Screw conveyor with anti-friction polymer coating for cotton transportation

A A Irgashev¹ and F A Ergashev²

¹Tashkent institute of irrigation and agricultural mechanization engineers, 39, st. Kara Niyaziy, Tashkent, 100000, Uzbekistan.
²Tashkent State Technical University named after I Karimov, 2, st. Universitetskaya, Tashkent, 100097, Uzbekistan.

E-mail: orif0916@mail.ru, qwerty0409@mail.ru

Abstract. Screw conveyors used in the ginning industry when interacting with raw cotton, significantly damage it and reduce the quality of the products. The article presents the results of a study of the effect of antifriction polycaproamide composite coating applied to the surface of the screw and the chute on the quality of cotton fiber and seeds, as well as on the productivity and power consumption of the screw conveyor for cotton. During the production tests, measurements are made of the magnitude of the linear wear of the coating on the surface of the screw and chute. It is established that with the recommended thickness of the coating of APCC-I 600–700 microns, its durability under operating conditions at the cotton gin plant, with two-shift operation during one season, will be fully ensured.

1. Introduction
Increasing demands on the improvement of the efficiency of the cotton-cleaning industry necessitate the continuous improvement of technological equipment, reduction of metal consumption, increase of productivity and durability of machines and mechanisms due to improvement of the design and widespread use of new, most effective structural materials, while maintaining the natural qualities of cotton fiber and seeds.

The studies by several authors show [1,2] that the working bodies of screw conveyors used in the cotton ginning industry when interacting with raw cotton significantly damage it and reduce the quality of products.

In addition, these metal-consuming aggregates consume a large amount of energy, have a relatively low productivity and operability, and are sources of fire due to sparking during the collision of their working bodies with solid inclusions of raw cotton.

It was previously found that these disadvantages can be eliminated or minimized using polymer coatings. Polymer coatings significantly improve surface microgeometry, eliminating burrs and sharp edges. In addition, microroughnesses formed on the surface of the polymer coating have a lower ability to incise cotton fibers due to the large radius of rounding of the microroughness vertices and the high elasticity of the polymer coating [3].

2. Materials and methods
Based on the study of the physic-mechanical and antifriction properties of various composite polymer coatings with cotton, considering their cost and manufacturability, as well as operating conditions, several compositions of antifriction compositions have been developed for use on the working surfaces of cotton machines with a set of necessary operational properties [4].
To conduct a study of the effect of the developed antifriction polycaproamide composite coatings (APCC), deposited on the surface of the screw and the gutter, on the performance of screw conveyors for cotton, we developed and manufactured a special stand-alone installation that works in closed form.

The test screw conveyor 4 m long (one section) is horizontally mounted on a bench installation.

The rotation speed of the feed rollers of the installation is adjustable, which allows feeding cotton on a screw conveyor with a different fill factor.

The studies were carried out on medium-fiber cotton of Tashkent-1 selection of the first grade machine assembly of conditioned humidity from 8 to 21% with weediness from 7.5 to 28%. The moistening of cotton was carried out according to the methodology of CRICI.

In the process of conducting experiments using a self-recording wattmeter, the power consumption was recorded at idle and under load. At the same time, raw cotton samples selected to determine conveyor performance were analyzed for damage to seeds and fiber.

The study of cotton fiber damage was carried out according to the method described in [5]. The essence of the method consists in studying the macrostructure of fibers using optical microscopy and quantitatively considering all types of fiber damage.

Seed damage was determined according to GOST 21820.3-76 [6].

The wear of parts is mainly measured by weight loss and by the change in the linear dimensions of the samples. The first method provides high accuracy, simplicity and ease of measurement. However, for our tasks, the application of this method is impractical due to the large dimensions of the tested samples and parts, as well as the complexity of studying the distribution of wear on the surface of parts.

From this point of view, to study the wear of polymer coatings during friction with raw cotton, depending on the test conditions, as well as the configuration of the parts, we used the MT-101M portable magnetic coating thickness gauge designed to measure the thickness of coatings on magnetic metals in accordance with GOST 51694.

In the work, for applying a powdery polymer composition on the surface of the working bodies of a screw conveyor, a plasma spraying method was used using the Kiev-7 industrial unit. The installation allows obtaining multilayer coatings with a change in the concentration of the components of the sprayed powder materials by the thickness of the layer and achieving the set of properties inherent in each of the sprayed components.

To obtain high-quality coatings, strict adherence to a given technology for the preparation of compositions and compositions is important.

We used an Anger mixer for preparing compositions in the required ratio of its components. Good homogenization of the components is obtained by mixing them in two stages.

The composition was mixed depending on the type of fillers for 20-40 minutes. The filler was dried at elevated temperatures (100-150 °C) to accelerate the drying process.

The polymer powder was preliminarily kept in a vacuum drying oven VD-0.035 M for 6 hours at 323-3330º K to a moisture content of 0.1-0.3%.

3. Investigation of the efficiency of a screw conveyor with an anti-friction polymer coating for transporting cotton

Figure 1 presents the results of the APCC (Antifriction Polycaproamide Composite Coating) study on the performance and power consumption of a screw conveyor for cotton NWR depending on the moisture of the transported cotton at various filling factors.

With increasing humidity of the transported cotton, the performance of the screw conveyor, both with and without coating, decreases linearly. In this case, the most intense decrease is observed in an uncoated screw conveyor. It is also seen that with a decrease in the fill factor, the performance of all screw conveyors decreases less significantly with increasing humidity.

The studies have shown that with a fill factor of $\Psi=1$ and a cotton moisture content of $W = 7.5\%$, the productivity of conveyors with automatic control systems is on average 9% higher than without coating, and power consumption is 21% lower, and with a cotton moisture content of $W = 20\%$ these figures are 29 and 34%.
The results of these studies are explained mainly by the regularity of the change in the friction coefficient of the APCC and steel with cotton, depending on the moisture content of the latter. The friction coefficient of APCC with cotton is, firstly, significantly lower than that of steel, and secondly, with an increase in the moisture content of cotton, the friction coefficient of APCC less intensively increases compared to steel [4].

With the increase in the friction force of the cotton over the surface of the screw’s feather, due to the greater cohesion of the cotton, it is thrown, that is, some of the cotton will begin to rotate with the screw. The latter affects not only the increase in energy costs for transporting cotton, but also reduces the productivity of the screw conveyor. Moreover, the phenomenon of throwing cotton with a screw manifests itself more strongly at high values of the fill factor.

![Figure 1](image_url)

**Figure 1.** Dependence of productivity a and consumed power b of a screw conveyor of ShKhR on moisture of transported cotton at $\psi = 1$ (1,2,3,4) and $\psi = 0.75$ (1’, 2’, 3’, 4’); 1’’, 2’’, 3’’ - the surface of the screw and trough are coated with developed antifriction polycaproamide compositions APCC-1, APCC-2, APCC-3, respectively; 4.4’-screw conveyor without coating.

The table shows the results of changes in the damage of fiber and cotton seeds after passing it fifteen times through a bench screw conveyor, with filling factors $\Psi=1$ and $\Psi=0.75$ and cotton moisture content $W = 9.6$ and $W = 20.8\%$.

With increased humidity of cotton, the damage to fiber and seeds increases. In all cases, the damage to fiber and seeds after a screw conveyor with a coating is 15–20% and 14–30% respectively lower compared to an uncoated conveyor, which is explained by the low coefficient of friction and the high damping ability of the polymer coating [7].

Thus, within the considered moisture content of cotton among the developed compositions, APCC-3 provides a relatively high and stable performance for a screw conveyor and significantly less damage to fiber and cotton seeds compared to an uncoated screw conveyor.

It is known that during the friction of polymers with cotton, electrostatic charges are formed and accumulate on the surface of the contacting bodies, which can become a source of ignition of raw cotton according to the scheme: discharge spark-cotton dust-cotton [8].
In this regard, studies have been carried out, including the determination of the possibility of sunburn of raw cotton from charges of static electricity. In this case, the electrification potential of the surface of the working body of the screw conveyor was measured with an S-53 electrostatic voltmeter. The measurement results showed that the most electrified area of the surface of the working bodies of the screw conveyor are the tops of the feathers of the screw and the bottom of the gutter. The calculation of the energy of a possible spark from electrostatic charges forming on the surface of the screw and the trough showed that the charge energy in this case does not exceed 0.157 J. This is significantly less than the ignition energy of cotton dust, which is 0.510 J. [9].

Table 1. Change in fiber damage (in the numerator) and seeds (in the denominator) after fifteen passes of cotton through a screw conveyor.

| Damage indicators of fiber and cotton seeds | Units of measure | $\Psi = 1$ | $\Psi = 0.75$ |
|------------------------------------------|-----------------|-------------|-------------|
| Damage to fiber and seed raw cotton      | %               | 11/2.4      | 11/2.4      |
| Damage to fiber and seeds after uncoated screw conveyor | %   | 19/5.12 | 26/7.24 | 17/4.68 | 24/6.52 |
| Damage to fiber and seeds after a screw conveyor coated with APCC-1 | % | 16/4.22 | 20/5.56 | 15/4.02 | 19/5.08 |
| Absolute damage reduction                | %               | 3/0.9       | 6/1.68      | 2/0.66    | 5/1.44    |
| Relative damage reduction                | %               | 15.8/17.5   | 23.1/30     | 11.8/14.1 | 20.8/28.3 |

In order to predict the durability of the developed antifriction control panels in real operating conditions, during the production tests, we measured the linear wear of the coating on the surface of the screw and trough using a portable magnetic thickness gauge MT-101M.

Figure 2. Distribution of linear wear of the coating made of APKP-3 on the working surface of the feathers of the screw 1 and chute 2 after 1400 hours of operation of the screw conveyor.
As it can be seen from Figure 2, the vertices of the feathers of the screw and the surface of the bottom of the gutter wear out most. After 1400 hours of operation of the screw conveyor, the linear wear of the coating surface in these sections of the screw and trough was 260 and 310 μm, respectively. Moreover, during the operation of the test conveyor for one season, peeling of the coating from the surface of the feathers of the screw and the trough was not observed.

Consequently, with the recommended coating thickness of APCC-3 600-700 microns, its durability under operating conditions at the ginnery, with two-shift operation during one season, will be fully provided.

4. Conclusion

Thus, the use of antifriction composite polymer coatings on screw conveyors increases their efficiency, helps to preserve the natural properties of cotton and eliminates the possible combustion of cotton from sparks arising from the collision of solid cotton impurities with the metal working bodies of these machines.

References

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