USING VALUE-ENGINEERING ANALYSIS + TRIZ METHOD FOR IMPROVING THE STRIPPING GRAIN-HARVESTING MACHINE

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INTRODUCTION

High quality of products is one of the main prerequisites for a company's success on the world market. The quality of products is laid down at the early stages of design. While designing, a situation often arises when using the known solutions does not produce a desirable result for some reason or other and the designer is compelled to look for new methods for solving a problem, i.e. to solve an inventive problem. Efficient methods of inventive problem solving may substantially accelerate the design process.

One of the methods that accelerate the process of technology improvement is the method based on the combination of the analytical part of the value-engineering analysis (VEA) and the analytical and solving tools of the Theory of Inventive Problem Solving (TRIZ) [1-3]. This method allows conducting a thorough analysis of an existing engineering system, revealing its deep disadvantages, building a more ideal model of a system and solving all the problems pertaining to the implementation of this model.

One of the main parts of this methodology is the method of function and ideality modeling of an engineering system. This method reflects the main law of technology evolution – the striving for ideality when the machine itself is absent while its function is performed. The essence of this method consists in revealing and eliminating those parts of an engineering system design which perform auxiliary functions. The system design is changed in such a way that the parts that perform auxiliary functions are removed from the system and their functions either become unnecessary or are transferred to the remaining parts. In this case, problems are formulated which are normally not posed by a designer – the new system design must be able to perform its functions with a smaller number of components providing the same or even better quality [3].

This article illustrates the high efficiency of the combined VEA+TRIZ method by the example of improvement of an agricultural machine – a stripper header of a grain-harvesting combine.

DESIGN AND OPERATION OF STRIPPER HEADER

In the 90's, the Belarusian Scientific-Production Amalgamation (NPO) “Belselkhozmekhanizatsia” conducted research in the field of the grain-harvesting technology based on stripping standing plants and using a stripper header. This is one of the most promising technological trends in harvesting crops, leguminous and grass seeds. The point of the new technology is in that not the entire plant - a stalk with a head – is fed to a harvester, but only heads with grains. The stalks (straws) are left standing in the field (Fig.1).

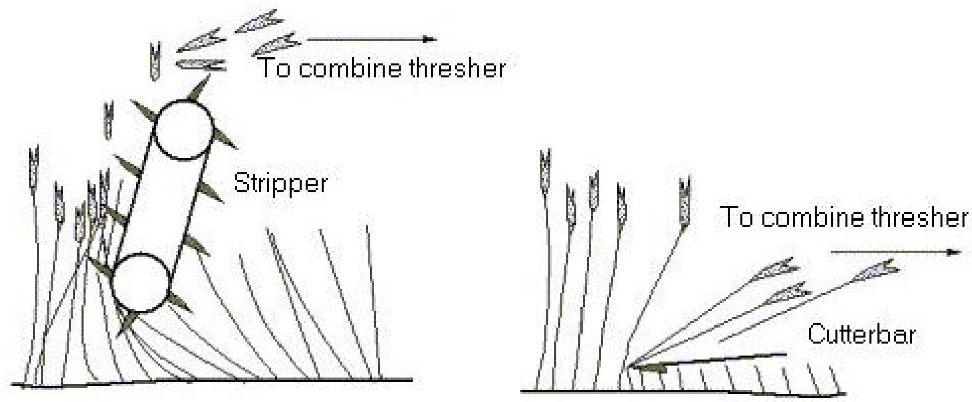

Fig 1. New and traditional technology of grain harvesting.

This grain-harvesting technology allows saving up to 70% of power spent by a combine on straw deformation in a thresher. In this case, the harvesting output doubles and fuel consumption reduces by half. To tear heads, a special stripper header is installed on a combine instead of a traditional header. This device combs stalks with its teeth and tears off the heads. Nowadays, leader of strippers manufacturing is Shelbourne Reynolds Engineering Ltd (GB) but stripper headers of different designs are manufactured by AGCO (USA), Krasnoyarks Combine Plant (RU), Prairie Habitats Inc. (CA) [4].

At NPO «Belselkhozmekhanizatsia», they have developed a stripper header that is installed on a combine CK-5 «Niva» (Fig. 5). The original design of this belt-type stripper header (its structural drawing is given on figure 3) was protected by several USSR authors' certificates [5, 6].
The stripper header was composed of the following principal units: a body, a stripper, a feeder, a roof, a beater, an auger, an inclined chamber, and a drive.

The body is designed to house working components of the stripper header and give a necessary rigidity to the entire construction. The body is a welded construction, the rear

Fig. 2. The stripper header for the combine CK-5 «Niva».

part of which forms a collecting chamber for detached heads.

The stripper is designed to tear off heads from stalks and to transport them to the collecting chamber. It is installed inside the body and is a two-shaft transporter with a belt provided with stripping teeth of a special shape.

The feeder is a device that feeds plants to the stripper and raises the laid stalks. The feeder is made in the form of a pipe with an eccentric shaft inside. The shaft is provided with flexible fingers. The feeder moves relative to the body and is installed depending on the height and state of the plants to be harvested.

The roof serves for directing a flow of detached heads to the collecting chamber. The roof is rigidly attached to the body and is provided with an access door that gives access to the inside of the body. The front wall of the roof as well as the feeder, body and stripper form a stalk-stripping chamber.

The beater is a rotating four-blade shaft. It is designed to remove heads and stalks caught on the stripper teeth and to prevent their hanging on the front edge of the collecting chamber.

The auger. The collecting chamber contains the auger that moves the torn heads toward the center and feeds them to the inclined chamber of the combine.

The drive is designed to transfer the torque from the combine to the working components of the stripper header – the auger, feeder, stripper and beater. There are also hydraulic cylinders for adjusting the height of the feeder and stripper. The drive units are attached to the body.

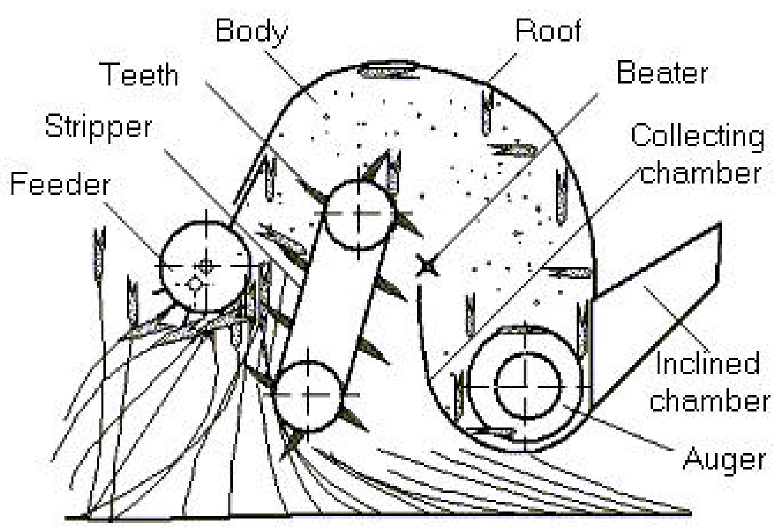

Fig. 3. The structural drawing of the stripper header.

Operation of the stripper header

The combine provided with a stripper header moves on the field and enters the crop. The rotating feeder moves and compact the plant stalks with its body, then grasp them with its fingers and feeds to the stripper. The stripper teeth move with a high speed thereby combing the stalks bottom-up and tearing off the heads. The teeth transport the detached heads up and throw them into the collecting chamber wherefrom the auger feeds them to the inclined chamber and then to the thresher. The heads caught on the stripper teeth are removed by the blades of the rotating beater and are also thrown into the collecting chamber.

The research and tests have proved that the developed stripper header has a number of disadvantages:

? a large weight (2,130 kg), which exceeds the allowed load on the front axle of the combine;
? a large size (the device limited the visibility of the working zone);
? an increased loss of grain – 4.5 to 9% at admissible 2.5 to 3.5%.

The attempts to eliminate the design disadvantages by traditional design methods did not give the expected result. That is why a decision was taken to apply the combined VEA-TRIZ method.

IMPROVING STRIPPER HEADER BY USING VEA+TRIZ METHOD

The improvement of the stripper header included the following stages: preparatory, informational, structural analysis, functional analysis, function and ideality modeling, formulation and solving of detected problems, preparation of technical offers, writing a report, designing the technical documentation, manufacture and testing of a prototype.

Preparatory and informational stages

The work was fulfilled by a temporary creative team formed especially for this purpose. It included a specialist in technical creativity methods, two researchers dealing with the new harvesting technology, design engineers, process engineers, and a patent engineer. During the informational stage, all of them were familiarized with the design and peculiarities of the stripper header operation. The complexity of the work consisted in that only two participants were initiated into the VEA and TRIZ methods, while a very short period (1 month) was allotted for this work. There was no time to teach TRIZ and VEA methods to the participants. A critical situation occurred – the work had to be fulfilled in a short time and with a good quality by people who did not know the methodology of doing that work.

The difficulty was solved by combining the training of the participants with the analyzing of the stripper header. At each working meeting, a next step of analysis was taught to the team and then the team learned to fulfill that step by analyzing the stripper header. The positive factor was that after getting a package of offers on the improvement of the stripper header, the same team of designers developed the design documentation.

Structural analysis of stripper header

The analysis resulted in the construction of the component and structural models of the stripper header and other components with which it interacts – soil, stalks, heads, combine, combine operator (fig. 4). There were also described the connections between the units, between the units and elements, and formulated the problems and proposals regarding the improvement of their design.

Each connection between the stripper header units was described in the following way:

Interacting components:
Head – Stripper
Useful action:
The stripper teeth detach heads from stalks and the stripper throws them into the collecting chamber.
Undesirable effect:
Part of the heads does not get into the collecting chamber but is carried away to the soil by the return run of the stripper toothed belt.

Task:
It is necessary to eliminate the undesirable effect – the carrying away of heads to the soil by the toothed belt, but to preserve the useful action – the detaching of heads from stalks and transferring them to the collecting chamber.

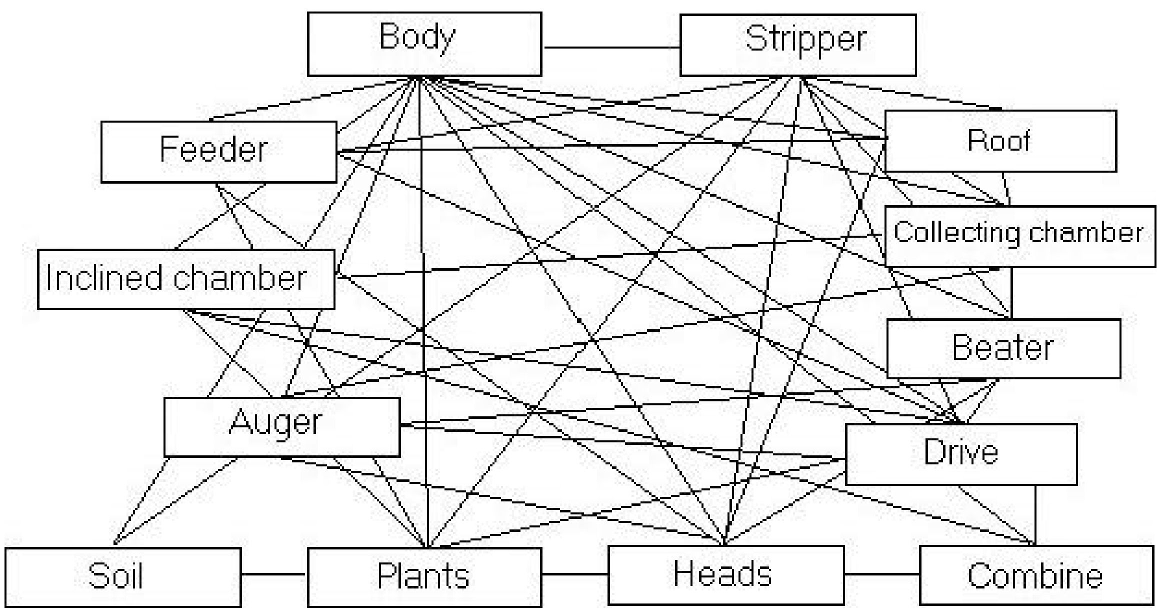

Fig. 4. The structural model of the stripper header.

Analyzing the connections helps formulate and detect many undesirable effects that occurred on the interaction of the stripper header units with each other and with the supersystem components. In the course of the analysis, there were made a lot of proposals that did not require special efforts for being introduced into the design.

Example.

The analysis proved that the great length of the stripper was expedient when there was no feeder in the stripper header design. The use of the feeder changed the character of interaction between stalks and the stripper and the necessity of such a long stripper fell away. However, while designing a subsequent stripper header, this circumstance was omitted. The analysis resulted in the proposal to reduce the belt length. A calculation was made and the interaxle distance between the stripper shafts was reduced by 375 mm. That allowed a considerable reduction in the size and weight of not only the stripper, but also of the stripper header frame.

Functional analysis

Based on the information obtained as a result of the structural analysis, there was formulated the main function of the stripper header and the functions of its main units. The functional analysis made it possible to understand which units of the stripper header perform main functions and which of them perform auxiliary functions. It also allowed formulating the tasks aimed at improving the function performance quality of the stripper header units.

While carrying out the functional analysis, the team faced the following methodological difficulty. As it turned out, almost all the units of the stripper header interact with the article – stalks and heads. In accordance with the VEA+TRIZ method of function ranging, all the elements of the machine engaged in processing the article are the carriers of the main functions [3, 7].

Indeed, all the units of the stripper header except, the drive work with stalks and heads and, from this point of view, they perform the main functions.
And in accordance with the rules of constructing a function and ideality model, first of all it is necessary to try to remove from an engineering system those parts that perform auxiliary functions.
How, in this case, can we get recommendations on convolving the stripper header units?

It was proposed to analyze not only the design of the stripper header itself, but also the stripping process and the operations of this process.
With such a technological approach, each unit of the stripper header was considered as an object performing a certain operation of the technological process of stalk and head processing.

Such an operation-by-operation analysis made it possible to understand which parts of the stripper header perform the main operations and make the main contribution to the performance of the main function of the machine and which of them only facilitate the performance of these functions.

The main operations are aimed at processing the plants in accordance with the preset requirements. The main operation for the plant stripping process is the detachment of heads from stalks.

The auxiliary operations provide performance of the main functions or correct the disadvantages that occur during the main or other auxiliary operations. The main function

is performed by the stripper header toothed belt, that detaches heads from stalks. All the other units of the device perform auxiliary or correcting operations.
So auxiliary operations are the compaction of stalks, feeding the stalks into the stripping zone, transporting the stalks into the collecting chamber, removing the stalks from the stripper teeth.

For instance, the beater performs the function «to remove stalks and heads caught on the stripper teeth». This is a correcting operation, because it eliminates the disadvantages of the auxiliary operation of moving the heads into the collecting chamber.
The disadvantage of the stripper consists in that not all the heads are thrown from the stripper into the collecting chamber because part of them are caught on the teeth and are carried away to the soil. A decision was taken to try to do without the beater – to remove it as an auxiliary part of the construction and to transfer its functions to the remaining parts.

Function and ideality modeling – convolution

So the functional analysis suggested the idea to reject the beater that performs a correcting function. After that, a function and ideality model of the stripper header was constructed in accordance with the object convolution rules. That model contained fewer auxiliary parts, which gave new possibilities of reducing the weight of the stripper header units and simplifying its design (fig. 5).

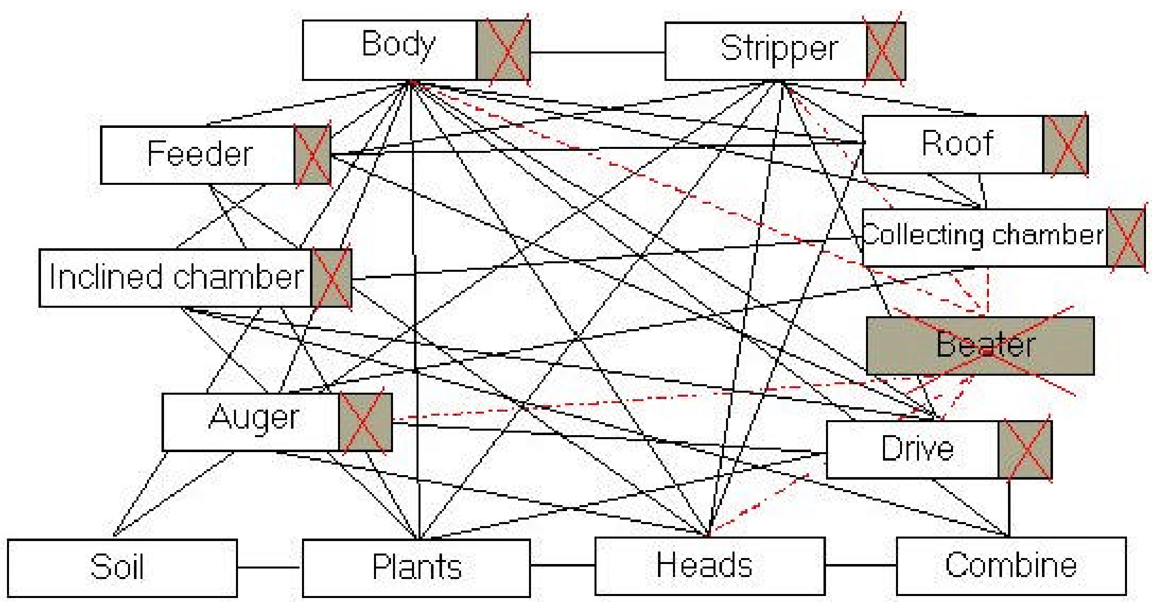

Fig. 5. The function and ideality model of the stripper header.

Then there were formulated inventive problems to be solved in order to realize the function and ideality model. It is necessary to check what changes in the construction the removal of the beater can entail.

In accordance with the convolution rules, the following convolution conditions were formulated for the beater [7]:

The beater performs two functions:

1. it removes heads from the stripper teeth;
2. it prevents the hanging of heads on the edge of the collecting chamber of the body.

Let us consider the convolution conditions for the first function of the beater «to remove heads from the stripper teeth».

The beater that performs the function «to remove heads from the stripper teeth» may be eliminated if:

A) there are no heads;

B) the function «to remove heads from the stripper teeth» will be performed by the stripper itself by using its own resources (material, shape, arrangement, etc.);

C1) the function «to remove heads from the stripper teeth» will be performed by the body;

C2) the function «to remove heads from the stripper teeth» will be performed by the feeder;

C3) the function «to remove heads from the stripper teeth» will be performed by the roof;

C4) the function «to remove heads from the stripper teeth» will be performed by the auger;

C4) the function «to remove heads from the stripper teeth» will be performed by the drive.

Let us choose the alternative C1, because the body element, namely the front edge of the collecting chamber, is in close vicinity to the operational zone, the place where the conflict – «incomplete removal of heads from the stripper teeth» - occurs.

Problem 1.

As a result of convolution of the first function of the beater, there occurs the problem how to change the body, namely the front edge of the collecting chamber, so as to enable it to perform the function «to remove heads from the stripper teeth»?

Let us consider the convolution condition for the second function of the Beater: «to prevent the hanging of heads on the edge of the collecting chamber body».

The beater that performs the function "to prevent the hanging of heads on the edge of the collecting chamber body" may be eliminated if:

A) there are no heads;

B) the function «to prevent the hanging of heads on the edge of the collecting chamber body» is performed by the edge of the collecting chamber body itself by means of its own resources (material, shape, arrangement, etc.);

C1) the function «to prevent the hanging of heads on the edge of the collecting chamber body» is performed by the stripper;

C2) the function «to prevent the hanging of heads on the edge of the collecting chamber body» is performed by the feeder;

C3) the function «to prevent the hanging of heads on the edge of the collecting chamber body» is performed by the roof;

C4) the function «to prevent the hanging of heads on the edge of the collecting chamber body» is performed by the auger;
C5) the function «to prevent the hanging of heads on the edge of the collecting chamber body» is performed by the drive.

We choose the alternative «B» because it is also preferable while performing the first function of the beater.

Problem 2.
As a result of convolution of the second function of the beater, there occurs the problem how to change the element «body» so as to enable it to perform the function «to prevent the hanging of heads on the edge of the collecting chamber body» by itself.

Solving the formulated problems

So as a result of constructing the function and ideality model of the stripper header there were formulated problems 1 and 2 aimed at changing the front edge of the collecting chamber so as to enable it to perform the following beater's functions as well as the beater does it:

1. to remove heads from the stripper teeth;
2. to prevent the hanging of heads on the collecting chamber edge.

To solve these problems, the laws of engineering systems evolution were used, in particular, the law of coordination – discoordination and other TRIZ tools. This problem was solved by placing the front edge of the collecting chamber in close vicinity to the stripper toothed belt and by coordinating its shape with that of the teeth on the toothed belt. It is proposed to make the front edge of the collecting chamber toothed so that the stripping belt teeth pass between the edge teeth. To avoid possible breakdowns, it was proposed to make the edge teeth elastic, flexible and, for better removal of heads from the stripper, to install the teeth at a certain optimal angle (Fig. 6).

To perfect the stripper design, the following proposals were formulated:

? to remove the beater and transfer its functions to the front edge of the collecting chamber;
? to make the upper edge of the trough in the form of flexible elastic teeth with their ends placed between the stripper teeth;
? to remove the beater drive which simplifies the design, reduces the weight of the stripper header drive, eliminates the slope of the stripper towards the drive;
? there was also formulated the image of an ideal stripper header which is a forecast of evolution of this class of machines (it is not given in this article).

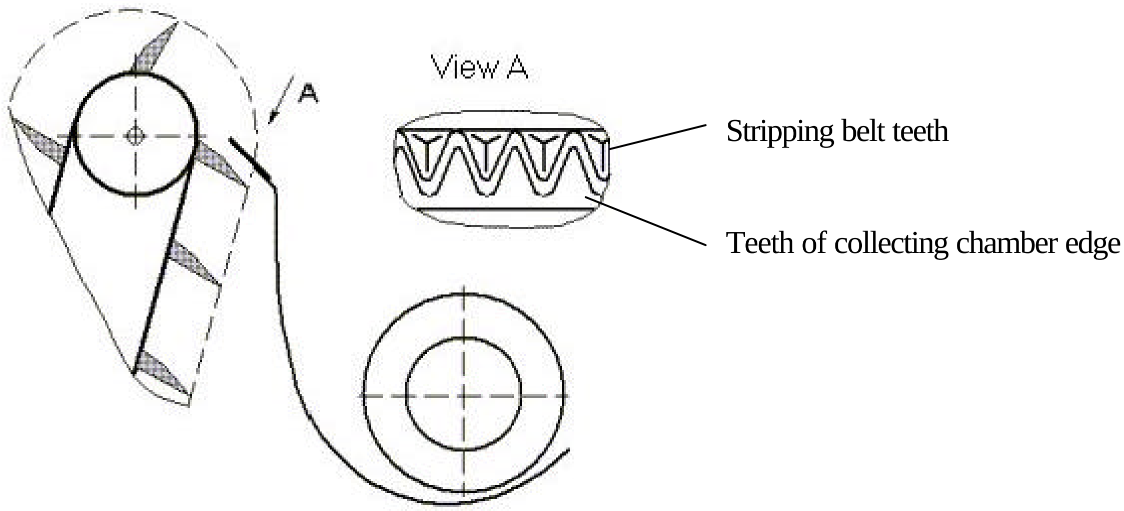

Fig. 6. Proposals for changing the upper edge of the collecting chamber wall.

STRIPPER HEADER MODERNIZATION

Having finished VEA, the team of designers engaged in analyzing and solving the problem developed the high-quality design documentation for the stripper header within the shortest possible time. A stripper header for the combine CK-5 «Niva» was built in accordance with this documentation. As a result, the machine weight reduced by 19% as compared with the previous construction and its size also reduced considerably (Fig. 7).

Fig. 7. The stripper header after VEA-TRIZ.

The research and tests proved that the teeth of the collecting chamber front edge ensure reliable removal of heads caught on the stripper teeth [8]. In operation, the teeth on the collecting chamber edge vibrate due to the action of heads and the air flow. As a result, the teeth self-clear thereby preventing the hanging of stalks and heads on the collecting chamber edge (Fig. 8).

All these changes in the stripping device design reduced the grain loss behind a combine to the required level of 1.5 to 3%. The combine with the stripper header was tested in Belarus and Russia. The tests proved that all the main purposes of VEA have been achieved. One of the versions of the stripper header was included in the production schedule of the Tula Combine Plant (Russia). Unfortunately the decline in economic activity did not allow starting the manufacture of stripper headers.

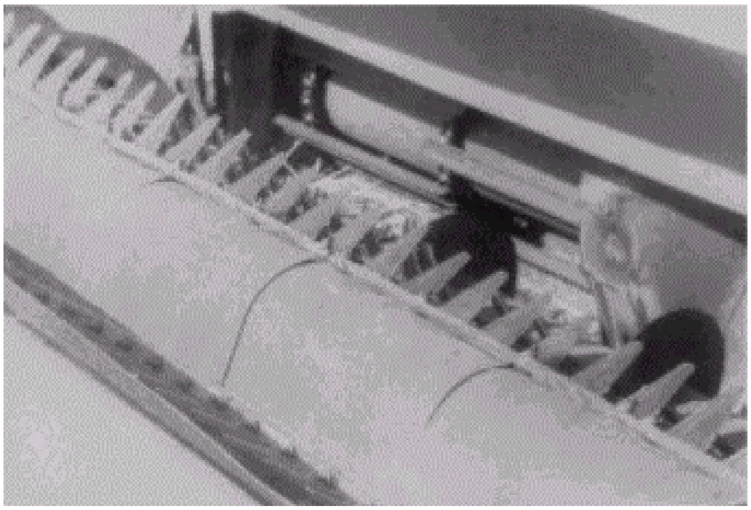

Fig. 8. View of the toothed edge of the collecting chamber.

CONCLUSION

Technical result

The work aimed at the improvement of the stripper header by VEA+TRIZ method reduced the weight of the machine by 19%, reduced considerably its size, and decreased grain loss to the required level of 1.5 to 3%.

Scientific result

In the course of the work, there were discovered several new technological and technical solutions, the image of an ideal stripper was formulated which is a far forecast of evolution of such devices (it is not given in this article). The technical solution pertaining to the convolution of the beater and the use of a toothed remover was later protected by patents of US, Canada and Great Britain [9].

Organizational result

After VEA, the knowledge obtained in the course of the work on the stripping design enabled the group of the designers to develop the high-quality design documentation within the shortest possible time.

Organizational finding

Training a temporary working group in methods of formulating and solving problems in the process of improvement of an object under analysis.

Methodological finding

Applying the rules of analyzing the functions of technological operations to a technical device.Any technical device is designed to realize processes of transformation of substance, energy and information. Therefore, the rules of analysis and improvement principles used for processes may also be used to improve objects. The process analysis methodology supplements the object analysis methodology. They must be used in combination.

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