On the quality of the harvested cotton and the energy efficiency of the air transport system of the cotton-picking machines

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Abstract. The article covers the analysis of research on the power consumption of air transport systems of spindle cotton picking machines of different designs and the quality of picked cotton. The main attention is paid to the mechanical damage of seeds, which is one of the quality criteria. Using the principles of air suction-compression, compression and ejection used in machines, power consumption and mechanical damage to cotton seeds were analyzed based on the results of the conducted experiments. Conclusions on scientific and technical solutions aimed at ensuring the quality of picked cotton at the required level are presented.

1 Introduction

The need for natural fibers, especially cotton fibers, is increasing worldwide year by year [1]. With the wheat, soybean and other plant cotton growing is one of the leading industries in the economy of Uzbekistan, and our republic ranks among the world's most advanced countries in terms of cotton cultivation and processing [2-7]. The machine harvester is of particular importance in short-term and high-quality picking of the cultivated cotton crop. Cotton picking machines (CPM) with horizontal and vertical spindles (VS) are used in most cases for picking cotton from high-yielding cotton stalks grown in the fields [8]. Such machines are mainly produced in Uzbekistan, the USA, China, India and other countries, and with them, cotton crops are harvested in fields with 60, 76, 90, 100 cm, and other spacing Technological processes in machines are widely covered in the literature [9-24]. At that, the cotton picked by machines is collected in their receiving chamber and from there it is sent directly to the bunker sucked by air (in VS machines), by compressed air through a pipe (in CPMs intended for the production of seeds) and by Jet Er Trole ejection-based system [8, 10, 16]. The above-mentioned type of cotton sent through air transport systems (ATS) from a fan or pipe directly to the bunker leads to a certain amount of power consumption from the energy source and affects the quality of the cotton seed.

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It is known that the ATS in CPMs carries out the task of transferring the cotton crop picked by the pickers to the bunker. It was noted in the results of field tests that the design of the semi-trailer VS 2-row MX-1.8 and 4-row MX-2.4 CPM ATS produced at JSC "Tashkent Agricultural Machinery Plant" cannot fully ensure the completeness of the harvest in the values indicated by agro-technical requirements [11]. One of the main reasons for this is the fact that ATS pipes have different lengths and complex geometric shapes, as well as the irrational location of the fan in the system structure. Therefore, the development of a rational construction of ATSs of semi-trailer VS CPMs and scientific substantiation of its parameters is one of the urgent issues.

2 Methods

The article describes the method of analysis representing the implementation of various construction and technological processes, the elements of the system participating in the process and the occurrence of local aerodynamic resistance in them. The results of the experiments on the power consumption in cotton transfer to the air bunker are expressed in the form of a histogram, and their analysis is presented.

3 Results and discussion

Transfer of cotton from the machine to the bunker in a continuous medium, i.e. through the air, remains one of the main stages of the technological process of cotton picking. In earlier CPMs, this process was systematic, starting from the apparatus receiving chamber and ending with the transfer of cotton through suction pipes to the separator with the low-pressure fan. Currently, this system is used in two-row and multi-row VS machines [7]. The structure of the system is relatively simple and the power consumption is not high but due to the fact that the picked cotton seeds hit the fan blade and the high-speed cotton air mixture hits the separator, its natural quality changes to a certain extent. Against these consequences, the high-speed air-picking device conveys the cotton coming from the receiving chamber to the bunker directly through the pipes, and the system with increased energy consumption is used in seed production and long-fiber cotton picking [8].

According to the information of the Main Special Design Bureau (BMKB-Argomash), the main drawback of the air transport system, which pushes air at a high speed (25-30 m/s), is the need for a large power for the fan. For example, XVN-1.2 CPMs require power from 5.3 kW for each row to about 20 kW for a 4-row machine [9]. In two-row self-propelled horizontal spindle CPMs, this indicator can reach 30 kW [10]. However, seed damage in ejection-type CPMs has been increased to the required level. For example, in 4-row John Deere 9940 machines, this indicator is 1.35%, and in Case 2155 it is 1.4% in field tests. Early versions of horizontal spindle CPMs were used in a suction-type ATS. In this case, the rate of seed damage was 7% on average and reached 12%. Later, the Jet Er Trole system was used. Through this system, the damage caused to the seeds by the ATS was reduced almost to zero. Despite the high power consumption, this system is currently used in CPMs with a horizontal spindle [11-21].

The power consumption of CPMs with an ATS, in which the picking device sucks cotton from the receiving chamber, is slightly less than that of the compressed or ejection type. For example, this indicator was 10.68 kW in the two-row 17XV-1.8 VS CPM, and 9.85 in the four-row 14XV-2.4 machine. A two-row XMG-04 horizontal spindle CPM with a suction-type ATS required 16.1 kW of power for the centrifugal fan [9]. However, the level of mechanical damage to seeds of the ATS operating in the suction type is 3-4 times higher than the standards given in GOST 22587-91 [17].

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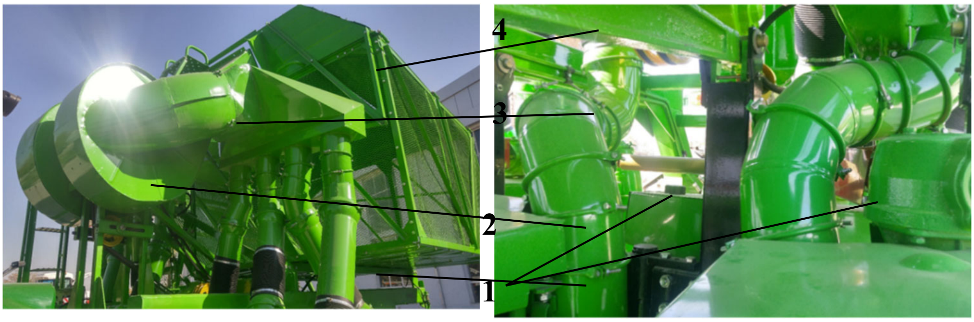

1-metal pipelines; 2-fan; 3- air collector; 4- bunker.

Fig. 1. ATS of the MX-2.4 serial VS CPM and its main parts.

In the years of independence, the MX-2,4 and MX-1,8 VS CPMs have a suction-type ATS, and the CE-220 with horizontal spindle CPM uses an ejection type ATS.

Figure 1 shows the ATS after the harvester of the MX-2.4 four-row machine. We will dwell on some results of the research conducted under the leadership of the Institute of Mechanics and Seismic Stability of Structures of the Academy of Sciences of the Republic of Uzbekistan. The basis of our analysis will be the results obtained at the Central Asian machine testing stations (currently the center of technology and technology testing) and the joint experiences of "Technology and Technology Testing Center" LLC and "Technics and Technology Testing Center" LLC. The results are plotted as a histogram in Figure 2.

It is known that as a result of the complexity of the structure of transmission pipes in the system, the geometric shapes of the structural elements change and additional local aerodynamic resistances appear in the space from the harvesting apparatus to the bunker. For example, the total resistance of the part from the intake chamber to the air collector has increased by 40% compared to the system in the previously designed suspension type machine, and the air collector and fan transmission elbow pipe has increased by 2%. As a result, the power consumption of a two-row machine for directing cotton to the bunker was 10.68 kW, now this indicator increased to 13...18 kW.

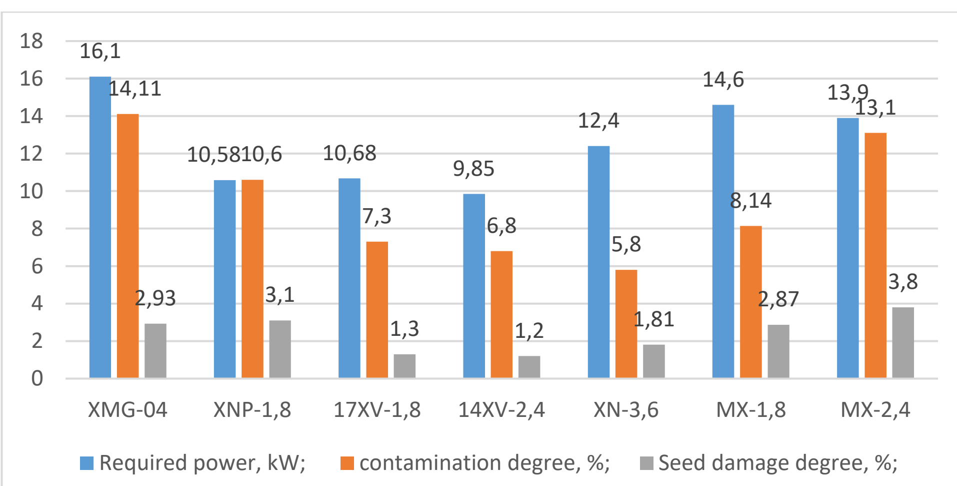

Fig. 2. Histogram of required fan power for CPMs, contamination of harvested cotton and degree of seed damage.

From the above histogram we can see that the seed damage rate is higher than the standard requirements [13] in CPMs with suction type ATS. At the same time, the power required for the fan is 2-3 times less compared to ATSs operating in the compression and ejection types.

A high level of seed damage requires additional cleaning of cotton. This leads to overspending. The problem of seed damage in suction-type ATSs has not been adequately addressed. Therefore, it is necessary to find a construction of an ATS that requires less power and causes minimal damage to picked cotton seeds.

The last research conducted to solve this problem was performed on the order of the Ministry of Innovative Development of the Republic of Uzbekistan by the chief executive organization - the Institute of Mechanics and Seismic Stability of Structures of the Academy of Sciences of the Republic of Uzbekistan in 2018-2020 MV-Atech-2018-92+BV-Atech-2018-13 "High technical "Development of a four-row semi-trailer VS CPM (adapted for single picking)"; these machines were successfully tested for row spacing of 60 cm in practical research [10].

In the initial version of the experimental construction work carried out as part of the practical project, the design of the air collector part of the centrifugal fan was changed and corrugated pipes were placed instead of the telescopic metal pipes of the previous designs (Figure 3 a). In this constructive solution, the air speeds in the transmission pipes were brought to a state almost equal to each other but the problem of mechanical damage to the seeds was not solved. After that, a variant was developed in which the fan was turned 180° and moved closer to the bunker, and all the transmission pipes were changed to corrugated pipes (Figure 3 b).

a b

a-initial version; b-latest version

1- telescopic metal pipelines; 2- corrugated flexible pipelines; 3- air collector; 4-fan;
5-an intermediate pipe that conveys the cotton crop from the fan to the bunker; 6- bunker.

Fig. 3. MX-2.4 CPM equipped with an improved ATS [4].

In 2020, the CPM with ATS of this new design was tested in laboratory and field conditions at the "Technics and Technology Testing Center". The quality indicators of the CPM obtained as a result of the test are presented in the following histogram [14].

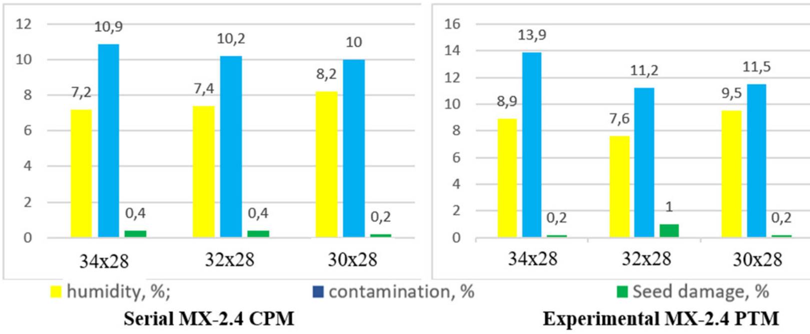

Fig. 4. Some results of testing serial and experimental cotton pickers.

As we can see, the mechanical damage of seeds does not exceed 0.4% even with the smallest working slot (30x28 mm). Centrifugal fan inlet and fan repositioning have minimized the impact of picked cotton on the fan blades. Flexible corrugated pipes are used instead of telescopic metal pipes. Due to the factors listed above, the mechanical damage of seeds was reduced compared to the previous design.

4 Conclusions

The transfer of cotton from the picking apparatus of CPMs to the bunker is carried out through continuous ambient air, and the lowest energy consumption is in the construction of the suction-compression type, its energy efficiency is approximately 2 times less than the air compression transfer, and 3 times less than the ejection type. At the same time, in semi-trailers of this system, the mechanical damage of seed is 1.8...3.8 times higher.

The calculated power consumption of the multi-row MX-2.4 machine in the rational ATS is 1.27 times higher than in the serial ones, and the mechanical damage of seeds is 1.2 times higher due to the increase in the fan blade speed.

The new technical solution of the rational design of the air inlet part of the ATS fan of the semi-trailer CPM is protected by a patent.

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