 \times 3,1416 \times 10^{-4} \times 0,052$	0,1282	38,46
IV	53	$7850 \times 3,1416 \times 10^{-4} \times 0,053$	0,1306	39,18

As can be seen from Table 3, increasing the pile length from 51 mm to 53 mm increases the weight of the drums by 0.72 kg to 2.19 kg (3.9%), given that the total mass of all 300 piles is 36.99 kg. This is a very small difference, and the main mass is not the piles, but the drum cylinder and shaft. Mass of the drum cylinder ( $D = 300$  mm,  $t = 6$  mm,  $L = 2,000$  mm, steel grade 45, assumed to be approximately cylindrical):

$$M_{list} = \rho \cdot \pi \cdot D \cdot t \cdot L = 7850 \cdot \pi \cdot 0,300 \cdot 0,006 \cdot 2,000 = 88,8 \text{ kg} \quad (6)$$

Shaft mass (rolling stock  $\varnothing 100$  mm, working length 2 200 mm, 40X steel):

$$M_{shaft} = \rho \cdot (\pi \cdot d^2 / 4) \cdot L = 7850 \cdot (\pi \cdot 0,100^2 / 4) \cdot 2,200 = 135,3 \text{ kg} \quad (7)$$

Total mass of each drum assembly:

$$M_{total} = M_{shaft} + M_{list} + M_{pile} \quad (8)$$

Weight force acting on the shaft:

$$Q = M_{total} \cdot g = M_{total} \cdot 9,81 \quad (9)$$

The results calculated according to (8) and (9) are presented in Table 4:

Table 4. Total mass of the drum assembly and the weight force acting on the shaft

Drum №	$M_{shaft}$ (kg)	$M_{list}$ (kg)	$M_{pile}$ (kg)	$M_{total}$ (kg)	$Q = M \times 9,81$ (N)
I	135,3	88,8	37,71	261,8	$261,8 \times 9,81 = 2\,568,2$
II	135,3	88,8	37,71	261,8	$261,8 \times 9,81 = 2\,568,2$
III	135,3	88,8	38,46	262,6	$262,6 \times 9,81 = 2\,576,1$
IV	135,3	88,8	39,18	263,3	$263,3 \times 9,81 = 2\,582,9$

As can be seen from Table 4, the mass of the four drum assemblies varies from 261.8 kg to 263.3 kg - that is, only 1.5 kg (0.6%) differs from each other. The mass practically does not change with increasing angle, since the increase in the pile length (51→53 mm) is very small. The shaft is supported on two bearings (bearing brand 212, distance between supports  $L=2000$  mm - equal to the length of the drum). The weight of the drum is considered as a distributed load on the middle of the shaft. Bending moment:

$$M_{eg} = Q \cdot L / 4 \quad (10)$$

The resistance moment at the working diameter of the shaft ( $d = 60$  mm,  $\varnothing 60^{+0,012}$  working surface, from the wedge drum technology):

$$W = \pi \cdot d^3 / 32 = \pi \cdot 0,060^3 / 32 = 2,122 \times 10^{-5} \text{ m}^3 \quad (11)$$

Bending stress and strength test (for 40X steel  $[\sigma_{eg}] = 80$  MPa):

$$\sigma_{eg} = M_{eg}/W \leq [\sigma_{eg}] \quad (12)$$

The calculation results are presented in Table 5:

Table 5. Shaft bending stress and strength test (d=60 mm,  $[\sigma]=80$  MPa)

Drum №	Q (N)	$M_{eg}=Q \times L/4$ (N·m)	$\sigma_{eg}$ (MPa)	$[\sigma_{eg}]$ (MPa)	Backup $n=\sigma/\sigma_{eg}$	Status
I	2568,2	$2568,2 \times 2,0/4 = 1284,1$	$1284,1/2,122 \times 10^{-5} = 60,5$	80	1,32	✓
II	2568,2	$2568,2 \times 2,0/4 = 1284,1$	$1284,1/2,122 \times 10^{-5} = 60,5$	80	1,32	✓
III	2576,1	$2576,1 \times 2,0/4 = 1288,1$	$1288,1/2,122 \times 10^{-5} = 60,7$	80	1,32	✓
IV	2582,9	$2582,9 \times 2,0/4 = 1291,5$	$1291,5/2,122 \times 10^{-5} = 60,9$	80	1,31	✓

As can be seen from Table 5, the bending stress for all four drums is  $\sigma_{eg}=60.5-60.9$  MPa, which is lower than the permissible value  $[\sigma_{eg}]=80$  MPa. The safety margin  $n=80/60.9 \approx 1.31$  is a standard value for mechanical devices. Therefore, the existing shaft with a diameter of d=60 mm is fully suitable in terms of strength for use in the improved cleaning device.

### Conclusions

1. Based on the pile height  $L_0 = 50$  mm and angles  $\alpha = 6^\circ-18^\circ$ , the actual pile lengths are determined to be in the range of  $L_q = 51-53$  mm — the difference is only 2 mm.
2. The transverse displacement amplitude increases 3.1 times from 5.33 mm to 16.38 mm with increasing angle. This indicates that the impact intensity on the mesh surface in the  $18^\circ$  drum (IV) is significantly higher than that in the  $6^\circ$  drum (I), and physically proves the cleaning efficiency results in Chapter 3 ( $\sigma: 62.5\% \rightarrow 86.2\%$ ).
3. Increasing the pile length increases the total mass of the drum assembly by only 1.47 kg (3.9%)—a practically negligible amount.
4. The total mass of the drum assembly is 261.8–263.3 kg, and the weight force acting on the shaft is  $Q = 2,568-2,583$  N.
5. Strength check (formula 3.12): for all drums  $\sigma_{eg} = 60.5-60.9$  MPa  $< [\sigma_{eg}] = 80$  MPa. The existing shaft with a diameter of d = 60 mm fully satisfies the strength condition, the safety margin is  $n \approx 1.31$ .

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