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Chassis loading investigation of two-shaft shredder for construction waste management

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ABSTRACT

Recycling industry development need cracked materials with different composition and characteristics. New constructions shredders creation, their engineering design, development through adequate mechanical-mathematical models and practical realization determines the actuality of this paper. The materials crushing for recycling solves important environmental tasks related to environmental protection.

The two-shaft hydraulic shredder realized the first and the second stage from the crushing (disintegration) process. Disintegration as part of the recycling process can be successfully applied to the domestic and industrial waste processing, single- and multi-component materials crushing, and to secondary raw materials grinding. The paper is dedicated to the emerging loading of the two-shaft shredder chassis and the resulting calculations and verifications.

In the present work has been performed a modeling study of the chassis for such type of shredder for concrete, rubber, plastic and wood crushing. The studies of the mechanical load and behaviour of the chassis have been conducted. The equations characterizing the mechanical processes in the working conditions by the finite element method are solved. For this purpose has been generated a chassis three-dimensional geometrical model, which has been discretized to a planned network of finite elements in the ANSYS MECHANICAL APDL programming environment.

1. Introduction

Construction waste, besides an environmental problem, can also be a source of a number of valuable ingredients, in relation to which they have to be analyzed in two aspects: as a sustainable development problem and as alternative raw materials.

The solution of problems in construction waste processing is of particular importance due to the gradual natural mineral resources depletion and the need of the full use waste as useful products. Urban density is rapidly increasing in line with an expanding global population.

The importance of sustainable legacy creating is widely recognized throughout the world at every level of society. Waste management is an extremely important factor in achieving sustainable development and fundamental element of long-term sustainability strategies (Grigorova et al., 2017).

The continuous process of production and use of products from rubber, plastic, and the intensified construction lead to serious accumulation of waste, imbalance, and danger for the environment. In all industrial societies, a need appears for the waste reducing and their re-integration in the production process. The recycling of construction waste, as well as waste from rubber, plastic and wood, as a process, is extremely important both for the environment and the society (Vatskicheva and Grigorova, 2017). The waste management is a challenge, because of the high rate of

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the numerous manual operations, high transport costs and negative impact on the environment. Therefore particularly important is study and development of the various machines for crushing of the diverse waste streams.

The recycling industry development shows increasing need of crushed materials with different composition and characteristics. New crushing machines creation, their research by adequate mechanical and mathematical models, engineering design and practical implementation are current scientific problem (Lowrison, 1974; Vatskicheva, 2017).

Disintegration is a part of the recycling process can be successfully applied for domestic and industrial waste treatment, component and multi-component materials crushing. The process is used also for grinding of refuse utility with different mechanical characteristics – from the tough-elastic car tires and some types of plastics to the hard and brittle materials, such as glass, porcelain, chamotte, mica, concrete and others (Abadjiev and Tonkov, 2017; Vatskicheva and Grigorova, 2017a).

The crushing technological purpose is dependent on next processes and stages of processing or the product application. Such an attitude towards the secondary materials is a prerequisite for sustainable development, and the mandatory protection of people and environment (Vatskicheva and Grigorova, 2015). Crushers are the main machines applied for crushing in the industry and the majority of them are intended only for particular type processing. One alternative of the machines for secondary and waste materials crushing are the shredders. This is a group of relatively new machines which are classified mainly according to the number of the working shafts (Tonkov, 2007), and the technology of crushing: single-shaft, two-shaft, three-shaft, four-shaft, five-shaft shredders, with varying automation degrees and key parameters control, noise different level, rotation speed, pressurization level and others (Abadjiev and Tonkov, 2017).

Shredders are configured according to each of their unique applications, with a selection of different thicknesses and number of cutting cogs, shaft diameter, thickness of the distance bushings, drive power, productive capacity. The knives are made through a specific technology from special steels. This ensures extreme hardness, duration of operation, and maintenance low cost (Vatskicheva and Grigorova, 2017a).

The two-shaft hydraulic shredder consists of feeding conveyor, feed hopper, crushing chamber, output belt, unloading belt, and belt for metal particles separation. The shafts, which perform the main function of the machine, are arranged in the crushing chamber. A serious advantage of the shredders is the possibility to be integrated into systems for simultaneous processing of different types of multi-component waste, with separation and utilization of the components having different degree of hardness. The two-shaft shredders advantage is their high productive capacity. The disadvantages are associated with the high price and the maintenance high cost (Vatskicheva and Grigorova, 2017; Vatskicheva, 2017; Vatskicheva and Grigorova, 2017a).

The purpose of this paper is to discuss and present a constructive version of two-shaft shredder with a universal practical application for crushing different types of materials - concrete, rubber, plastic and wood. The two-shaft hydraulic shredder realized the first (initial) and the second (middle) stage from the crushing (disintegration) process. Due to the process specificity, these stages are less studied and there is the smallest number of implemented technological solutions of industrial importance.

The shredder separate assemblies are located on a common chassismultilift type. The feeding strip is a separate part of the shredder, and is transported independently. The shredder is moved from one platform to another through a towing vehicle multilift type with capacity up to16 tons. The focal point of this work is focused on the chassis model study of the shredder for waste concrete crushing. The structure of the chassis should be of durable material. This condition is very important for safely support of the vehicle components weight, and also for transmits loads, resulted from vertical, longitudinal and lateral accelerations.

When designing a chassis, should be considered material selection, strength, stiffness and weight and component packaging (Gauchia et al., 2010). The most significant issue in the truck manufacturing industries is to vehicles design with large load pay. When is possible the high strength steel use the load capacity can also increase.

Another important feature of the chassis, except strength is to have suitable torsional and bending stiffness. The two important criteria for chassis design are stiffness and strength (Tushar et al., 2012).

The studying, designing and chassis analysis should include and stress distribution, as well fatigue prediction process life.

In the studying the fatigue processes of materials and components life prediction the stress analysis is very important. Through this analysis can be determined the highest stress point (critical point) which gives information about a probable failure. The stress magnitude can be used to predict the chassis life span. For the components mounting (transmission, engine, suspension and ect.), the determination and optimization of the critical stress point location is important. (Ghazaly, 2014; Braess, 2007). This study discusses some aspects of the truck chassis stress analysis. For predicting and stress analyses investigating different finite element packages have been used.

2. Influence of the crushing machine selection criteria

The selection of the shredder type is made according to the properties of the crushed material and its strength characteristics. For brittle materials are used shredders, working with impact and pressure. Cutting single-,

Figure 1. Different types shredders (Vatskicheva and Grigorova, 2017a)
a) Single-shaft shredder, working by scraping;
(b) Single-shaft shredder, working by cutting;
(c) Two-shaft and (d) Four-shaft shredders

two- and four-shaft shredders are used for tough-plastic materials. The material may be crushed by scraping or cutting. For scraping are suitable single-shaft shredders (Figure 1a), which are crushing machines with universal application. They are intended for materials with great thickness and resistance against destruction. Their advantages compared to the other types shredders are solid and stable structure, long service life. A disadvantage is the low productive capacity, determined by the slow working speed. In crushing by cutting, selection can be made between single-shaft, two-shaft or four-shaft shredder (Vatskicheva and Grigorova, 2015; Vatskicheva and Valkov, 2013).

The single-shaft shredders (Figure 1b) are rarely used for this type of materials crushing, because of their low productive capacity. Most often are used two-shaft shredders (Figure1c). An advantage of the two-shaft ones is their high productive capacity. The disadvantages are the high price and the machines maintenance activities (Vatskicheva and Grigorova, 2017a).

The two-shaft shredders realize the factual scissors effect, and the four-shaft ones provide larger zone of cutting (Tavakoli et al., 2008). The four-shaft shredders, shown on fig. 1d, are equipped with working shafts, on which there are installed cutting knives-disks. Both upper shafts are feeding, and the lower two – cutting. The existing two pairs of shafts (feeding and crushing) form a working chamber with conical shape (Vatskicheva and Grigorova, 2017a; Borshchev, 2004). The size of the crushed material determines the feed hopper dimensions and shape as well as crushing chamber dimensions.

The final product influence on the shredder selection is expressed in the following: as much as the size of the product is smaller than the size of the source material, the time and effort should be spent for crushing increase.

For particularly small fractions may be necessary second shredder, and sometimes whole production line, for example line for crushing to fine rubber powder. The output granulometry is depending on the crushing disks distance. (Abadjiev and Tonkov, 2017; Vatskicheva and Grigorova, 2017a; Borshchev, 2004).

The choice of crushing machine is determined by four main factors (Vatskicheva and Grigorova, 2017a; Vatskicheva and Grigorova, 2015; Vatskicheva and Valkov, 2013): material type for reduction, size of the material for shredding, the shredder productive capacity and the final product particle-size distribution. The specification of these four factors determines the best way for shredder design, manufacture and application.

3. Shredder machine specification

On the platform, the chassis is leveled on four hydraulic supports, driven and controlled by the shredder engine (Figure 2).

Figure 2. Two-shaft hydraulic shredder mounted on the chassis, subject of the study

For designing the basic unit of the machine – the crushing chamber and the shredding shafts, the following data are used (Vatskicheva and Grigorova, 2017a):

- Compressive strength of the destructed elements: maximum 55 MPa;
- Approximate dimensions of the chamber neat area: 900 x 700 mm;
- Feeding of the shredder: flow, discrete, controlled by an operator;
- Crushed material separation and loading: flow, continuous, automatic;
- Metal particles separation in the crushed material: flow, continuous, automatic, with magnetic boards;
- Approximate operated power: 210 kW.

The chassis of the machine is a frame structure, typical for the devices of type multilift. It consists of two main longitudinal beams and two vertical beams for gripping from the transport vehicle, as it is shown on Figure 3.

The part of the chassis, in which the hydraulic station is located, is closed with tin lids, and the part under the crushing chamber and the output strip are open. In the four corners of the chassis are installed four lifting and leveling cylinders, each with separate command for precise leveling on uneven terrains. The type of cylinders is CBX4 2 1 A1 D100 S600 with 600 mm step (move). In the ends of each cylinder is mounted a round seating for distribution of the weight over the terrain (Figure 4).

The chassis of the machine is a structure of rectangular and square welded pipes ISO 4019, 100x100x5, 100x50x5 and 100x50x4. It is analyzed for deformations during its lifting from the vehicle multilift type by the hook in its front part. The three points in which the chassis is supported at this position are the hook and the rear two levelling roller supports. The chassis frame has been verified, as on the weights of all elements – chamber, hoppers, tanks, engine have been applied. The chassis structure has been verified for total strength. There have been applied the loads from the shafts weight, the chamber elements, the input hopper, as well as the support reactions (resistances) in the shafts bearings (Ghazaly, 2014; Gauchia et al., 2010). The investigations have been conducted through the mathematical models and numerical procedures described below.

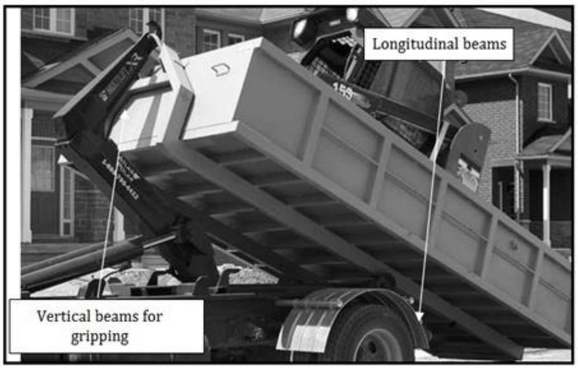

Figure 3. Chassis construction type

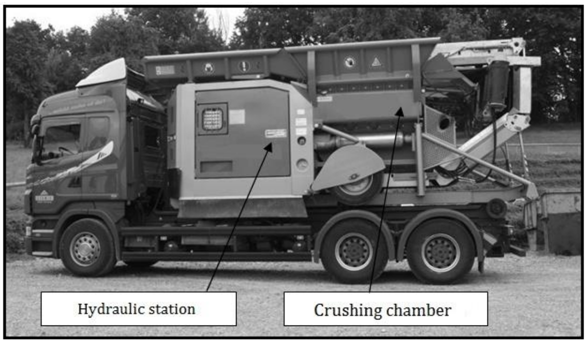

Figure 4. Crushing chamber and hydraulic station placed on the chassis

4. Model study conception

One of the many design tools, which has increasingly popular is The Finite Element Analysis (FEA). It has been used for the solution of many types of problems. FEA is used in civil construction design, aviation and for many others goods industries. The market competition puts tremendous pressure on the corporations to launch reasonably priced products in short time, making them to rely more on virtual tools (CAD/CAE) accelerating the design and development of products (Sathish and Balakrishnan, 2013; Prakash and Srikanth, 2016).

FEA is used to predict multiple types of static and dynamic structural responses. Due to FEA optimizations can be performed before the parts are constructed and implemented. The widely used and most common commercial finite element packages are ANSYS, ABAQUS, COMSOL, ALGOR, HYPERVIEW, LSDYNA, NASTRAN, etc. The powerful computers and FEA software creation gives opportunity for realization of complex models. This resulting in the better decisions to the problems, both of design engineers, as well as the customer (Siraj and Sheikh, 2014).

The mechanical load and behavior of the chassis are investigated through solving equations. These equations characterize the mechanical processes under operating conditions by the method of the finite element (FEM). For this purpose has been generated a chassis three-dimensional geometrical model, which has been discretized to a planned network of finite elements in the ANSYS MECHANICAL APDL programming environment.

In Table 1 are shown summarized results of the verification of the chassis strength with the accepted steel mechanical properties.

The chassis maximum and minimum deformations are presented on the Table 2 and the Figure 5.

The study results show that the maximum stresses for the examined structure do not exceed the permissible values for the material of the chassis multilift type.

Table 1
Data for the accepted in the verification material of the beams of the frame

Name	Steel	
General	Mass Density Yield Strength Ultimate Tensile Strength	7.85 g/cm^3 207 MPa 345 MPa
Stress	Young's Modulus Poisson's Ratio Shear Modulus	210 GPa 0.3 ul 80.7692 GPa
Stress Thermal	Expansion Coefficient Thermal Conductivity Specific Heat	0.000012 ul/c 56 W/(m K) 460 (kg c)

Table 2
Maximum and minimum frame deformations

Name	Minimum	Maximum
Volume Mass	303,791,000 mm^3 2,386.94 kg	
Von Mises Stress Displacement	0 MPa 0 mm	614.396 MPa 2.57114 mm

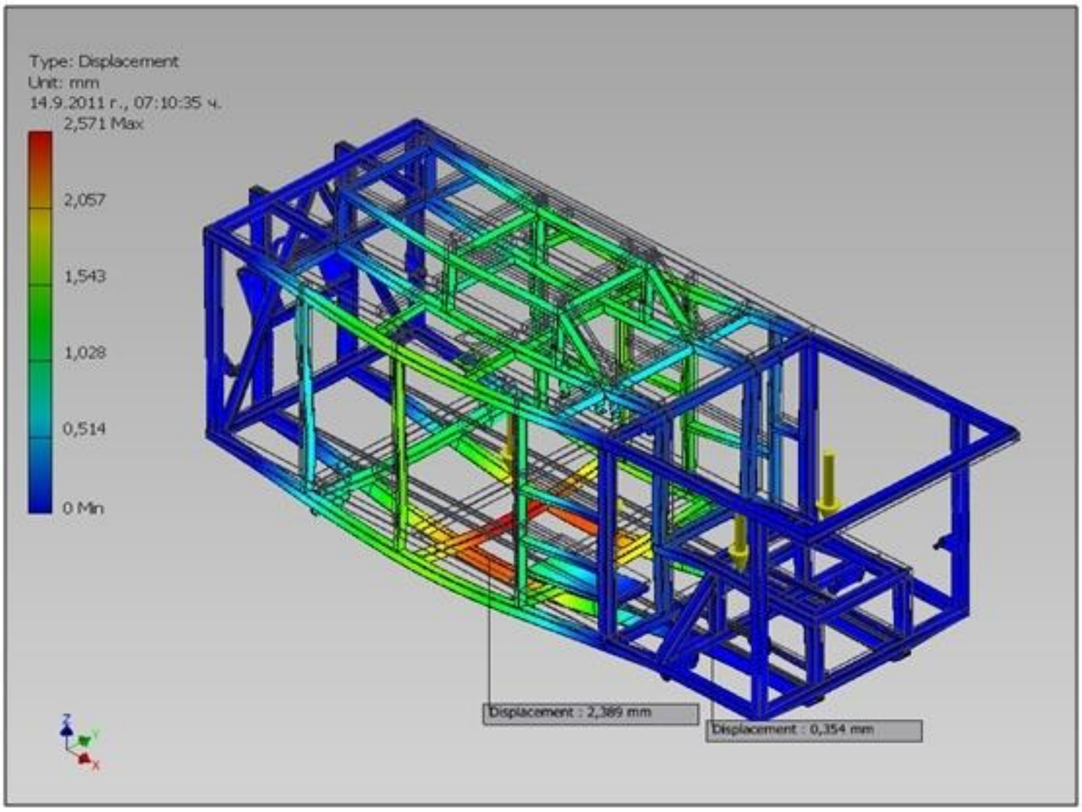

Figure 5. Data for frame maximum and minimum deformations

5. Conclusions

The crushing processes have a complex character. Solids resist crushing, so achieving the required size consumes a significant amount of energy. Therefore, the technological shredding mechanisms design with the highest energy efficiency is important.

Disintegration is an important process related to the processed raw materials destruction. The crushed materials growing need, with different composition and characteristics, has consistently led to create new shredder designs with universal application to process different materials. The recycling machines development which realizing the first and second stages of the disintegration cycle is an innovation factor for large economic potential use of many waste products, as well as secondary raw materials.

The refinement of the basis factors for choosing a crushing machine, namely: material type for reduction, size of the material for shredding, productive capacity and final product particle-size distribution, determines the best way to design and shredder apply.

Need to create universal shredding mechanisms with high technically efficient is based on number of facts. The most important are:

- Huge quantities of waste accumulation that are currently not processed;
- Inadequate and cost-effective technique for carrying out the environmentally friendly processing of these products;
- High energy consumption of existing recycling facilities.

The studies, related to the shredder constructions theoretical investigations and practical implementation present a number of challenges. Two-shaft shredder is the optimal combination of structural and economic parameters. The result of the studies carried out indicates that the examined chassisstructure, type multilift, can be used for two-shaft shredder crushing machines.

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References

Abadjiev V., Tonkov G., On the synthesis of technological gear mechanisms for disintegration processes, Proceedings of the Industrial Innovation Forum „Machines, Technologies, Materials", of the Federation of scientific unions, Sofia, Bulgaria, 2007, 123,

Borshchev V., Equipment for crushing of materials, State Technical University Tambovsky, Moscow, 2004,

Braess D., Finite Elemente – Theorie, schnelleLöser und Anwendungen in der Elastizitätstheorie, Springer, Auflage, 2007,

Gauchia A., Diaz V., Boada M., Boada B., Torsional stiffness and weight optimization of a real bus structure, International Journal of Automotive Technology, (11), 2010, 41-47,

Ghazaly N., Applications of Finite Element Stress Analysis of Heavy Truck Chassis: Survey and Recent Development, Journal of Mechanical Design and Vibration, 2 (3), 2014, 69-73,

Grigorova I., Ranchev M., Yankova T., Waste management - current trends, Proceedings from the 60th International Scientific Conference of the UMG "St. Ivan Rilski", Sofia, Bulgaria, Mining and Mineral processing, 60 (2), 2017, 83-88,

Lowrison G., Crushing and Grinding. Size Reduction of Solid Materials, Butterworths, 1974,

Prakash K.S.J., Srikanth A., Static and Dynamic Stress Analysis of Auto Chassis and Crank Shaft Using ANSYS, International Journal of Advanced Scientific Technologies in Engineering and Management Sciences, 2 (11), 2016, 26-30,

Sathish K., Balakrishnan M., Theoretical Evaluation and Finite Element Analysis of Commercial Truck Chassis Assembly, SAE Technical Paper 2013-01-1361, 2013,

Siraj M., Sheikh A., Analysis of universal coupling under different torque Condition, International Journal of Engineering Science & Advanced Technology, 2 (3), 2014, 690-694,

Tavakoli H., Mohtasebi S., Jafari A., Comparison of Mechanical Properties of Wheat and Barley Straw, Engineering International: CIGR Journal, 10, 2008, 1-9,

Tonkov, G., Aspects on the design and the manufacture of a disintegrating gear mechanism, Proceedings of the Scientific Conference of the Technical University - Sofia, branch Plovdiv, Technical and Natural-Mathematical Sciences, 2, 2007, 68-76,

Tushar M., Patel M., Bhatt G., Analysis and Design Modification of a Chassis, LAP Lambert Academic Publishing, 2012,

Vatskicheva M., Grigorova I., Stresses and Deformations in the Shredding Shafts of Two-Shaft Shredder for Crushing of Concrete, Rubber, Plastic and Wood, Proceedings from the 60th International Scientific Conference of the UMG "St. Ivan Rilski", Bulgaria, Mining and Mineral processing, 60 (2), 2017, 86-89,

Vatskicheva M., Development of universal recycling machine for crushing of concrete, rubber, plastic and wood, Defensed Phd thesis, University of Mining and Geology "St. Ivan Rilski", Sofia, 2017,

Vatskicheva M., Grigorova I., Study of dual shaft shredder for crushing of concrete, rubber, plastic and wood, Journal of International Scientific Publications, Materials, Methods & Technologies, 11, 2017a, 238-253,

Vatskicheva M., Grigorova I., Criteria for selection of a crushing machine, Proceedings of the University of Mining and Geology "St. Ivan Rilski", Sofia, Bulgaria, 2015, 51-56,

Vatskicheva M., Valkov M., Existing structures of multi-purpose shredders and guidelines for their improvement, Proceedings of the University of Mining and Geology "St. Ivan Rilski", Sofia, Bulgaria, 2013, 55-59.

Ispitivanje konstrukcije šasije sekača sa dva vratila za upravljanje građevinskim otpadom

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I Z V O D

U reciklažnoj industriji kao ulazna sirovina koriste se usitnjeni materijali različitog sastava i karakteristika. Shodno tome, u ovom radu, akcenat je stavljen na sagledavanju uticaja konstrukcijskog rešenja i inženjerskog dizajna sekača, kroz razvoj adekvatnih mehaničko matematičkih modela i same praktične realizacije, na mogućnost usitnjavanja. Usitnjavanje materijala rešava veoma bitne probleme po pitanju zaštite životne sredine. Hidraulični sekač sa dva vratila može se efikasno koristiti za primarno usitnjavanje (komunalnog i industrijskog otpada, jedno ili više komponentnog otpada) i sekundarno usitnjavanje (mineralnih sirovina). U radu su predstavljena istraživanja modeliranja šasije pomenutog sekača za usitnjavanje betona, gume, plastike i drveta, kao i uticaj konstruktivnog rešenja šasije na mehaničko opterećenje vratila. Kreiranje trodimenzionalnog geometrijskog modela šasije i formiranje mreže metode konačnih elemenata izvršeno je programskim paketom ANSYS MECHANICAL APDL.