UKRAINIAN JOURNAL OF MECHANICAL ENGINEERING AND MATERIALS SCIENCE

Vol. 10, No. 4, 2024

Sviatoslav Fyk[1], Vadym Stupnytskyy[2]

[1] Department of Robotics and Integrated Mechanical Engineering Technologies, Lviv Polytechnic National University, 12, S. Bandery str., Lviv, Ukraine, E-mail: sviatoslav.v.fyk@lpnu.ua, ORCID 0009-0002-7872-1062

[2] Department of Robotics and Integrated Mechanical Engineering Technologies, Lviv Polytechnic National University, 12, S. Bandery str., Lviv, Ukraine, E-mail: vadym.v.stupnytskyi@lpnu.ua, ORCID 0000-0002-0921-3980

ANALYSIS OF DESIGN AND TECHNOLOGY FEATURES OF INDUSTRIAL SHREDDERS

Received: October 22, 2024 / Accepted: November 6, 2024

https://doi.org/

Abstract. The article is devoted to an overview of shredder designs for the processing industry and domestic and industrial waste utilization. The shredder designs of leading European companies are presented. Their design and technological advantages and disadvantages are analyzed. Recommendations for improving the design of knives for shredding various types of waste – from construction to household waste – are added. The advantages of modern shredder designs manufactured by the Kivshservice company (Ukraine) are shown.

Keywords: shredder, industrial waste, waste utilization, shredding knives, shredder design.

Introduction

Shredding equipment is an indispensable part of modern industry, especially in the recycling, waste management, woodworking, and metal recycling sectors. The amount of waste in the world is growing every year and with it, the need for high-performance equipment that can effectively reduce the size of materials for further processing or disposal. In such a situation, primary shredders that can handle bulky and heterogeneous materials come to the fore. Due to their special characteristics, twin-shaft shredders have carved out an important niche in this market.

The purpose of this article is to review the largest shredding equipment manufacturers, focusing on twin-shaft shredders. The article will analyze their design features, compare approaches to the manufacture of shredding shafts, and consider key innovations that affect the efficiency of the equipment. The article will also draw attention to the challenges faced by manufacturers and the solutions they implement to improve the performance of their equipment. The main focus will be on shredder shafts, as they are one of the most important elements of a shredder that determine its efficiency, reliability, and durability. We will also look at how different manufacturers are trying to solve the problems of wear, performance, and maintenance, which are important factors in this area [1].

The shredding industry has evolved in response to the growing need to efficiently process materials of various origins and structures. Today, shredders play a key role in many industrial sectors, including waste recycling, wood processing, metal recycling, plastic processing, biofuel production, and construction raw materials.

In the waste recycling sector, shredders are used to reduce the size of various materials, from plastics and rubber to construction waste and household waste. This facilitates transportation and further processing and allows for the extraction and separation of useful components for reuse.

In wood processing, chipping equipment processes large trunks, branches, and wood residues into wood chips or fuel pellets. This allows for more efficient use of natural resources by reducing waste and producing products that can be used as fuel or raw materials for wood-based panels.

Metal recycling also depends on powerful shredding equipment to handle metal waste, including car bodies, aluminum products, and other large structures. These materials require significant effort to shred due to their strength, but once processed, they can be easily melted down and used in new products [2].

Modern shredding equipment, such as multi-shaft shredders, is an important tool that helps ensure the efficiency of these processes. Their ability to handle bulky, heavy, and heterogeneous materials makes them indispensable in a wide range of applications, helping to reduce waste, increase resource efficiency, and support environmental sustainability.

Peculiarities of the Development of the Production Waste Shredding Industry

The need to grind materials arose in the early stages of human civilization. Even in ancient times, there were primitive devices for grinding agricultural products and minerals. Over time, there was a growing need for more efficient methods of grinding various materials associated with increased production, construction, and waste generation. The real development of shredding technology began with the Industrial Revolution when it became necessary to process raw materials and industrial waste on a large scale.

The first mechanical shredders were relatively simple machines that used impact or pressure to reduce the size of materials. However, these machines had many limitations, including low efficiency and limited ability to handle different densities and stiffness materials. Gradually, engineers improved shredder designs by adding new cutting elements and improving drive mechanisms.

With the development of technology in the 20th century, the first twin-shaft shredders were introduced, which became a real breakthrough in the industry. Unlike single or multi-screw systems, twin-shaft shredders offered higher productivity and versatility in handling large and complex materials. They utilize two parallel shafts with cutting segments that rotate in opposite directions, ensuring efficient gripping and shredding of even very bulky and heavy objects.

The advantages of twin-shaft shredders include their ability to handle heterogeneous materials, reliability, ability to operate under high loads, and relatively easy maintenance. Thanks to these advantages, they have quickly become popular in both waste recycling and other industries.

Manufacturers have faced numerous challenges in the historical development of twin-shaft shredders. One of the main ones was to ensure the durability and wear resistance of the shredding elements, which had to operate in high-friction conditions and under heavy loads. The solution to this problem was found by introducing new materials, such as high-strength steels and special alloys, as well as improving heat treatment and production processes for cutting elements. Another challenge was improving the equipment's energy efficiency and productivity – significant progress has been made by improving drive systems, optimizing the shape of cutting segments, and using electronic control systems [3].

Thus, the development of shredding technology, especially twin-shaft shredders, has addressed the issues of efficiency, versatility, and reliability. The use of new materials, the development of innovative designs, and the improvement of technical solutions have allowed shredding equipment to become an important tool in the fight against industrial waste and efficient use of resources.

Overview of the Current Market of Shredding Equipment Manufacturers

The modern market for shredding equipment is represented by some large and well-known companies that specialize in developing and producing shredders for various applications. Companies such as Arjes, Hammel, Lindner, and Pronar are particularly noteworthy among the market's largest players. Each manufacturer has its own development history, innovative solutions, and a special approach to creating primary shredders [4].

Arjes was founded in Germany and has become one of the leading shredding equipment manufacturers, specializing in mobile twin-shaft shredders. Their equipment is characterized by its compact size and high maneuverability, which allows it to be used in tight spaces, such as construction

sites or construction waste processing facilities. One of the key features of Arjes shredders is their versatility – the ability to work with wood, metal products, plastics, and construction waste.

The innovative approach of the company Arjes to the creation of shredding shafts includes the use of modular designs, which allows for easy replacement or updating of individual parts of the shafts, ensuring effective adaptation to different types of materials. This solution helps to reduce maintenance time and increase overall machine productivity. In addition, Arjes is actively introducing new materials with high wear resistance for cutting elements, which allows for longer shaft life.

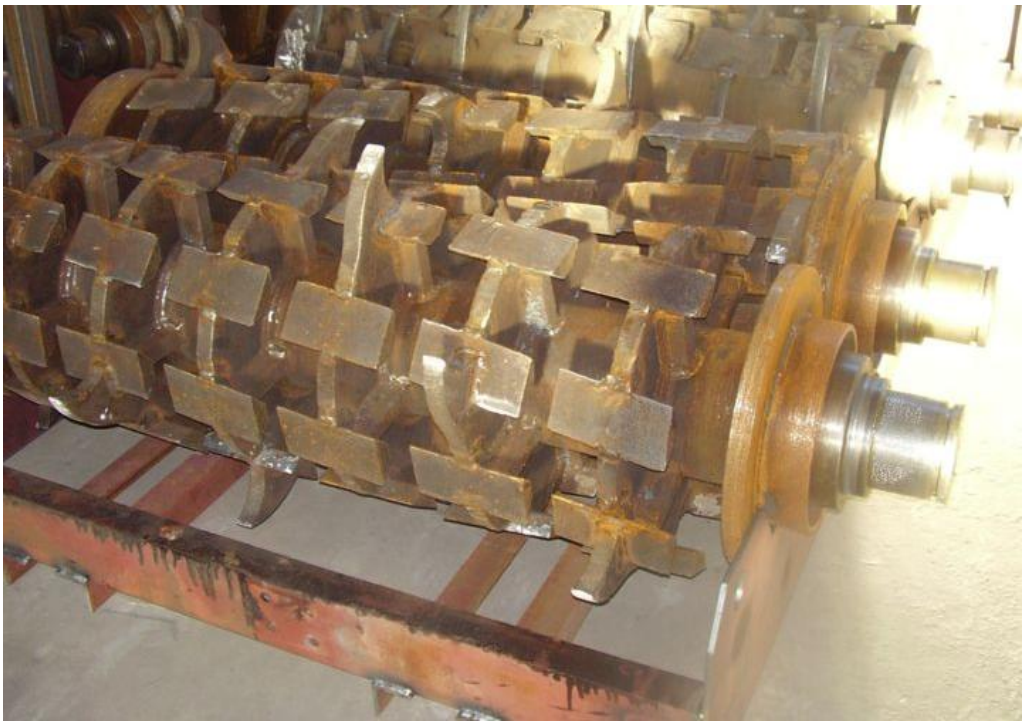


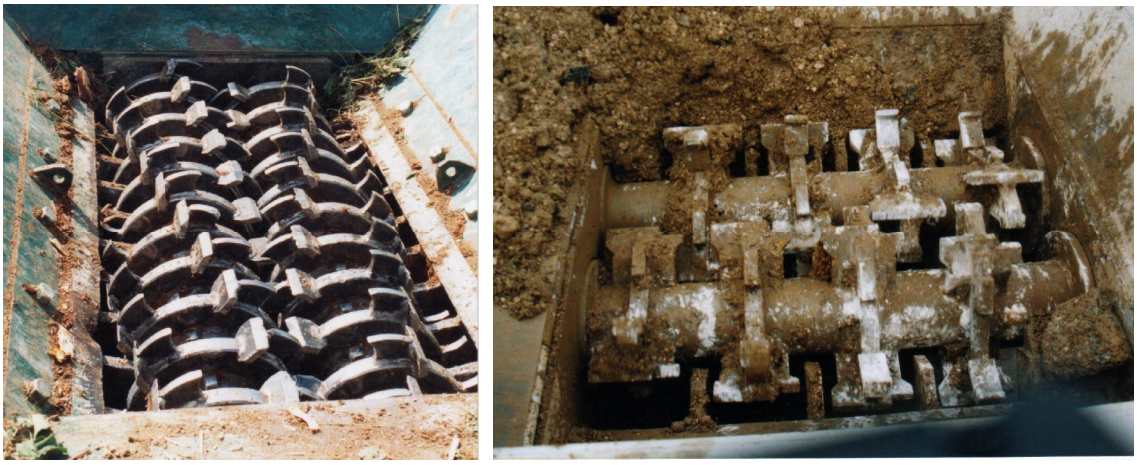
Fig. 1. Design of a 2-roll shredder by Arjes (Germany) designed for wood waste processing

Hammel also originates from Germany and is one of the world's most well-known shredding equipment manufacturers. It specializes in heavy industrial shredders capable of handling bulky materials such as car bodies, wooden beams, metal structures, and other bulky waste. Hammel's twin-shaft shredders are characterized by their power and reliability, which allows them to handle even the most difficult materials.

Hammel Co. also stands out for its shredder shaft optimization technologies. They use shaft designs with cutting segments that can be changed depending on the material being processed. Thanks to the specially designed shape of the segments, shredding becomes more efficient as material jamming is minimized, which improves machine performance and reduces energy consumption.

The Austrian-based company Lindner has a special place in the market thanks to its emphasis on environmentally friendly waste processing and the development of innovative recycling solutions. Lindner's twin-shaft shredders are used to process plastic, textile, organic, and mixed waste. Their machines are characterized by high efficiency and precision shredding, ensuring optimal material preparation for further use.

Lindner's engineers have developed their own technology for manufacturing shafts, including a comprehensive approach to heat treatment and surface treatment, which ensures a longer service life and higher resistance to abrasive wear. Another important aspect is the use of intelligent control and automatic adjustment systems that optimize the grinding parameters depending on the type of material and operating conditions.



a *b*

c

Fig. 2. The design of a shredder for processing biowaste (a), wood (b), and railway sleepers (c) by Hammel (Germany)

Fig. 3. A shredder made by company Lindner (Austria) for recycling household waste

Poland-based company Pronar is a well-known waste recycling machinery and agricultural equipment manufacturer. Their twin-blade shredders are characterized by a relatively simple design and high reliability, making them affordable and efficient for various materials. Pronar shredders are often used to process wood, organic waste, and plastics, ensuring stable operation even under high loads.

Pronar applies a special approach to the manufacture of shredder shafts, in particular, using a combination of welding and casting to achieve maximum strength and reliability of the cutting elements. This technology helps to reduce production costs while maintaining high product quality.

Typical Design and Operation of Primary Twin-Shaft Shredders

Primary double-shaft shredders are equipment designed for coarse shredding of various materials such as wood, metal, plastic, rubber, construction waste, and other bulky waste. These machines mainly aim to reduce bulky materials' size to a level suitable for further processing, transportation, or recycling [5].

Double-shaft shredders use two parallel shafts with cutting elements rotating in opposite directions. This arrangement allows a large volume of material to be captured and shredded. Each shaft is equipped with special knives or teeth that interact with each other to ensure high productivity and process efficiency.

The principle of operation of a twin-shaft shredder is based on several basic mechanisms:

1. Material capture. As the shafts rotate, the teeth of the cutting segments grab large material, pulling it between the shafts. This is due to the pressure and force created by the opposing rotating cutting elements.
2. Shredding: Once gripped, the material is subjected to multiple cutting forces. Due to the fact that the knives are positioned on both shafts, the material is shredded from several sides simultaneously. This allows the material to be reduced to the required size, even in the case of very dense or large objects.

a *b*

Fig. 4. Designs of 2-shaft shredders by the Pronar company (Poland), designed for processing wood and construction waste

3. Pressing and breaking: In addition to pure cutting, double-blade shredders also utilize the principles of breaking and squeezing the material. During the shredding process, the material can fall into “dead zones” where it is squeezed between the shafts. This provides additional deformation and destruction of the material’s structure, which is particularly effective for metallic and tough materials.
4. Reverse and jam protection: One of the important features of twin-shaft shredders is the ability to reverse the direction of rotation of the shafts. This is necessary to prevent material from getting stuck, which can lead to a shutdown or damage to the equipment. Reverse mode allows you to free the material and continue the process without long downtime.

One of the key advantages of twin-shaft shredders is their versatility. Two shafts with cutting segments allow them to handle a variety of materials, including bulky and heavy objects. They can provide shredding even in cases where single-screw shredders fail due to insufficient power or design limitations.

Another important advantage is the stability of operation and relatively low sensitivity to material heterogeneity. Double-shaft shredders can efficiently process materials with a mixed structure without losing performance. As a result, they are often used in situations where materials have unpredictable shapes or include different types of impurities, such as in recycling construction waste or old cars.

The reliability of twin-shaft shredders is also an important operational characteristic. The twin-shaft system reduces the load on each cutting segment, reducing wear and tear and extending the components’ service life. Additionally, using strong steels and special alloys for the cutting elements ensures high wear resistance even under intensive operation.

The successful combination of power, efficiency, and reliability makes twin-shaft shredders an indispensable tool in many industries that require efficient processing of various waste and raw materials.

Shredding Shafts: Design Features and Manufacturing Technologies

Shredding shafts are one of the most important elements of twin-shaft shredders. They determine the shredding process’s efficiency, affecting the equipment’s productivity and durability [6]. The production of shafts involves the use of special materials and sophisticated technologies to ensure maximum strength and wear resistance. The focus is on optimizing the design to increase equipment efficiency and reduce production costs.

Modern manufacturers like Arjes, Hammel, Lindner, and Pronar use a fully welded structure at the heart of their shafts. Shafts are made of various rolled materials, which are selected depending on their function. The bearing elements are made of S355 structural steel, ensuring their strength and resistance to loads. The cutting elements that come into direct contact with the material to be crushed are made of special wear-resistant steels, such as HARDOX 400/450/500, Creusabro 4800/8000, and others. These steels have a high level of resistance to abrasive wear, which ensures a long service life of the cutting elements even when working with aggressive materials.

The main differences between rollers from different manufacturers are the shape, configuration and number of cutting elements. Each manufacturer has developed its own shape and arrangement of the cutting teeth to ensure optimal shredding efficiency depending on the type of material being processed. For example, Arjes uses cutting elements with special contours that minimize rotational forces and ensure efficient wood and mixed waste shredding. Hammel focuses on the shape and placement of the teeth, which prevents material from getting stuck in the shredder, ensuring consistent performance.

However, this technology has not gained sufficient popularity despite numerous attempts to introduce replaceable cutting elements. The main reason for this is the insufficient reliability of the fasteners of the replaceable elements, which could lead to their disconnection or insufficient stability during intensive work. This, in turn, reduced shredders’ productivity and increased maintenance downtime. Therefore, manufacturers have focused on developing more robust designs with fixed cutting elements to ensure the uninterrupted operation of the equipment.

One of the main goals for shredder shaft manufacturers is to reduce the cost of their manufacturing process, as shafts must be completely replaced after wear and tear. Shredder shafts are manufactured by welding individual elements, which reduces material costs and shortens production time.

Although they could provide high strength and reliability, fully cast shafts are not used due to the high casting cost and technological complexity. Casting large parts is costly and time-consuming, making this method impractical for mass production.

The only manufacturer significantly contributing to shaft manufacturing technology development is the Ukrainian company Kivshservice. They have introduced the technology of welding cast segments to create shredding shafts, significantly reducing the number of parts that need to be welded together. This innovative solution allows for a several-fold reduction in shaft manufacturing time, cost savings, and process efficiency. The use of cast segments also improves the quality of the structure by reducing the number of potential welding points that can be weak points during heavy use.

Analysis of the Main Problems in the Production of Twin-Shaft Shredders and Alternative Ways to Solve them

The production of twin-shaft shredders is a complex process that ensures many aspects, including operational efficiency, component reliability, durability, and economic viability. Manufacturers face several challenges that require innovative solutions to overcome them. Among the biggest problems in this area are the issues of wear resistance of working elements, ensuring their stable operation and reducing the cost of manufacturing and replacing the main components of the shredder structure.

The cutting elements of shredder shafts are subjected to significant loads, especially when shredding hard materials such as metal waste, concrete, or heavy wooden beams. The main challenge is to ensure high wear resistance of the cutting elements and shafts in conditions of constant exposure to abrasive materials.

To solve this problem, all major manufacturers use high-strength steels such as Hardox and Creusabro, which are known for their excellent wear resistance characteristics. These steels can significantly increase the service life of shafts and cutting elements. In addition, manufacturers are constantly improving heat treatment technologies to ensure the best possible strength and flexibility. For example, cutting elements can be hardened or specially coated to increase their wear resistance.

Shaft replacement is an important step in the maintenance of twin-shaft shredders, and its complexity significantly influences the length of equipment downtime. As mentioned earlier, replaceable cutting elements have not gained popularity due to their unreliability. Instead, manufacturers have focused on developing solutions that make the process of replacing shafts as simple as possible. For example, design changes that make it easier to dismantle and install new shafts significantly reduce maintenance time.

The company Kivshservice offered an innovative approach to this problem by introducing the welding of cast segments to manufacture shafts. This reduces the number of welding points, shortens the overall production time, and, as a result, reduces the cost of manufacturing new shafts. Fewer welds also contribute to increased reliability, as welds can be structural weaknesses that require special attention during operation.

Another important problem for manufacturers is the high cost of shredder shafts, which is associated with both material and technological costs for their production. The use of high-quality steels, on the one hand, ensures high performance and wear resistance, but on the other hand, it increases overall costs.

To reduce manufacturing costs, manufacturers such as Arjes, Hammel, Lindner, and Pronar are experimenting with optimizing welding processes, introducing automated quality control systems, and selecting optimal material combinations. For example, some of the load-bearing elements can be made of less expensive structural steels, while the cutting elements remain made of highly wear-resistant materials. This allows us to reduce costs without losing key characteristics.

Efforts to reduce production costs also include optimizing the shaft design to reduce weight while maintaining high strength. This helps to reduce the load on the drives and increase the overall efficiency of the shredder.

Another important topic for discussion is the automation of the manufacturing and maintenance of shredding shafts. Many large manufacturers are already implementing robotic systems for welding, machining, and quality control, which allows them to improve the accuracy and quality of manufacturing and reduce the cost of manual labor. For example, automated welding robots can significantly speed up the shaft assembly process, ensuring high-quality welds and minimizing the risks associated with the human factor.

Thus, the main challenges in the production of twin-shaft shredders are related to the need to ensure high reliability and wear resistance of components, reduce manufacturing and maintenance costs, and introduce innovations to improve productivity. Manufacturers are actively working to improve shaft production technologies using the latest materials, process automation, and design optimization, which allows them to remain competitive in the market and offer customers reliable and cost-effective shredding solutions

Conclusions

Primary double-shaft shredders are important tools for material processing in many industrial sectors, and technological innovations in their production allow for increased efficiency and reliability of this equipment. The world's largest manufacturers, such as Arjes, Hammel, Lindner, Pronar, and others, continue to improve their technologies, focusing on improving the wear resistance and reliability of cutting elements, as well as reducing manufacturing and maintenance costs.

Particular attention is paid to chopping shafts, which are a key component of these machines. All leading manufacturers use a fully welded shaft design made of high-quality steels, such as Hardox and Creusabro. This ensures high wear resistance but adds complexity to manufacturing and increases production costs. That is why innovative technologies, such as welding of cast segments, introduced by the Ukrainian company Kvshservice, have become an important step towards improving production efficiency.

The market for shredding equipment is constantly evolving, and each company strives to find the optimal balance between production costs, reliability, and efficiency of its machines. Despite challenges such as high manufacturing costs and the need for frequent maintenance, new technological solutions help ensure the equipment's stable operation and increase its service life. An important area for further development is the automation of production processes, which will reduce dependence on the human factor and improve the quality of the final product.

In general, shredding equipment continues to play an important role in processing various types of materials, contributing to the efficiency of processes in many industrial sectors. Innovative solutions in the manufacture of shredder shafts, including technologies that reduce production time and increase reliability, allow companies to remain competitive and provide their customers with reliable and productive shredding solutions

References

[1] A. Raji, N., S. Ojo, S., M. Hunvu, "Design development and performance evaluation of waste plastic shredder", *Journal of Production Engineering*, vol. 23(1), pp. 22–28, 2020.

[2] M. Sanjay Kumar, H. Kumar, "Design and Development of Agricultural Waste Shredder Machine", *International Journal of Innovative Science Engineering and Technology*, vol. 2, No. 10, 2015

[3] S. Luo, B. Xiao, L. Xiao, "A novel shredder for municipal solid waste (MSW): influence of feed moisture on breakage performance", *Bioresour. Technol,* vol. 101 (15), pp. 6256–6258, 2010.

[4] H. Screenivas, Y. Sundeep, K. A. Naveen and N. Krishnamurthy, "Conceptual design and development of shredding machine for agricultural waste International Journal of Innovative Research in Science", *Engineering and Technology*, vol. 6, No.5, pp. 2347–2510, 2017

[5] K. Khodier, C. Feyerer, S. Möllnitz, A. Curtis, R. Sarc, "Efficient derivation of significant results from mechanical processing experiments with mixed solid waste: Coarse-shredding of commercial waste", *Waste Management,* vol. 121, pp. 164–174, 2021.

[6] A. E. Oladejo, S. I. Manuwa, T. B. Onifade, "Design and fabrication of a shredder", *IOP Conference Series: Earth and Environmental Science*, vol. 445, 012001, 2020.