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IMPROVING THE DESIGN OF A JAW SHUTTER TO INCREASE THE EFFICIENCY OF MATERIAL CRUSHING

The object of research is the design of a jaw crusher for crushing limestone for the production of silicate bricks. The article is devoted to the study of the problem of reducing the efficiency of material crushing in a jaw crusher. The efficiency of crushing materials in jaw crushers ensures the quality of manufacturing bricks, etc. Therefore, this work is aimed at choosing a way to improve the design of the jaw crusher to increase the efficiency of material crushing.

The article defines the classification of jaw crushers, their advantages and disadvantages, describes the principle of operation of the most widely used jaw crushers in the construction industry with simple and complex rocking of the cheek. A literature and patent search and analysis of existing methods of increasing the efficiency of material crushing in jaw crushers was carried out. As a result of the literature and patent search, one of the methods of improving the design of the jaw crusher to increase the efficiency of material crushing based on the use of longitudinal protrusions on the movable jaw was selected and proposed. The protrusions on the flat sections of the working surface of the plate are made with the same pitch of their location within each section with a decrease in the pitch of the protrusions in the direction of distance from the upper part of the plate. The considered design of the movable jaw with longitudinal protrusions in the jaw crusher will ensure reliable pulling of the material into the gap between the movable and stationary jaws, which ensures high contact stresses acting on the crushed material from the side of the working surface of the plate.

Compared to known designs of jaw crushers, the improved design of the movable jaw in the jaw crusher with longitudinal protrusions of different sizes with a decrease in their size in the direction from the upper part of the plate on three sections of the working surface of the plate will contribute to ensuring high contact stresses acting on the crushed material from the side of the working surface cheeks, during its advancement between the moving and stationary cheeks and increases the efficiency of destruction of various materials.

Compared to known designs of jaw crushers, the improved design of the jaw crusher has a movable jaw with longitudinal protrusions of various sizes. At the same time, these protrusions are located on three sections of the working surface of the plate with a decrease in their size in the direction from the upper part of the plate. This will help ensure high contact stresses acting on the crushed material from the side of the working surface of the cheek, during its advancement between the moving and stationary cheeks. Also, this design of the working jaw of the jaw crusher with longitudinal protrusions helps to increase the efficiency of destruction of various materials.

Keywords: *jaw crusher, moving jaw, fixed jaw, longitudinal protrusions, material crushing efficiency, contact stresses.*

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1. Introduction

Industrial crushers and shredders are essential tools in the processing of various materials in many industries. They provide efficient grinding of materials, which allows for improved waste production and disposal processes. Jaw crushers are one of the most common types of crushing equipment used in a variety of production lines [1].

A jaw crusher is a machine for mechanical destruction (disintegration) of pieces of solid material by crushing between two flat surfaces in order to bring their size to the required size. They are usually used in the mining industry for coarse (1500–350 mm) and medium (350–100 mm) crushing of strong and viscous rocks (ores of ferrous and non-ferrous metals), non-metallic and other minerals, shale, coal) [2].

The relevance of this study lies in the fact that the jaw crusher is one of the important elements of equipment in technological lines. Depending on the type of finished product, the jaw crusher provides crushing of the starting material at different stages of the technological process. The jaw crusher is often used in the chemical, mining and building materials industries to crush stones, ores and other hard materials.

The peculiarity of the jaw crusher is that it has movable and fixed jaws, the configuration and size of which determine the efficiency of crushing the material. The jaw crusher is the simplest and most used in real conditions of chemical,

polymer and other modern industries. In this paper, it is proposed to consider one of the ways to improve the design of a jaw crusher in order to increase the efficiency of crushing materials.

The solution to the problem of reducing the efficiency of grinding material in jaw crushers is considered by scientists for various industries, including chemical engineering. The efficiency of crushing material in jaw crushers depends on many factors, which ensures the quality of the resulting product and it is possible to deal with them in more detail.

The issues of improving the design of the jaw crusher are considered by researchers in educational, patent, scientific literature in several aspects:

– technological description of the features of the grinding process in jaw crushers [3, 4];
– analysis of the process of material destruction in jaw crushers [3, 4];
– achieving an increase in the efficiency of material grinding in a jaw crusher [4–7];
– increasing the productivity of the jaw crusher [6, 8];
– structural and technological measures with specific operating conditions, taking into account the peculiarities of power and temperature load, corrosion effect, kinematics of wear at high contact loads of jaw crusher plates [9];
– improvement of technical and operational characteristics of the jaw crusher (moving jaw stroke, grip angle, eccentric shaft rotation speed, etc.) [10];
– analysis of the existing shapes of the working surface of the jaw crusher cheeks (flat, convex, corrugated, with protrusions) [4–7, 11];
– ways to strengthen the structure and increase the reliability of the jaw crusher [4, 8];
– causes of deformation and methods of strengthening lining plates [4, 9].

The source [3] analyzes the process of material destruction in jaw crushers. As the authors of the work note, the imperfect study of the process of material destruction in the jaw crusher grinding chamber, a large number of theories of material destruction, empirical dependencies that have no theoretical basis prompted them to analyze the fracture process in jaw crushers. The authors recommend identifying new effective ways to intensify grinding processes and their regulation depending on technological requirements, as well as successfully combining several effects of material destruction in jaw crushers, which will be of great practical importance.

In the source [4], the author notes that in the chamber of the jaw crusher, the lining is made of manganese steel, which hardens on the surface due to deformation caused by the interaction of the material with the lining. The main features of the protrusions on the lining of the cheeks are the number and profile of vertical corrugations, performed on both movable and fixed cheeks. In some cases, protrusion designs with a curved convex surface are used, mainly on the movable cheek. This curved lining profile is commonly used to limit the compaction that occurs in the crushing chamber of the jaw crusher, especially when the raw material has a large number of fine particles and contributes to the crushing efficiency.

The authors of the source [5] analyzed the existing forms of the working surface of the jaw crusher. The most common in jaw crushers are lining plates with a flat shape of the working surface. As the authors note, for the initial product of larger size, it is advisable to use the stepped shape of the lining surface of the cheek. This shock design allows to divide the crushing chamber into separate zones. In each of these zones, the piece is crushed to a size that does not exceed the width of the gap at the bottom of the corresponding zone. The results of the authors' study show that the crushing efficiency of a jaw crusher can be improved by using a combined shape of the lining surface. Namely, when the upper part is made in the form of spikes, this will contribute to the splitting of the original material. And when the lower part of the cheek is flat, this will provide additional grinding of the material to fine-grained fractions.

The source [6] suggests the execution of a movable cheek with protrusions of different sizes and pitches in three sections with a decrease in their size in the direction from top to bottom of the plate. This design of the movable jaw in the jaw crusher provides high contact stresses acting on the material to be crushed from the side of the working surface of the jaw. In this way, there is a more efficient movement of the grinding material between the moving and stationary cheeks. This, in turn, significantly increases the efficiency of crushing and the productivity of the resulting material.

In [7], jaw crushers for specific rock types must take into account the variability of point load strength and deformation capacity inherent in any rock. As the rock particles fall between the stationary and moving plates, they are crushed, hence the design of the plates must be improved in this area. Therefore, it must be taken into account that this surface of hardened steel plates can be flat or corrugated, which is more effective for crushing the material.

In the paper [8], the analysis of jaw crusher designs was carried out and the methods of strengthening the structure of the working plate by increasing the stiffeners based on modeling in the CATIA program were considered. Also, the author of the work certifies that convex cheeks are better in configuration than flat ones, which reduces their frequency of closure, as well as increases the efficiency of crushing and increases the productivity of the crushed material.

In the source [9], the authors consider structural and technological measures with specific operating conditions, namely, taking into account the peculiarities of power and temperature load, corrosion effect, kinematics of wear at high contact loads of jaw crusher plates. It is proposed to perform various protective coatings or surfacing on the plates of jaw crushers when crushing clay and wet ores.

The authors of the paper [10] propose to improve the technical and operational characteristics of the jaw crusher. One of the most important parameters of the jaw crusher is the stroke of the moving jaw, on which the intensity of grinding depends. For optimal cheek travel, it is necessary to choose the most favorable rotation speed of the eccentric shaft.

In the source [11], the surfaces of the jaw crusher are proposed in the form of broken lines and the lower and upper plates are attached to each jaw, which forms a material grinding chamber from two compartments. The first compartment is between the upper plates, and the second is between the lower plates. At the same time, the working surfaces of the upper plates have longitudinal wedge-shaped teeth. And the working surfaces of the lower plates are made with transverse corrugation in the form of teeth with rounded surfaces. Also, the upper and lower plates are made equal in size, which ensures the opposite orientation of the tops of the teeth of the working surfaces of the upper and lower plates. This design of the cheeks provides increased contact stresses acting on the material to be crushed from the side of the longitudinal protrusions of the flat working surface.

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However, the invariability of the geometry and pitch of the protrusions on the working surface of the cheek reduces the efficiency of crushing the material as it moves between the moving and stationary cheeks.

As the analysis of literature and patent sources [3–11] shows, most scientists offer various ways to improve the design of the jaw crusher to increase the efficient crushing of the material. It is on the basis of this analysis of the problem of low crushing efficiency in jaw crushers that it is possible to conclude that this issue has not been fully resolved by scientists and in various aspects. That is why this problem cannot be considered completely solved and confirms the relevance of the study carried out in the work.

The aim of research is to choose a way to improve the design of the jaw crusher in order to increase the efficiency of crushing the material. This will allow for better grinding of the material in the jaw crusher.

Achieving this aim requires solving the following objectives:

– to determine the types and features of jaw crusher designs, their advantages and disadvantages;
– to conduct a literature and patent search for ways to improve the design of the jaw crusher in order to increase the efficiency of material crushing;
– to select, describe and justify the method of improving the design of the jaw crusher to increase the efficiency of crushing the material.

2. Materials and Methods

The object of research is the design of a jaw crusher for crushing limestone for the manufacture of silicate bricks. *The subject of research* is the method of improving the design of the jaw crusher in order to increase the efficiency of grinding the material.

A jaw crusher is a crusher in which material is crushed by squeezing it between the cheeks. Jaw crushers belong to coarse crushing machines [12]. Jaw crushers work on the principle of crushing and partially bending between two jaws, of which one is stationary and the other is movable.

Jaw crushers are distinguished by the following characteristics:

– according to the kinematic scheme of the drive mechanism: with a simple movement of the movable jaw, with a complex movement of the movable jaw;
– by the method of attaching the movable cheek: with its upper and lower suspension;
– by technological purpose: coarse and medium crushing [2].

In a jaw crusher with a simple jaw movement, the moving jaw moves along a straight trajectory or along the arcs of a circle that are close to straight lines (Fig. 1, *a*), in a jaw crusher with a complex jaw movement, the movable jaw moves along the trajectory of closed curves (Fig. 1, *b*) [12].

A fixed jaw 2 with a wear-resistant armor plate 3 is attached to the body 1 of the crusher with a simple jaw movement, which is schematically represented in Fig. 1, *a*. The armor plate 4 is attached to a movable jaw 5 which oscillates on an axis 6 to suspend the movable jaw. The crushing chamber 7 is limited to smooth armor plates. A connecting rod 8 is fixed on the eccentric shaft 9, with the help of which the movable cheek oscillates. The connecting rod and movable cheek are articulated by means of a front spacer plate 10. The connecting rod and the rear spacer plate 11 of the crusher are connected to each other. Also, the spacer plate 11 is connected to one of the wedges 12, which regulate the width of the discharge hole 18 of the crushing chamber. The departure of the movable jaw from the stationary jaw during unloading of the crushing chamber from the next portion of crushed material is regulated by a rod 13 with a spring 14. The flywheel 15 is mounted on an eccentric shaft which stores energy as the moving jaw moves away and facilitates the crushing process as it approaches the stationary jaw. Also, with the help of a flywheel, the uniformity of rotation of the eccentric shaft is ensured, which helps to reduce the negative impact of vibration during the operation of the crusher [12].

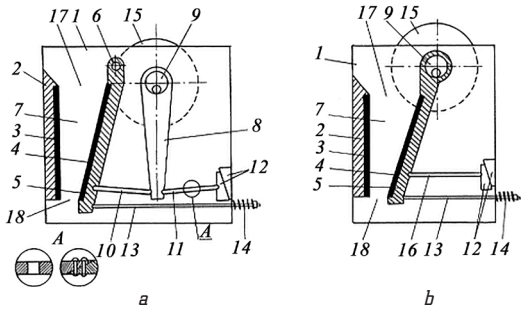

Fig. 1. Execution of jaw crushers: *a* – with a simple jaw movement; *b* – with a complex movement of the cheek: 1 – body; 2 – fixed jaw; 3, 4 – armor plates; 5 – movable jaw; 6 – suspension axis of the movable jaw; 7 – crushing chamber; 8 – connecting rod; 9 – eccentric shaft; 10 – front spacer plate; 11 – rear spacer plate; 12 – adjusting wedges; 13 – rod; 14 – spring; 15 – flywheel; 16 – spacer plate; 17 – loading hole (mouth, pharynx); 18 – discharge hole

The starting material for grinding is loaded into the crushing chamber from above. Under the influence of gravity, the crushed material is gradually lowered into the discharge hole. To prevent the destruction of critical elements of the crusher, the rear spacer plate is made loosened due to through holes or made of two parts, cut at an angle and connected with rivets (Fig. 1). If too strong material gets into the crushing chamber, then this spacer plate is destroyed, after which it is restored or replaced with a new one.

The advantages of jaw crushers are: simplicity and reliability of design, relative ease of maintenance. The disadvantages of jaw crushers are: discreteness of action on the crushed material (only during the convergence of the jaws), and therefore the imbalance of the moving parts, which leads to vibration, shocks and concussion.

The advantages of crushers with simple jaw movement compared to crushers with complex jaw movement are: higher crushing forces, easier removal of crushed material from the crushing chamber of the jaw crusher. And the disadvantages of crushers with a simple jaw movement are:

– the presence of two spacer plates;
– larger dimensions, uneven dimensions of the finished product;
– crushing the material only due to crushing, in contrast to a crusher with a complex jaw movement, where grinding takes place and due to abrasion.

The disadvantage of a crusher with a complex jaw movement is increased dust formation [12].

Jaw crushers with complex jaw movement are used for medium and fine crushing of hard and viscous rocks. They are characterized by higher performance and lower power consumption than simple-motion crushers. But the

design disadvantage of crushers with complex jaw movement is that the forces are almost entirely transmitted to the eccentric shaft, which makes it difficult to create large crushers. Also, the specific trajectory of the cheek leads to increased wear of the lining due to abrasion [13].

Based on the above, it can be noted that the movable jaw is one of the most important nodes in the jaw crusher. Therefore, there is a need to pay attention to ways to improve the movable jaw crusher to ensure an increase in the efficiency of crushing the material. On the topic of the study, a literary-patent search for a way to improve the design of a jaw crusher in order to increase the efficiency of crushing material and an analysis of the existing methods for improving the design of a jaw crusher considered in the work were used.

3. Results and Discussions

To choose a method for improving the design of the jaw crusher, it is possible to take into account the features of the considered possible design technical solutions for improving the crusher in order to increase the efficiency of crushing the material. The movable jaw crusher is known, which is made in the form of a plate with a hole in the upper part for its suspension on an eccentric shaft with a flat working surface (Fig. 1, *a*) [12]. The disadvantages of this jaw crusher design are: low contact stresses acting on the material to be crushed from the side of the flat working surface of the jaw; a flat work surface that requires a small grip angle, which reduces the productivity of the crusher.

As a result of the literature and patent search [3–13] of the design features and operation principle of jaw crushers as a very common type of crushers in the production of various industries, the choice of the most expedient in our opinion jaw crusher design was made to increase the efficiency of crushing the material. In order to increase the contact stresses on the surface of the movable jaw crusher, a prototype of the design of a movable jaw with longitudinal protrusions in three sections with a decrease in the pitch of protrusions from top to bottom of the movable jaw crusher was chosen, which ensures reliable retraction of the material between the movable and fixed jaw crusher cheeks [6]. Fig. 2, and a longitudinal section A–A of the improved design of the movable jaw crusher with the proposed longitudinal protrusions is presented. The movable cheek 1 has a hole at the top for its suspension on an eccentric shaft (not shown). The side view (Fig. 2, *b*) shows a movable cheek with longitudinal protrusions in three areas with different pitches and sizes.

The advanced movable jaw crusher consists of: movable jaw 1, axis 2, longitudinal protrusions 3, plate section 4 with the largest protrusions, plate section 5 with medium-sized protrusions, plate section 6 with the smallest protrusions (Fig. 2).

Let's take a look at how a jaw crusher with an advanced movable jaw works. The movable jaw is made with longitudinal protrusions with the same pitch of their location within each of the three flat areas on the working plate. At the same time, the step of the protrusions in each section decreases in the direction of distance from the top of the plate. The material to be crushed enters the gap between the movable and stationary jaws from the top of the movable jaw plate. The largest pieces of material are broken into smaller pieces as a result of the action of longitudinal protrusions 3 on them and then gradually move from section 4 to section 5. At site 5, smaller pieces of pre-crushed material at site 4 are exposed to the corresponding protrusions 3, arranged with a certain pitch smaller than in area 4. At site 6, the destruction of even more crushed material occurs in the same way [6].

The aim specified in this work is achieved by the fact that the improved design of the jaw crusher contains longitudinal protrusions with different sizes on each of the three sections of the working surface of the movable jaw on the movable jaw.

In the existing designs of the jaw crusher, the movable and fixed cheeks can be completely flat, with protrusions in the form of spikes in a certain part of the cheek or with grooves throughout the cheek, etc. In contrast to the existing jaw crusher designs, the advanced design based on the prototype [6] has longitudinal protrusions of different sizes and pitches on the movable jaw in three sections in shape, which decrease in the direction from the top of the plate. This ensures that the material is crushed from the area with the largest protrusions to the area with the smallest protrusions and contributes to more efficient crushing of the material by increasing the contact stresses on the grinding material between the moving and stationary cheeks.

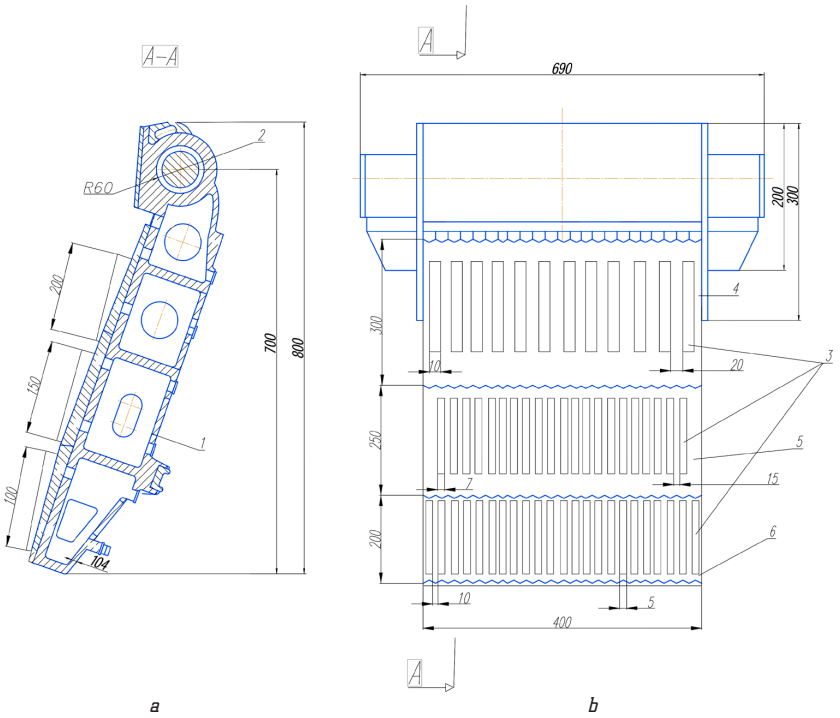

Fig. 2. Advanced design of the movable jaw crusher with longitudinal protrusions: *a* – frontal view of the advanced movable jaw; *b* – longitudinal incision of the cheek; 1 – movable jaw; 2 – axle; 3 – longitudinal protrusions; 4 – plate (section 1); 5 – plate (section 2); 6 – plate (section 3)

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Practical value. In the course of the study, on the basis of the prototype [6], a constructive technical solution was made for an improved movable jaw crusher with longitudinal protrusions in Fig. 2, which can be implemented for the manufacture of such a jaw crusher design, for example, for the introduction of silicate bricks for limestone crushing in production.

Limitations of the study. This study has only the provided design technical solution based on the prototype of the advanced jaw crusher in Fig. 2, and does not quantify how much the size of the fractions of the crushed material will be reduced due to longitudinal protrusions. Also, on the way to solving the problem of our study Improving the crushing efficiency of the material is not the only way to improve the crushing efficiency of the material in the jaw crusher, but it is a very interesting way and has a right to exist. The proposed design of the movable jaw with longitudinal protrusions provides high contact stresses from the working surface of the cheek, acting on the material to be crushed between the movable and stationary cheeks during its advancement due to a decrease in the size of the material particles. This helps to ensure that the material is reliably drawn into the gap between the moving and stationary jaws and to increase the breaking efficiency of a wide variety of materials in the jaw crusher.

Impact of martial law conditions. The method proposed in this paper to increase the efficiency of crushing material in a jaw crusher in the form of a constructive technical solution for a jaw crusher with a movable jaw with longitudinal protrusions has limitations with its introduction into production in difficult wartime conditions in Ukraine.

Prospects for further research. In further research, it is planned to analyze the directions of improvement of the jaw crusher in the wear of the lining of armored plates that interact directly with the grinding material. It is the lining of the jaw crusher that is most subject to constant wear when crushing the material to be crushed.

4. Conclusions

It has been established that the jaw crusher is an important element of equipment among machines in the technological process for the manufacture of various types of materials, which provides crushing of materials to large (1500–350 mm) and medium (350–100 mm) size for strong and viscous rocks. Jaw crushers work on the principle of crushing between two jaws, of which one is stationary and the other is movable. The advantages of the jaw crusher are: simplicity and reliability of design, relative ease of maintenance. The disadvantages of jaw crushers include: discreteness of action on the crushed material – only during the convergence of the jaws, as a result, imbalance of moving parts, which leads to vibration and concussion.

Having analyzed the existing ways to improve the design of the jaw crusher in order to increase the efficiency of crushing the material, it was found that scientists do not have a single approach to achieve this goal. The solution to this problem is considered by researchers in the following aspects:

– analysis of the process of material destruction in jaw crushers;
– achieving an increase in the efficiency of grinding material in the jaw crusher along with this and increasing the productivity of the jaw crusher;
– structural and technological measures with specific operating conditions, taking into account the peculiarities of power and temperature load, corrosion effect, kinematics of wear at high contact loads of jaw crusher plates;
– improvement of technical and operational characteristics of the jaw crusher (moving jaw stroke, grip angle, eccentric shaft rotation speed, etc.);
– analysis of the existing shapes of the working surface of the jaw crusher cheeks (flat, convex, corrugated, with protrusions);
– ways to strengthen the structure and increase the reliability of the jaw crusher; causes of deformation and ways to strengthen lining plates.

Of the listed existing ways to improve the efficiency of crushing material in a jaw crusher, the work mainly pays attention to the method of changing the shape of the working surface of the movable jaw crusher. Namely, the execution of a movable cheek from three sections, each of which has longitudinal protrusions to reduce their size and the step of the protrusions in the direction of distance from the top of the plate. This will ensure higher contact stresses acting on the material to be shredded from the flat work surface and cheek as it moves between the moving and stationary jaws and will lead to an increase in the efficiency of the material grinding.

Among the considered directions in the study of the problem of increasing the efficiency of grinding material in a jaw crusher, the author has chosen as the most expedient and effective, in our opinion, way to improve the design of a jaw crusher based on a prototype [6]. The proposed design contains a movable cheek with longitudinal protrusions in its three sections with a decrease in the size and pitch of these protrusions in the direction of distance from the upper part of the plate. This design of the jaw crusher will increase the efficiency of crushing the material due to the high contact stresses acting on the material to be crushed from the working surface of the cheek during its movement between the moving and stationary jaws. It can also be noted that the proposed improved design of the jaw crusher with longitudinal protrusions on the movable jaw is easy to manufacture and operate.

Conflict of interest

The authors declare that they have no conflict of interest concerning this research, whether financial, personal, authorship or otherwise, that could affect the study and its results presented in this paper.

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Data availability

The paper has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating this work.

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