UNIUNEA EUROPEANĂ

Programul Operațional Capital Uman
Axa prioritară 6 - Educație și competențe
Proiect: Burse pentru educația antreprenorială în rândul doctoranzilor și cercetătorilor postdoctorat (BeAntreprenor!)
Cod MySMIS: 124539

Instrumente Structurale 2014-2020

UNIVERSITATEA POLITEHNICA DIN BUCUREȘTI
FACULTATEA DE INGINERIA SISTEMELOR BIOTEHNICE
ȘCOALA DOCTORALĂ INGINERIA SISTEMELOR BIOTEHNICE

Summary of the Doctoral Thesis

Research on the optimization of the constructive and functional parameters of the waste translation compaction system, in a stationary or mobile locations

Cercetări privind optimizarea parametrilor constructivi și funcționali ai sistemului de compactare prin translație a deșeurilor, în amplasare staționară sau mobilă

Author : Eng. Mircea Bucur LAZEA

Scientific leader: Prof. dr. ing. Gheorghe VOICU

Bucharest 2023

Rezumat

Încă de la generarea deșeurilor, apare problema volumului foarte mare ocupat, aceasta generând în afara disconfortului și costuri însemnate. Procesul de compactare este întâlnit în fiecare etapa din ciclul de viață al deșeurilor, atât în fazele intermediare de tratare, cat și în fazele finale înaintea reciclării sau eliminării. Obiectivul principal al tezei a fost crearea unui ansamblu de proceduri de cercetare și sisteme de măsurare, colectare și prelucrare/analiză date, privind comportamentul fizico-mecanic al deșeurilor în interacțiunea cu organele de lucru în sisteme de compactare prin translație. Teza de doctorat cuprinde o sinteză analitică a sistemelor de compactare a deșeurilor, selectate sau neselectate, atât în amplasare mobilă cât și staționară, factorii care influențează compactarea, precum și a stadiului actual al cercetărilor în domeniul compactării acestor deșeuri. În cadrul cercetărilor experimentale sunt prezentate unele aspecte privind modelarea fizico- matematică a procesului de compactare a deșeurilor în structuri paralelipipedice cu secțiune dreptunghiulară, o analiză cinematică și una cinetostatică a unor mecanisme de preluare a deșeurilor la sisteme de colectare a deșeurilor aflate în amplasare mobilă, precum și o simulare cu element finit a rezistențelor plăcii de compactare/evacuare de la sistemele mobile de colectare a deșeurilor municipale. Se face, totodată, analiza structurală cu elemente finite a pieselor de uzura din ghidajele plăcii de contrapresiune-compactare la aceleași sisteme de compactare aflate în amplasare mobilă.

În cadrul determinărilor experimentale s-a urmărit atât comportamentul fizico–mecanic al deșeurilor, cât și comportamentul sistemelor de compactare prin translație. În determinări s-au utilizat sisteme mecanice de tip prese cu flux vertical sau orizontal, în interacțiune cu diverse eșantioane de deșeuri: deșeuri din carton, recipiente din material plastic și altele. Pe parcursul experimentelor s-a determinat consumul de energie necesar pentru compactarea și balotarea deșeurilor, dar și comportamentul la compactare al sistemelor tehnologice de presare. Pentru colectarea datelor experimentale a fost conceput un sistem de achiziție a datelor folosind sisteme de senzori prin intermediul cărora datele au fost transmise și prelucrate informatic, construindu-se, astfel, o prima etapa de culegere și analiza date în timp real. S-a urmărit, în principal, determinarea rezistențelor la compactare (forțe, viteze, presiuni, deformații, energie specifică) a categoriilor de deșeuri amintite, compactare executată în mai multe etape, până la realizarea unui balot legat care să poată fi manipulat și transportat mai ușor la locurile de procesare și reciclare.

In acest mod sunt oferite specialiștilor noi date și metode de cercetare pentru soluționarea modelelor constructive și calcule de consum energetic.

Abstract

Since the generation of waste, there is the problem of the very large occupied volume, which generates, in addition to discomfort, significant costs. The compaction process is encountered at every stage of the waste life cycle, both in the intermediate stages of treatment and in the final stages before recycling or disposal. The main objective of the thesis was the creation of a set of research procedures and data measurement, collection and processing/analysis systems, regarding the physical-mechanical behavior of waste in the interaction with working bodies in translational compaction systems. The doctoral thesis includes an analytical synthesis of waste compaction systems, selected or unselected, both in mobile and stationary locations, the factors that influence compaction, as well as the current state of research in the field of compaction of these wastes. As part of the experimental research, some aspects are presented regarding the physico-mathematical modeling of the waste compaction process in parallelepiped structures with a rectangular section, a kinematic and a kinetostatic analysis of some waste collection mechanisms in mobile waste collection systems, as well as a finite element simulation of compaction/discharge plate strengths from mobile municipal waste collection systems. At the same time, the structural analysis with finite elements of the wear parts of the counter-pressure-compaction plate guides is done at the same compaction systems in mobile location.

As part of the experimental determinations, both the physical-mechanical behavior of the waste and the behavior of translational compaction systems were monitored. Mechanical systems such as vertical or horizontal flow presses were used in the determinations, in interaction with various waste samples: cardboard waste, plastic botles and others. During the experiments, the energy consumption required for the compaction and baling of waste was determined, as well as the compaction behavior of the technological pressing systems. For the collection of experimental data, a data acquisition system was designed using sensor systems through which the data were transmitted and computerized, thus building a first stage of real-time data collection and analysis. The aim was mainly to determine the compaction resistances (forces, speeds, pressures, deformations, specific energy) of the mentioned categories of waste, compaction carried out in several stages, until a tied bale is made that can be handled and transported more easily at processing and recycling sites.

In this way, specialists are offered new data and research methods for solving constructive models and energy consumption calculations.

Thanks

At the end of this important stage in my life, I would like to offer respectful thanks accompanied by a deep respect to Prof. Univ. Dr. Ing. Gheorghe Voicu, the scientific coordinator of the work, for the professionalism with which he guided me, for the competence and permanent scientific guidance, for the real support granted during the entire period of the doctoral internship, for the preparation of scientific reports and the elaboration of the doctoral thesis, but also during the student period.

I thank Prof. Univ. Emeritus Dr. Ing. Ladislau David for all the precious suggestions and recommendations. I would also like to thank Prof. Dr. Ing. Edmond Maican, mr. dr. ing. Gabriel-Alexandru Constantin and mr. conf. dr. ing. George Ipate, both for the useful discussions and permanent encouragements granted throughout the preparation of the doctoral thesis, for the help given to the experimentation and simulation part, and for the necessary guidance throughout this period.

I sincerely thank the entire team of teachers from the Department of Biotechnical Systems, Faculty of Biotechnical Systems Engineering, especially to Prof. Univ. Dr. Ing. Sor in-Ștefan Biriș, for the encouragement and suggestions received during the entire period of the doctoral studies.

I thank the distinguished referees and members of the evaluation committee of the doctoral thesis, prof. univ.dr. Razvan George Rapeanu, prof. univ. dr. Ion Saracin, prof.univ.dr. Ilie Filip, for the honor given to being part of the committee, for the patience with which they analyzed the work and for the particularly useful suggestions for the successful completion of this stage of my life.

On this occasion, I thank the management of the companies RLG Waste Management Systems, Rom Waste Solutions, Best Tools and Romprest Energy, who allowed me to carry out the experimental research inside the unit, but also to those from these companies who helped me in sampling.

And last but not least, I would like to express my gratitude to my entire family and all my close friends for the countless proofs of love and moral and physical support, in this way thanking them from the bottom of my heart

A part of the results presented in this doctoral thesis were obtained with the financial support of the Ministry of Labour, Family and Social Protection through the European Social Fund, Sectoral Operational Program Human Resources Development 2007-2013, Contract no. POSDRU/107/1.5/S/76903.

Bucharest, March 2023 *Mircea-Bucur Lazea*

Foreword

The doctoral thesis "**Research on the optimization of constructive and functional parameters of the waste translation compaction system, in stationary or mobile location"** is structured on 7 (seven) chapters, developed on a number of xxx pages, comprising xxx figures and graphs, xxx tables, mathematical relations, as well as a bibliographic list consisting of xxx references. This work also contains a list of notations and symbols (x pages), and, at the end, a series of annexes (xy pages) are presented that present informative materials and data in the form of tables, graphs or figures related to the studies and researches presented in this paper.

The main objective of the theoretical and experimental researches was the study of compaction systems by translating waste, in stationary or mobile location, and the identification of the main variables involved in this process, including the identification of correlations between the parameters of the process (the force resistant to compaction, the displacement of the piston of the pressure plate, the action time on the material, the specific compaction energy).

In ***chapter 1*** of this work *"Introduction. The importance of compacting waste. Objectives of the doctoral thesis"* is presented the importance of the theme approached and the main and subsidiary objectives pursued in the elaboration of the thesis.

Chapter 2 entitled *'Physico-mechanical characteristics of the compacted material (wastes)'*, contains some general notions regarding the situation of waste in the world, its classification, composition and how to generate it, as well as the basic characteristics involved in the sorting and compaction process, together with some methods of determining them, in some places being presented results obtained by researchers in the field

*In **chapter 3**,* entitled *'Systems for compaction of waste by translation, in mobile or stationary location',* the factors influencing the compaction of bulky materials (coefficients of friction, adhesion and cohesion, the modulus of elasticity and the coefficient of Poisson, the link between compaction pressure and density, etc.), several translation compaction systems in stationary or mobile location are presented, as well as some mechanisms for taking over and pre-compacting autonomous waste collection and transport equipment.

In ***chapter 4***, entitled "*The current state of research on the compaction of municipal waste"*, the synthesis of theoretical research on the process of compaction of waste in fixed or mobile presses is made, as well as the synthesis of experimental research on the compaction of municipal waste, using presses with movement by translation, the requirements regarding the construction of vehicles to collect and transport waste, some deterministic mathematical models for expressing the physical link between parameters of the translational pressing/compaction process.

This chapter ends with some conclusions regarding the importance of knowing the factors that influence the waste compaction process, but also the main aspects resulting from the analysis of theoretical and experimental research on compaction systems.

Chapter 5, entitled *"Theoretical aspects and contributions regarding the process of compaction of waste by translation into rectangular section structures"* presents some deterministic mathematical models that express the physical connection between the parameters of the process of pressing / compaction by translation into parallelepipedic structures with rectangular section, the main aspects of stress simulation in the component organs of systems with compaction by translation, kinetic and kinetic analysis of the mechanisms of waste collection and pre-compaction to mobile waste collection systems in mobile location, as well as simulation with finished element of the resistances of the compaction / discharge plate from mobile municipal waste collection systems. The structural analysis with finished elements of the wear parts of the backpressure/compaction plate guides to the compaction systems of the waste collection and transport machines shall also be provided. The chapter concludes with conclusions on the applicability and use of these mathematical models.

Chapter 6, entitled *'Experimental research on the compaction of waste in mills with stationary or mobile location'*, contains the objectives of the thesis and experimental research, the working apparatus and equipment for experimental research on waste compaction systems, respectively the system for the determination and acquisition of data for the compaction of waste in fixed vertical presses and the basic characteristics of the presses used in experiments. The methodology of the determinations of the experiments and the relationships underlying the calculation of some basic parameters of compaction (specific energy at compaction) and the link between them by regression analysis in the Microcal Origin 8.0 program shall also be presented.

The results of the researches on the determination of the resistances to the compaction of plastic waste, respectively of the 2-liter PET cylinders in several phases and successive loads of the vertical press pressing chamber HSM-V 605, in correlation with the displacement of the press pressure plate, as well as with the travel time, respectively the speed of displacement of the plate according to the resistance encountered in the process, are presented. Based on the surfaces of the force-displacement curves plotted graphically, the energy consumed in the compaction process, respectively the specific energy, was determined.

The results of the research on the same parameters for the compaction of the 0,5-litre PET cylinders in three phases and three different loads of the press pressing chamber, with at least two successive compactions for each phase, as well as the compaction energy, as in the previous case, shall also be presented.

Experimental research was carried out on the parameters of the process (resistant forces, pressure plate stroke, travel speed, specific compaction energy) in the case of compaction of used cardboards using the fixed vertical press model PP-1207, Strautmann also in seven independent phases with successive equal loads of the pressing chamber.

Also, in this chapter are presented some aspects regarding the dimensional optimization of the wear parts of the guide system of the pressing plate of the compaction plate from the machines for collecting and transporting household waste.

The chapter ends with a section of conclusions on the results of experimental research and the importance of knowing the parameters specified

In Chapter 7, "*General conclusions. Perspectives. Contributions"* are presented the final conclusions regarding the theoretical and experimental researches presented in the thesis. Their own contributions are synthetically exposed, but also the future directions of research in the field of the topic.

Taking into account the above, I appreciate that the topic of the doctoral thesis is topical and addresses an important field, that of waste collection for recycling as reusable materials and has a special technical and scientific importance.

List of notations and symbols.

Chapter 2. Physical- mechanical characteristics of the material to be compacted(waste)

D – volumetric mass, (kg/m^3)
w_1 – the weight of fresh waste and waste measured in the container, (kg)
w_2 – weight of the waste measuring container (kg)
V – volume of waste measured in the container, (m^3)
W_t^i - the humidity of the waste, (%).
Q_i^{mc} - heat of combustion of the waste relative to the state of combustible mass (kJ/kg)
A^i - the ash content of waste (%).

Chapter 3. Compaction systems for waste by translation, in the mobile or fixed location

G_d – waste mass, (kg);
V_d – volume of waste, (m^3).
D- density of waste (t/m^3)

W_t – total waste humidity,(%)
W_r – relative humidity of waste, (%)
W_h - hygroscopic humidity of msw, (%)
T – the temperature in the press de, (°C)

Chapter 4. State of play research on the compaction of municipal waste

D – the diameter of sample (*m*)
L_s - sample lenght, (*m*);
P_b - pressure at the base of the compression chamber , (*MPa*);
p –oil pressure, (bar);
ρ – density of the working pressure
L - lenght, (m);
d – diameter of the hole, (m);
v- fluid velocity in the distribuitor, (m/s);

Chapter 5 Aspects and theoretical contributions on the process of compaction of the waste by translation

D – sample diameter, (m);
L_s – sample lenght , (m);
P_b – pressure at the base of the compression chamber, (MPa);
P – compression presure (MPa);
γ_s – volumetric weight of the material (kg/m^3);

CHAPTER 1. INTRODUCTION. THE IMPORTANCE OF COMPACTING WASTE. OBJECTIVES OF THE THESIS

The management of municipal solid waste is solved differently in many countries around the world, given its degree of development. There are countless systems for collecting, transporting and storing collected waste. Most DSM collection machines are equipped with pre-compaction and compaction systems to reduce the volume of waste and transport a larger amount over distances that often reach several tens of kilometers, [60].

Compaction or baling of waste reduces the volume of waste and has similar benefits in maintaining an appropriate level of sanitation. The process depends on the material that is reduced and what happens next to it. For example, waste paperboard or polyethylene terephthalate (PET) can be both baled and compacted

The general objective of the doctoral thesis was to carry out theoretical and experimental researches regarding the compaction by translation of waste, in stationary or mobile location, and the identification of the main variables involved in this process.

The general objective of the doctoral thesis was to carry out theoretical and experimental researches regarding the compaction by translation of waste, in stationary or mobile location, and the identification of the main variables involved in this process.

In order to achieve the general objective of the work, it was necesary to achieve the folowing specific objectives:

- analysis of the state of the play of the methods, technologies and equipment currently used in the waste compaction process
- the documentary study on the factors inlfuencing the compaction process.
- The study and synthesized presentation of constructive compaction systems.
- Theoretica study of the process of compaction by translation of waste into rectangular section structures
- Summary presentation of the physico-chemical characteritics of the categories of waste most often pre-processed by compaction,

- Simulation in specific software of the movements of the active organs of mobile compaction systems.
- Simulation the stresses in the working bodies of the compactions systems by translation
- Theoretical study of the work baler presse with vertical or horizontal flow, regarding the compaction of waste.
- Experimental research on the mechanical compaction of waste, in baler with stationary or mobile location.
- Indentification of viable solutions to optimise components of compaction systems in mobile locations
- Wide dissemination of the research results on the process of compaction by waste translation, by publishing scientific papes in specialized journals and volumes of specialized conferences.

CHAPTER 2. PHYSICO- MECHANICAL CHARACTERISTICS THE MATERIAL TO BE COMPACTED (WASTES)

2.1. General Notions

The properties of waste are the main factor on which depends on how it is made, developed and recovered, as well as on the storage area that is temporarily occupied

Worldwide, according to a World Bank report for 2016 (fig.2.1), the most important share of municipal waste is food and green waste (44%), followed by a 38% share of waste such as plastics, paper and cardboard, metal and glass. It is important to note that these percentages vary from country to country, taking into account that they depend on the level of national economic development, cultural characteristics, etc., [126].

2.2. Waste generation

Since the Industrial Revolution, a large amount of garbage has been generated for more than 2 centuries, and the amount of garbage has increased dramatically in recent years. According to World Bank statistics, in 2016, the amount of municipal waste generated alone reached 2.01 billion tons. Although the advanced economy is home to only 16% of the world's population, it is responsible for 34% of global waste generation. However, the contribution of developing countries to the generation of waste has increased significantly in recent years,[130].

It is estimated that by 2025, the urban population will increase from 3 billion to 4.3 billion. This means that the amount of waste generated will double by 2025.

EU waste management policy requires a long-term systematic approach, including investments in regional waste collection, recycling and disposal schemes, as well as the closure of non-compliant landfills and incinerators (fig. 2.4), [97].

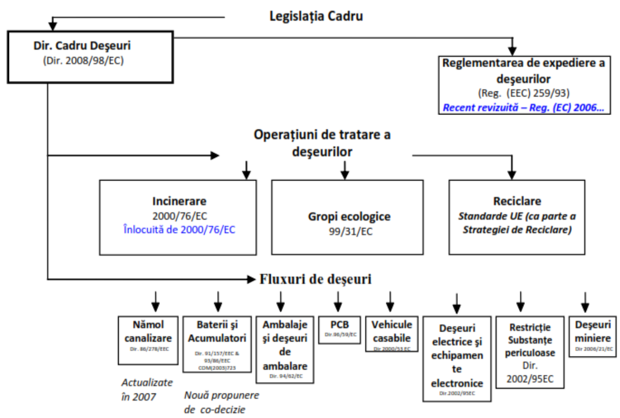


Fig.2.4. Overview of EU waste legislation, [125]

2.3. Classification of waste

The waste, according to the specific legislation in Romania, is defined as any substance or object that the holder throws away or has the intention or obligation to throw away, but it can also be analyzed / defined from the resource perspective, [124].

The identification of hazardous properties in waste is considered a priority for their classification and correct management. In 2018, in the Communication and Information section of the *Official Journal of the European Union*, the Commission published a Communication on technical guidelines on waste classification, which provides various technical guidance on the establishment of waste inventories, [118].

2.4.Physico-mechanical characteristics of the compacted material (wastes)

The characteristics of the waste are the main element on which depends the way in which it is made, operated and recovered, as well as the areas temporarily occupied for landfilling, depend.

The physical, chemical, mineralogical and geo-mechanical characteristics of waste are determined by several factors, including:

- the natural characteristics of the material before its use;
- the technological process they come from;
- the mode of transport and storage;
- Physico-mechanical stability over time, under loads, in relation to atmospheric conditions, in contact with water and other waste or materials

2.5. Conclusions

Waste is an unavoidable byproduct of most human activity activities. The properties of waste are the main factor on which it depends on how it is made, developed and recovered, as well as on the storage area that is temporarily occupied.

In practical terms, different types of materials that are valuable in terms of calorific value appear as a result of sorting waste, and they can be recovered by burning in cement plants or in combustion plants whose first result is the production of electricity. For the immediate analysis method, a document for the determination of the content of municipal solid waste in the mixture has been attached, a model which provides conclusive information on some physico-chemical characteristics

CHAPTER 3.WASTE COMPACTION SYSTEMS BY TRANSLATION IN MOBILE OR STATIONARY LOCATION

The purpose of compaction is to increase the density of waste, that is, to reduce the volume occupied by a certain amount of waste. The density increases, during compaction, from 0.2–0.3 t/m^3 to approximately 1 t/m^3. Thus, it is possible to increase storage capacityes, [98].

Compaction can be achieved both by means of mobile compactors and static presses, which are indispensable equipment for reducing the volume of waste. The pressing unit performs compaction of waste up to 20% of the initial dimensions. The horizontal pressing head is driven by electro-hydraulic equipment that copes with the most diverse types of waste. The robust construction of the presses, the use of high-strength materials and the reliable hydraulic system guarantee the maximum compression ratio and the long service life of the entire machine.

3.1.Factors influencing the compaction of bulky materials

In the literature, emphasis was placed on determining the distribution of unit weight and moisture content according to the depth and age of the waste. Even though compaction controls the efficient use of storage capacity and the stability of a landfill, well-developed guidelines for ground compaction practices are not available [42,88,114].

Similarly, limited information is available on the compaction of waste in the laboratory, in particular for fresh waste. In two studies, common soil testing procedures for fresh waste were used in geotechnical investigations on waste characteristics [88,98]. Compaction systems have evolved over the last 30 years. They were designed on experimental models and from this resulted several modes and principles of operation

Therefore,the main factors influencing the compaction/densification process may be the physico-mechanical properties of the materials,namely; the moisture content the material, the coefficient of frictions between the material and the walls of the pressing chamber, the rigidity of the material, the elasticity modulus and the coefficient of Poisson

Coefficients of friction, adhesion and cohesion

The maximum frictional force (limit) is the maximum force required to move a body, which is subjected to a normal force against another body at rest. Once the body begins to move, the frictional force decreases in comparison with the maximum frictional force. This lower frictional force is called the *sliding frictional force*

Experiments and determinations carried ou by researchers on physical processes of friction

Although most of the research concerns the coefficient of friction of agricultural materials in the seed area, however, some research has also been found regarding the coefficient of static friction of feed materials. By similarity we can expose some conclusions of the researches

Richter (1954) [89], for example, determined static and sliding friction coefficients for various feed materials. Snyder, Roller, and Hall (1967) [101] studied the effect of normal pressure and relative humidity on the coefficient of friction when sliding to wheat grains on various metal surfaces. Thompson and Ross (1983) [15] reported that the coefficient of friction in the grains of wheat per steel was affected by the moisture content of the wheat. It was found that the coefficient of friction increased with the increase in humidity from 8% to 20%, only to 24% the moisture content decreased. Lawton and Marchant (1980) [52] designed and manufactured a device for measuring the coefficient of friction of the seeds of agricultural crops

Poisson's modulus of elasticity and coefficient

Stroshine (2000) [27] proposes that the apparent modulus of elasticity be calculated on the basis of two different definitions called the definition of the secant and the definition of tangent. Norris and Bilanski (1969) [76] pointed out that the tear-resistant elasticity modulus for alfalfa strains was proportional to the volumetric weight of the stems and ranged from 0.9 to 6.8 GPa (1.3x105 to 9.87x105 psi). These values are very high for feed materials and are no longer reliable. O'Dogherty, Huber, Dyson and Marshall (1995) [77] studied the influence of plant maturity, the position of the stem internods, and the moisture content in the stem on the mechanical properties of wheat straw

Pressure to density ratio

There is a direct dependence between the applied pressure and the apparent density of the material during the compaction process. Hundtoft and Buelow (1971) [43] studied the relationship between tension and deformation during compression of loose lucerne. Experimental results show that wastes with larger particle sizes have higher pressure propagation properties, while materials with smaller particle sizes are less capable of transferring pressure, [115]. In particular, several models for the relationship between pressure and density have been reported that are either of power function or the form of exponential function

Specific mass of bulky waste

The specific mass, set in the loose state, before the househpld waste undergoes any further modification, the specific reference mass is also defined.

Time required for compaction

Shrivastava et al.(1990) use the following relationship (4.1) for the determination of the retention time of the compacted material [96]/

$$Y = \alpha_0 + \alpha_1 P + \alpha_2 T \qquad (3.x)$$

Particle size

Knowledge of particle sizes of the waste is an important factor in selecting the method of compaction or biologicak treatment of waste. Thos parameter is also relevant when slecting the waste sorting and re-use equipment.

3.2. Classification of the waste compaction systems

Compaction systems are classified from the point of view of the movement of active organs into:

- compaction systems by translation movement of active working organs
- compaction systems by the rotational movement of the working organs

Translation compaction systems may be classified into:

- compaction systems by translation, in stationary location .The systems of this kind are a compact assembly, positioned in fixed points, where waste is collected and compacted, and their unloading is carried out at regular intervals of time, by transporting with specialized vehicles to the treatment / processing sites.
- compaction systems by translation, in mobile location - the systems are permanently mounted on a carrier bus, with which collection and transport are executed, by moving from gate to gate

3.2.1. Translation compaction system in stationary location

The baling technique proved to be the most economical with high productivity being a promising method of landfilling for all waste incineration plants

Fig. 3.3. Baling- packing installation

In particular, baling-packaging technology has been studied in terms of physical, chemical and biological processes, mainly with regard to the environmental impact of gas and leachate emissions (at the final landfill). Up to a certain maximum size, bales wrapped in plastic are an environmentally promising option that solves the problems of leachate and biogas generation

Some compaction systems by translation may be provided with auxiliary systems for forming recyclable waste bales and binding them. They are intended for use in the recycling industry, for waste paper/plastic or cardboard.

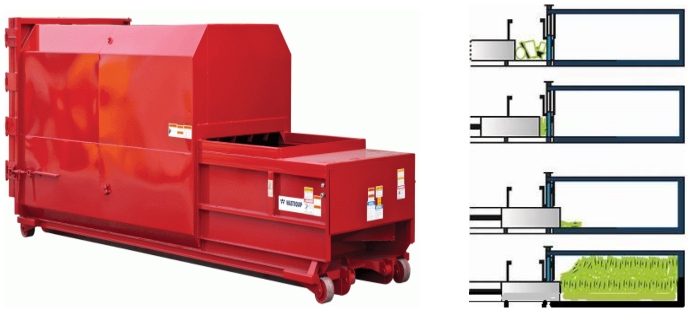


Fig.3.5. Translation compaction system in stationary location for dry waste

The robust construction with central compaction cylinder allows for the optimal distribution of compaction forces. High compaction force and operating capacity are the factors that contribute importantly to reducing the costs of waste transport

Fig. 3.8. Compaction system by traslation, with fixed location, for waste from building materials and removable container

3.2.2. Translation compaction systems in mobile location

These are complex equipment, consisting of a compact and load-bearing parallelepipedic structure, which continue auxiliary hydraulic, pneumatic and electrical control systems. They are located on chassis of various masses and configurations.

Their purpose is to collect/compact and transport in an economical and sanitary safety way, the household/municipal waste collected.

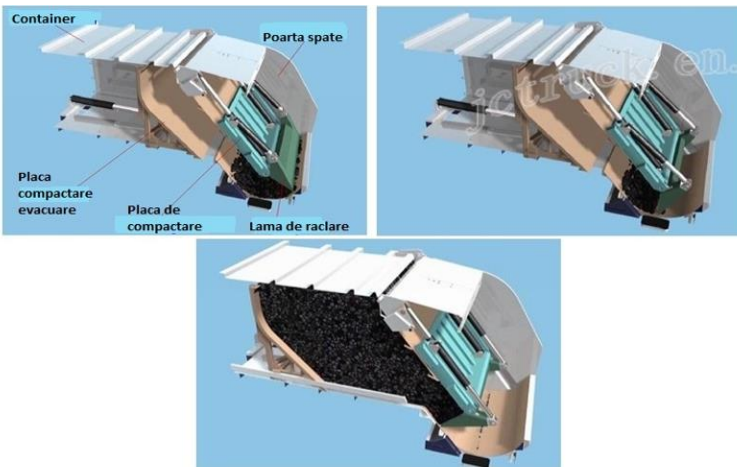


Fig. 3.12. Diagram of the flow of feed and compaction / storage of waste in a compaction equipment by translation

Rear-loading compaction system

In this ensemble we can observe 3 distinct component parts from the point of view of the functional role (fig.3.13)

- auxiliary container loading/unloading system positioned at the rear
- the pick-up/reception/pre-compaction system. It is attached to the pressing / compaction chamber, with multiple functionalities, such as: discharge cover of the pressing / compaction chamber, contains the pick-up and pre-compaction plates and hydropneumatic drive / movement control systems.
- the chamber for compaction/pressing of residues. It can be of several capacities (cubic meters), the side walls, the floor and the ceiling together with the compaction plate (exhaust blade), constitute the compaction chamber and implicitly the transport of residues

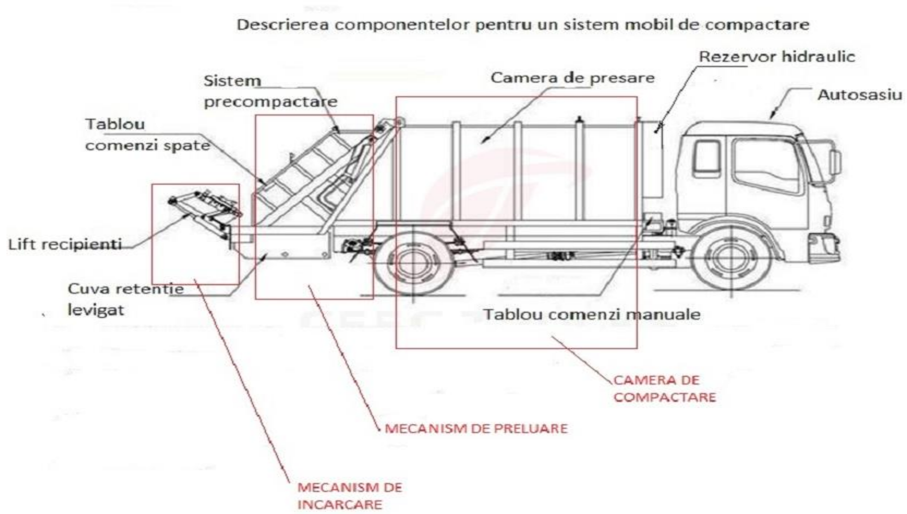


Fig. 3.13.Scheme of a specialized vehicle (equipped with compaction system in mobile location)

B. Compaction system in the placement of furniture – the arrangement of hydraulic cylinders

Depending on the type of container, the following are distinguished:

- the container of 4-7 cubic meters is attached to the device and lifted and overturned using the mechanism operated by the winch cylinder
- the container of small size (240 liters, 1100 liters), is caught in the lifting / rollover mechanism, set in motion by the minicontainer lifting cylinder.

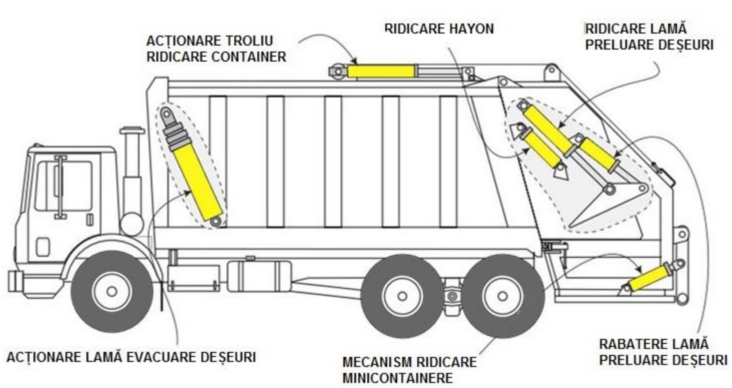


Fig. 3.14. The general scheme with the positioning of the hydraulic drive cylinders

C. Side loading compaction system

And these systems can identify the 3 main mechanisms:

- compacted waste storage room
- the system of reception and compaction of waste
- auxiliary container loading-lifting system

Unlike rear-loading systems, they do not have a compaction blade/plow inside the storage chamber, but the pressing is done by a blade (ram) positioned in the reception /compaction chamber (fig.3.15). The discharge of the collected residues is done by tipping the entire assembly and discharging the residues on the warehouse platform, through the back cover.

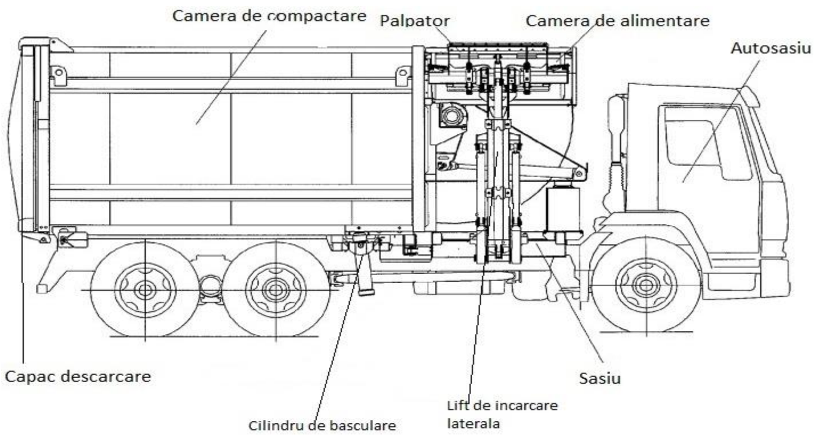


Fig. 3.15. General scheme of a vehicle equipped with a translational compaction system with side loading

3.3. Conclusions

The mechanical behaviour of municipal solid waste can be described analytically by linking relationships between process parameters, such as applied axial pressure and volumetric mass, within the limits of estimated initial conditions, but then the determined models must be validated by experimental research. From the mechanical point of view, the waste supply and precompacting systems are mechanisms with articulated bars and levers with movement in the longitudinal-vertical plane of the machine, with hydraulic or pneumatic drive. For the structural analysis of mechanisms, they are decomposed into component elements, drive couplings, moving elements and the degree of mobility of the mechanism are determined. By kinematic analysis of the mechanism, one can determine the positions, velocities and accelerations of the moving elements, but it is primarily of interest in the movement of its working elements.

CHAPTER 4. STATUS OF THE RESEARCH ON THE COMPACTION OF MUNICIPAL WASTE

4.1.Requirements for the construction of vehicles for the collection and transport of waste.

The construction of trucks for the collection and transport of waste imposes some sanitary requirements, [25]:

- ensure that the loading is as light as possible, without spreading, the release of dust and noise, the closed transport of waste and its rapid unloading;
- enable a useful load factor to be obtained, at an economical operation of the machine and at a maximum load capacity;

- be equipped with mechanisms for the continuous movement of the material loaded inside the machine, compacting and evenly distributing them throughout the surface of the machine;
- be as simple as possible, reliable and with a convenient operational safety coefficient; - have safe start and braking systems, because they start and stop often;
- comply with valid prescriptions regarding traffic on public roads and traffic safety.

The phenomenon of compaction observed for waste is explained by the increase in unit weight and **Gs** specific weight of solids in the mass of waste with an increase in the compaction effort. A sharp increase in unit weight occurs with a relatively low change in moisture content due in part to an increase in the unit weight of solids. The potential crushing and reorganization of the internal structure of the solid components of various materials present in the waste mass under high loads, that is, high compaction efforts lead to an increase in the density of solid matter

4.2. Synthesis of global research on the process of compaction of waste in fixed or mobile presses
4.2.1. Mathematical models proposed for the process of compaction of waste in fixed or mobile mills:

a) Ferrero, Horabik și Molenda (1990) [26] has proposed the following analytical model for the calculation of the coefficient of friction of straw between the mould shape, the length of the mould obtained and the pressure applied:

$$\mu = -\left(\frac{D}{4 \times P_r \times L_s}\right) \times \ln(P_b - P)$$

b) O'Dogherty și Wheeler (1984) [77] have introduced the following empirical models to demonstrate the pressure-density bond to compressed barley straws in a cylindrical mold:

$$P=0{,}000012\ \gamma s^{2}\ \text{pentru}\quad 150 < \gamma < 400 \text{kg/m}^3$$

$$\ln P=0{,}00226*(\ln(\gamma_s))^4-2{,}32\ \ \text{unde}\ \gamma_s > 400\ \text{kg/m}^3$$

4.2.2. The current state of experimental research on the compaction of municipal waste, using presses with movement by translation.

In paper [49], Pantic and his collaborators studied a new way of performing the Proctor compaction test, which is adapted to municipal solid waste, and the results obtained were used to perform an analysis with the results obtained using the standard hammer of the Proctor compaction test.

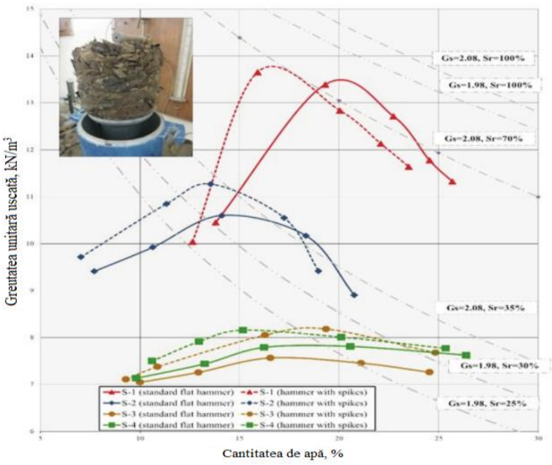


Fig. 4.12 Results obtained with proctor compaction test (standard hammer and hammer with spikes)

The results of the Proctor compaction test indicate certain changes in the behaviour of municipal solid waste during compaction using an innovative non-standard machine.

Another study, [39], aimed to evaluate household waste probing drilling that was used to assess the mechanical and biological properties of a waste column in Lincoln Bluff Road Landfill, Nebraska, to a depth of 28 m.

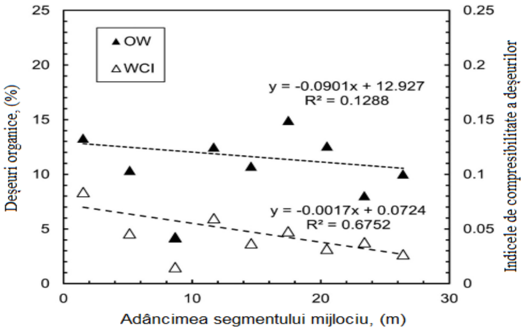


Fig.4.13 Organic waste (OW) and the compressibility index of waste (WCI) according to the depth in the landfill

Compaction is the process of densification of a material by reducing air voids. The degree of compaction is measured according to its dry density and depends mainly on its moisture content, compaction energy and the type of material.

CHAPTER 5. ASPECTS AND THEORETICAL CONTRIBUTIONS TO THE PROCESS OF COMPACTION OF WASTE BY TRANSLATION

5.1. Aspects regarding the physico-mathematical modeling of the compaction process in parallelepipedic structures with rectangular section

Afzalania [1,2] proposes another pressure-density relationship for the large cubic baler during the process of baling alfalfa and barley straws, experimentally confirmed, expressed by the following model:

$$\gamma = \gamma_0 + (A + BP + CP^2)(1 - E^{DP})$$

For more understandable description of the densification process in a piston press, Ivanova et al. [47] they divided the pressing chamber into three distinct zones and did the force analysis and pressure distribution during the passage of the material through it.

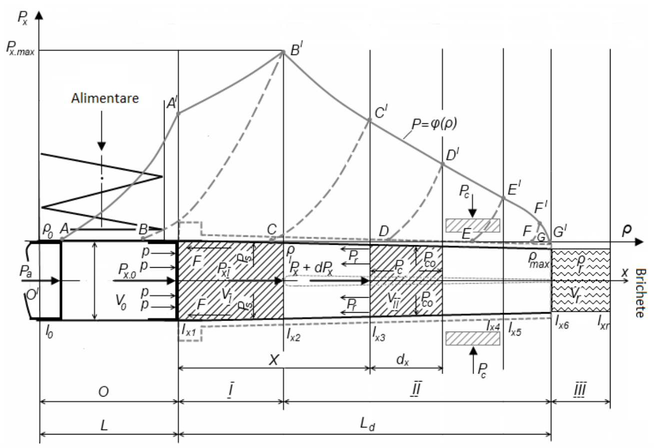


Fig.5.1. Model of the process of pressing biobriquettes in a hydraulic piston press, [47]

For the theoretical justification of the dependence of the Px pressing pressure on the volume mass of the material ρ in the pressing chamber, as well as in open channels, almost all researchers take over the hypotheses developed so far [47], such as:

- the initial volume mass (o is the same in all the material located in the compaction channel;
- the rules for modifying the volume mass in the bale material are linear;
- the normal voltages at each point of any cross-section of the pressing channel are the same
- the volume mass of the material continuously increases during the compression process,
- pressing efforts do not depend on the speed of deformation.

5.2. Kinematic analysis of waste collection mechanisms for mobile waste collection systems in mobile location, in order to optimize

In this subchapter, several constructive variants of supply systems are presented and their comparative analysis is made, both from a constructive and functional point of view. It also makes the kinematic analysis of a mechanism with bars and levers, used in a wide range of waste collection machines with compaction by translation

For the equipment shown in the previous chapters [61], the working positions and the parts of the supply and compaction system are shown in Fig. 5.3. These positions are somewhat characteristic of most of such mechanisms.

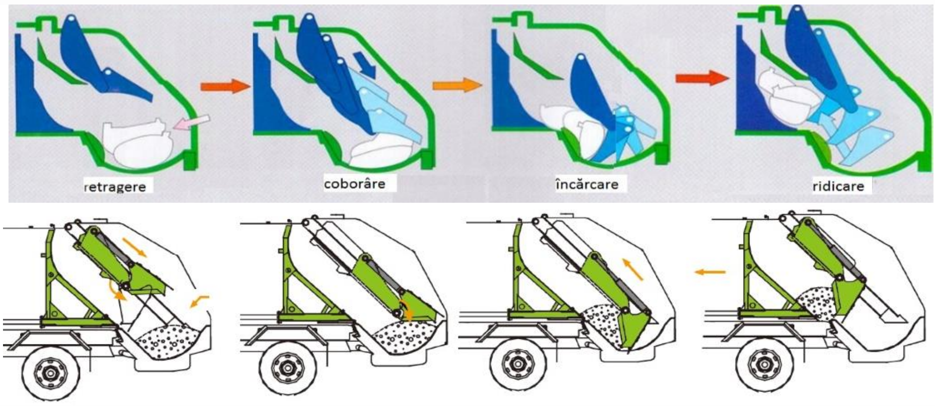


Fig.5.3. Compaction mechanism at a municipal waste collection machine (Value), [121]

When emptying, the receiving part of the vehicle is folded and the drain plate actuated by the telescopic hydraulic cylinder moves the material behind the container and pushes it out.

Other pick-up and compaction mechanisms for rear-loading cars are shown in Fig.5.5. The degree of compaction achieved by these mechanisms can be 1:3 – 1:4, bringing the waste to a density of 0.6 – 0.8 t / m3.

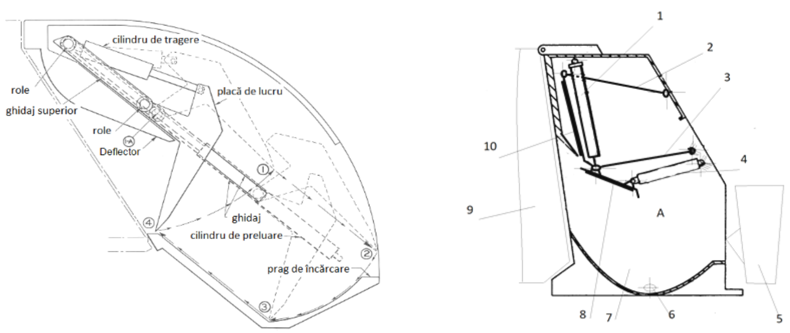


Fig.5.5.Some compaction mechanisms for MSW collection machines, [72, 111,b, 138]
1,4.hydraulic cylinders; 2,3.swivel arms; 5.container; 6,7.reception tank; 8.mobile plate; 9.compaction container; 10.Compaction plate

The compaction system in fig.5.3 was schematized in the form of the mechanism in fig.5.6 for which the kinematic analysis was performed. The A, D, F and H points represent fixed joints, while the joints C, E and G are mobile when acting on the elements of the mechanism by means of hydraulic AC and HG cylinders. Couplings B and I are translational couples, representing the pistons of hydraulic cylinders.

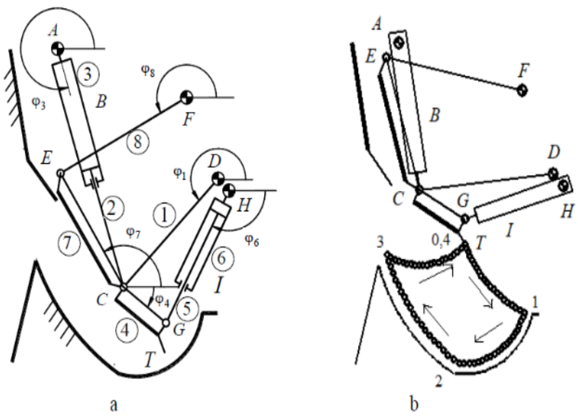


Fig.5.6.Kinematic diagram of the pressing mechanism (a) and the motion diagram of the tracer point T (b), [5, 60, 61, 72, 72,a]

For the numerical analysis of the kinematics of the mechanism in fig.5.6, the following constructive characteristics were used (in correlation with the actual dimensions of a specific machine):

1. The dimensions of the elements and the positions of the adjacent couplers are: CE = 0.76 m, CD = 0.86 m, CG = 0.33 m, EF = 0.89 m, GH = 0.83 m, XD = 1 m, YD = -0.73 m , XF = -0.8 m, YF = -0.27 m, XH = 1.07 m, YH = -0.8 m;
2. initial position of the mechanism: S230 = AC = 0.66 m, S560 = GH = 0.83 m;
3. working stroke of the pistons of the hydraulic cylinder: C23 = 0.59 m, C56 = 0.39 m
4. the relative speeds between elements 2 and 3, respectively 5 and 6 (relative speeds in translational couplings B and I): v23 = ±0,05 m/s (the plus sign is considered when the piston rod exits the cylinder and minus sign when the piston rod enters the cylinder), v56 = ±0,05 m/s;
5. the relative accelerations between elements 2 and 3, respectively 5 and 6 (relative accelerations in translational couplings B and I): a23 = 0 m/s2, a56 = 0 m/s2.

For the structural analysis of the mechanism, the kinematic couplings, the mobile elements and the degree of mobility of the mechanism were determined.

The mechanism shown in fig.5.6 is a synchronous one in which the CT and CE compaction plates have synchronous movement determined by the two hydraulic ac and HG cylinders, respectively. The initial position of the mechanism is the top position where both the AC cylinder and the HG cylinder are in the closed position so that the T-point, called the tracer, is in position 0.

For each of the two hydraulic cylinders, the calculation program has 20 intermediate positions so that by opening the AC hydraulic cylinder, the tracer point T follows the trajectory 0-1 of the figure in which the CT pick-up plate begins to take over, on the width of the machine, the volume of solid waste from the receiving part of the machine, closing the connection to the outside.

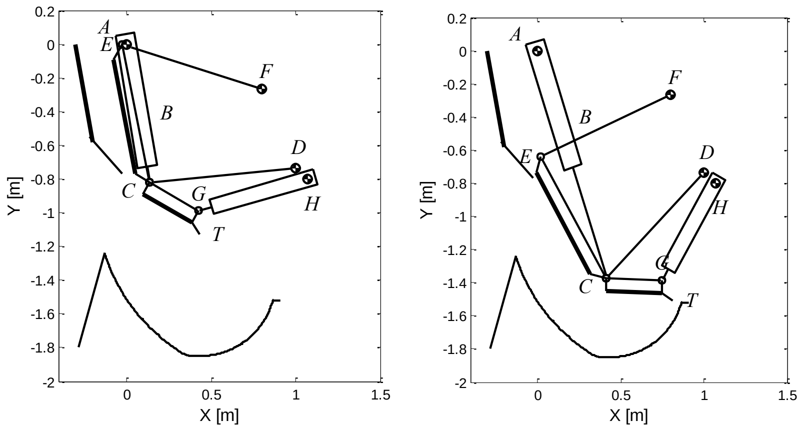


Fig.5.7. The first intermediate positions of the elements of the pressing mechanism in fig.5.6, [111,d]

In Fig.5.9 shows the kinematic diagrams of the structural groups, on the basis of which the formal parameters of the calculation procedures were selected.

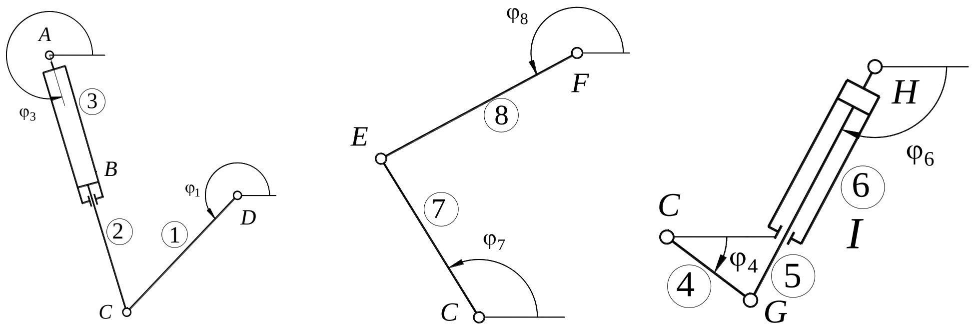


Fig.5.9. Kinematic diagrams of the structural groups in the composition of the mechanism

(a) the RRTaR engine group (1,2,3); b) RRR diada (7,8); c) engine group RRTaR (4,5,6)

Table 5.2 shows the numerical values of the kinematic parameters of the positions for the elements of the mechanism, for values from 45 to 45°.

Table 5.2

Poz.	φ_1	φ_3	φ_4	φ_6	φ_7	φ_8
0	-3.0390	-1.4085	-0.3369	-2.9437	1.8536	-3.3513
1	-3.0385	-1.4086	-0.3366	-2.9431	1.8538	-3.3507
2	-3.0346	-1.4088	-0.3347	-2.9388	1.8553	-3.3465
3	-3.0244	-1.4093	-0.3297	-2.9277	1.8593	-3.3355
4	-3.0055	-1.4100	-0.3204	-2.9071	1.8667	-3.3152
5	-2.9764	-1.4103	-0.3061	-2.8753	1.8778	-3.2842
			....			
24	-2.3151	-1.2802	-0.0358	-2.1222	2.1090	-2.6285
25	-2.3151	-1.2802	-0.0935	-2.1095	2.1090	-2.6285
26	-2.3151	-1.2802	-0.1695	-2.0958	2.1090	-2.6285
27	-2.3151	-1.2802	-0.2618	-2.0836	2.1090	-2.6285
28	-2.3151	-1.2802	-0.3671	-2.0749	2.1090	-2.6285
29	-2.3151	-1.2802	-0.4819	-2.0713	2.1090	-2.6285
30	-2.3151	-1.2802	-0.6023	-2.0732	2.1090	-2.6285
31	-2.3151	-1.2802	-0.7241	-2.0803	2.1090	-2.6285
			....			
70	-3.0390	-1.4085	-1.0760	-2.7729	1.8536	-3.3513
71	-3.0390	-1.4085	-0.9535	-2.7820	1.8536	-3.3513
72	-3.0390	-1.4085	-0.8326	-2.7978	1.8536	-3.3513
73	-3.0390	-1.4085	-0.7171	-2.8198	1.8536	-3.3513
74	-3.0390	-1.4085	-0.6106	-2.8465	1.8536	-3.3513
75	-3.0390	-1.4085	-0.5169	-2.8752	1.8536	-3.3513
76	-3.0390	-1.4085	-0.4402	-2.9023	1.8536	-3.3513
77	-3.0390	-1.4085	-0.3847	-2.9239	1.8536	-3.3513
78	-3.0390	-1.4085	-0.3520	-2.9373	1.8536	-3.3513
79	-3.0390	-1.4085	-0.3388	-2.9429	1.8536	-3.3513
80	-3.0390	-1.4085	-0.3369	-2.9437	1.8536	-3.3513

Based on the results of Table 5.2, fig.5.9 shows the angle variation diagram (1, (3, (4, (6,, (7, (8).

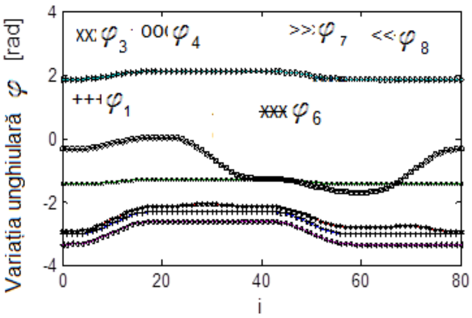


Fig.5.10. Angle variation diagram (1, (3, (4, (6,, (7, (8)

In Fig.5.11 shows the diagrams of the angular velocity of the elements of the mechanism and in Fig.5.6, the corresponding angular acceleration diagrams.

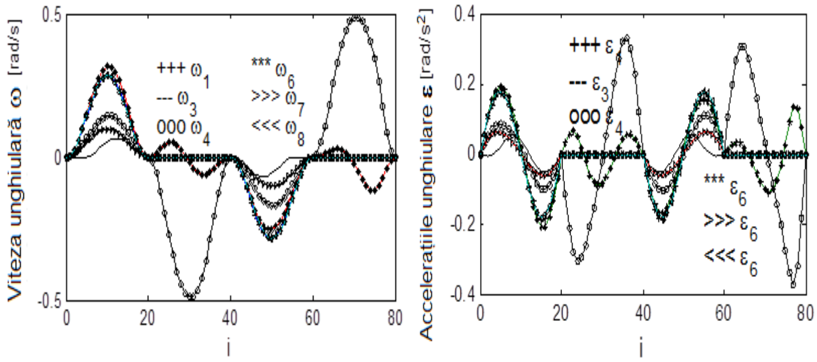


Fig.5.11. Variation diagram of angular velocities ((a) and angular accelerations ((b), corresponding to angles (i)

From the analysis of the hodographs of the angular velocities (fig.5.11,b) of the working element 4 (fig.5.8) it is observed that it follows a cyclic variation with maximum values (about 0,5 rad/s) for positions 30 and 70 respectively of the drive element (i.e. the hydraulic drive cylinder), on the push stroke and on the retraction stroke respectively. The same cyclic variation is observed for the angular acceleration of working element 4 (see Fig. 5.12), maximum values for which are noted for four positions of the mechanism (i.e. the hydraulic actuator cylinder).

In order to verify the results obtained by kinematic analysis, the driving forces in the hydraulic cylinders and the method of virtual exponents were determined, and the results were identical to those in the kinetic calculations. Depending on the driving forces in the hydraulic cylinders, cylinders can be chosen from the manufacturers' constructive offer. For the collection and compaction of waste, the constructive form of kinematic elements can be chosen by machine designers.

Fig.5.12 shows the graphs of the angular speed and acceleration of the elements of the mechanism for the 20 positions of the hydraulic cylinders in the normal working process (trajectories of the curvilinear parallelogram in Fig. 5.6,b). It is found that for trajectory positions 0-1 and 2-3, the angular velocities of element 4 (pick-up plate) are relatively constant, while for trajectories 1-2 and 3-4, the angular velocities are very different from the others, with a positive sense (the travel to close the HG hydraulic cylinder) or negative (the opening stroke of the HG hydraulic cylinder).

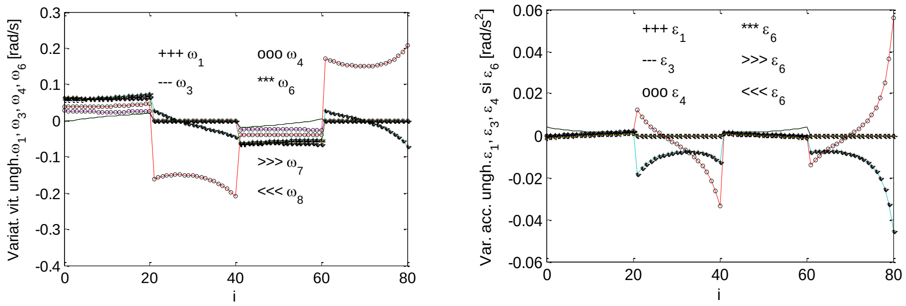


Fig.5.12. Angular speeds and angular accelerations of the elements of the mechanism for a full work cycle, [5, 60, 61, 72, 111,d]

For a sinusoidal variation law of the motion of the two rods of the hydraulic cylinder, the speed and acceleration handographs of the tracer point T (the upper part of the pick-up and compaction plate) are shown in Fig. 5.13. There is a cyclic distribution of T-point velocities on the horizontal and vertical axis necessary for a good takeover of the material from the palette without significant losses and a distribution of the bike accelerations that imprint different forces along the point trajectory.

The maximum acceleration at point T (0,202598 m/s2) shall be recorded in zone 2 to 3 of the trajectory, where the resistance forces are maximum.

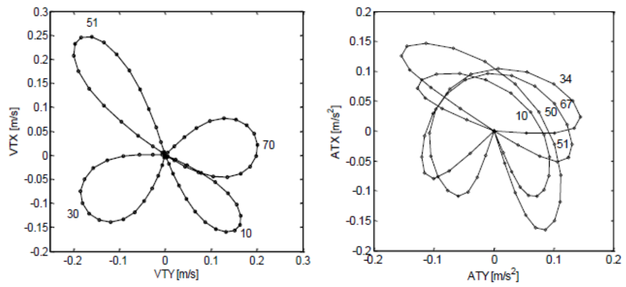


Fig.5.13. Speeds and accelerations of the T-tracer point hodograph of the waste collection and precompaction mechanism in rear-fuelled machinery, [72, 111,d]

For the equipment of the ValuE Pack residue collection machine, the working positions and parts of the feed and compaction system are shown in fig.5.14.

Note: These positions are somewhat characteristic of most of these mechanisms

Thus, in position (a), the waste collection and pressing plate is in a high position, and its side consoles are in a retracted position, allowing the supply of fresh waste from the hopper. The subsequent movement of the pressure plate must follow the contour of the hopper, which is visible in positions (b, c, d) of fig.5.14. Therefore, position (b) (fig.5.14), shows the yoke in the lowered position. towards the rear of the entire machine, with the pressure plate whose outer end passes the trajectory 2

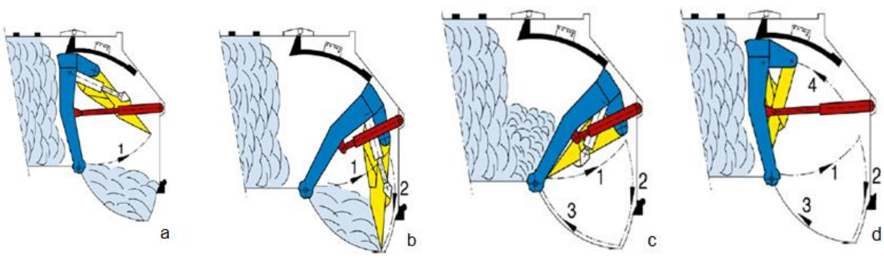


Fig.5.14. Compaction mechanism of value waste collection machine, [111,c] a.the cylinders of the pressing panel push the pressing panel to the outside; b. the cylinders of the yoke pull the yoke back; c.the cylinders of the pressing panel pull the pressing panel towards the yoke; d.the yoke cylinders push the yoke inwards

In the next position (c), the hydraulic cylinders for operating the pressure plate are closed and the plate follows trajectory 3 in the figure, raising the hopper waste over the previously deposited waste, and in the last position of the mechanism (d), the yoke presses the large waste (by trajectory 4) and causes the vertical compaction plate in the truck system to move slightly under the pressure of the waste. After that, the pressure plate of the power mechanism will be withdrawn to the initial position by trajectory 1 and the process of supply and compaction will resume until the entire warehouse is filled.

The compaction system in fig.5.14 was schematized in the form of the mechanism in fig.5.15 for which the kinematic analysis was performed. The A and D points represent fixed joints, while the B, E, F and G joints are mobile, when acting on the elements of the mechanism by means of hydraulic cylinders C and H.

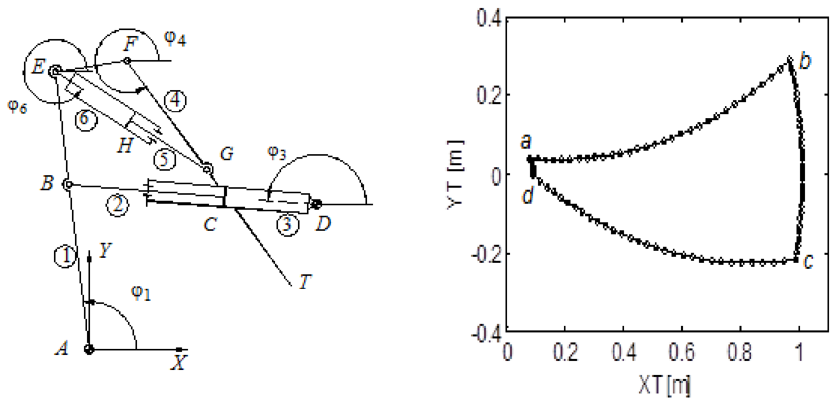


Fig.5.15. Kinematic diagram of the pressing mechanism (a) and the motion diagram of the point scroll T(b), [72,111,c]

For the numerical analysis of the kinematics of the mechanism from fig.5.14, the following constructive characteristics were used:

1. The dimensions of the elements and the positions of the adjacent couplings are: AB=0.8 m, AE=1.35 m, BE=0.55 m, EF=0.35 m, AF=1.4 m, FG=0.65 m, GT=0.700 m, FT=1.35 m, XA=0, YA=0, XD=1.1 m, YD=0.7 m, (=0.252648 rad, ((((AE, AF);

2. initial position of the mechanism: S230 = BD = 0.8 m, S560 = EG = 0.67 m;

3. the working stroke of the pistons of the hydraulic cylinder: C23 = 0.4 m, C56 = 0.2 m;

4. the relative speeds between elements 2 and 3, respectively 5 and 6 (relative speeds in translational couples C and H): v23 = ±0,05 m/s (the plus sign is considered when the piston rod exits the cylinder and the minus sign when the piston rod enters the cylinder), v56 = ±0,05 m/s;

5. the relative accelerations between elements 2 and 3, respectively 5 and 6 (relative accelerations in translational couples C and H): a23 = 0 m/s2, a56 = 0 m/s2.

For the structural analysis of the mechanism, the kinematic couplings, the mobile elements and the degree of mobility of the mechanism were determined.

Kinematic analysis of the mechanism consists in determining the position, speed and acceleration parameters corresponding to all elements. The highlighting of the angles made by the vectors attached to the kinematic elements in the positive direction of the AX axis are shown in fig.5.16 (a), and in fig. 5.16 (b) the motion diagram of the tracer point T of the mechanism is presented.

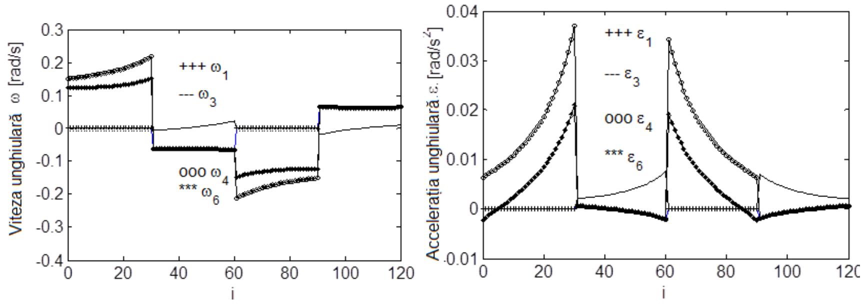


Fig.5.16. Angular speeds and angular accelerations of the elements of the mechanism for a full work cycle, [111,c]

The movement of the elements of the mechanism must be well established in such a way that the pressing plate can pick up the waste from the receiving hopper, lift it onto the pressure plate from the vehicle bin and press it over the previously deposited waste

Mechanisms with bars and levers can be used in a wide range of variants of systems and machines with waste pre-compaction systems. Elucidation of the movement of the working organs of these mechanisms is necessary for a good understanding of their functioning, but especially for the redesign and improvement of functional parameters for low-energy operation.

In conclusion, the mechanisms of compaction plates of waste machines are usually flat mechanisms with articulated bars driven by hydraulic cylinders. The movement of the elements of the mechanism must be correlated with the movement of the waste collection plate from the receiving part of the machine so as to retrieve the material from the unloading funnel, lift it and push it over the previously collected waste in the collection container. Thus, the upper part of the pick-up plate follows predetermined trajectories along the trajectory, trajectories that can be determined by kinematic analysis of the drive mechanism. The speed or acceleration of the pick-up plate or plates and of the compaction plates also follows predefined distributions depending on the movement of the hydraulic cylinders and the pressure in the hydraulic system.

5.3. Kinetic analysis of the waste collection mechanism at mobile waste collection systems in mobile location, in order to optimise

The kinetic analysis of the mechanism presented in the previous subchapter starts from the initial position, i.e. from the position where the hydraulic cylinders 2-3 and 5-6 are in their original position, [55, 72,a].

For the kinetic analysis of the mechanism, the applied and inertial forces in the centers of gravity of the elements are reduced, after which the functions corresponding to each structural group are used. It is observed that the kinetic analysis is performed in reverse kinematic analysis, i.e. from the last kinematically analyzed structural group (RRTaR motor diode (4,5,6)) and ends with the first group (RRTaR motor group (1,2,3)).

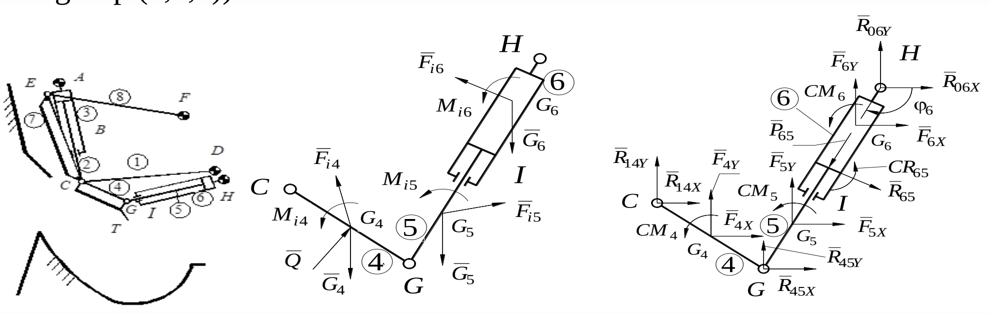


Fig.5.10. Initial position of the mechanism and elements of the RRTaR engine group(4,5,6), [55, 72,a] a) the initial position; b) highlighting the forces and moments acting on the elements of the structural group; c) kinetic diagram of the RRTaR engine group (4,5,6)

a. Power group RRTaR (4,5,6)

the motor diode element RRTaR(4,5,6) actions (fig.5.10,b):

- Gravitational forces::

$$\overline{G}_4 = -m_4\overline{g}\,,\ \overline{G}_5 = -m_5\overline{g}\,,\ \overline{G}_6 = -m_6\overline{g} \tag{5.19}$$

- Forces of inertia:

$$\overline{F}_{i4} = -m_4\overline{a}_{G4},\ \overline{F}_{i5} = -m_5\overline{a}_{G5};\ \overline{F}_{i6} = -m_6\overline{a}_{G6}; \tag{5.20}$$

- The resulting moments of the forces of inertia:

$$\overline{M}_{i4} = -IG_4\cdot\overline{\varepsilon}_4,\ \overline{M}_{i5} = -IG_5\cdot\overline{\varepsilon}_6\,,\ \overline{M}_{i6} = -IG_6\cdot\overline{\varepsilon}_6 \tag{5.21}$$

- Technological forces: Q.

Force reduction point systems will be considered in the centres of gravity G4, G5 and G6, corresponding to elements 4, 5 and 6. The kinematic parameters of points G4, G5 and G6 are calculated using the procedure A1R, [84, 85].

The reactions in the kinematic couplings of the engine groups, together with the force acting in the hydraulic cylinder, form the existing data of the A2RC procedure.

b) Diada RRR (7,8)

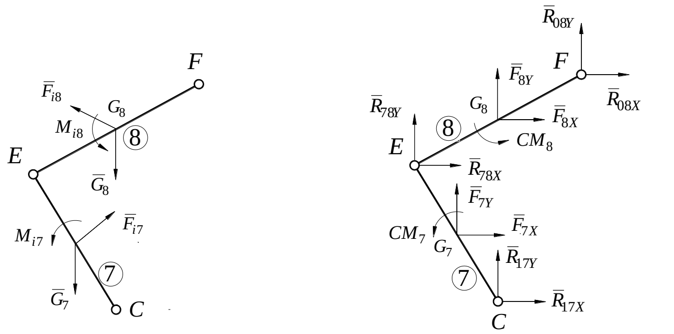


Fig.5.11. Diada RRR(7,8)

a) highlighting the forces and moments acting on the elements of the structural group; b) the kinetic scheme of the RRR diade(7,8), [55, 72,a]

c) Motor group RRTaR (1,2,3)

On the elements of the RRTaR motor diode (1,2,3) acts (fig.5.13,a):

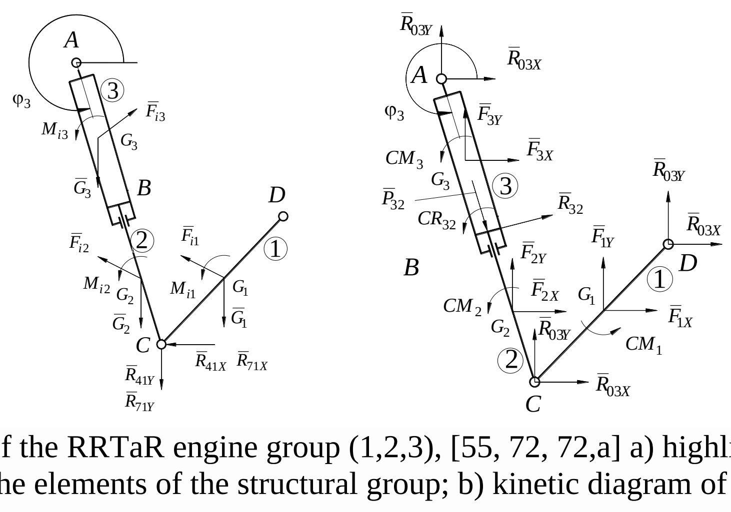


Fig.5.12. Elements of the RRTaR engine group (1,2,3), [55, 72, 72,a] a) highlighting the forces and moments acting on the elements of the structural group; b) kinetic diagram of the RRTaR engine group (1,2,3)

The points of reduction of system forces in the centres of gravity G1, G2 and G3, corresponding to elements 1, 2 and 3, were taken into account. The kinematic parameters of points G1, G2 and G3 are calculated using the procedures A1R and A1RALFA, [59,61,84,85].

Applying the theoretical method described below, by simulating the work process of a machine intended for the collection of municipal residues, for constructive dimensions corresponding to those on the machine, the elements presented below resulted.

For kinetic analysis of the mechanism were used:
a) kinematic diagram of the mechanism (fig.5.10,a);
b) the positions of the coupling adjacent to the base and the dimensions of the elements, as follows: XA = 0 m, YA = 0 m, XD = 1.0 m, YD = –0.733 m, XF = 0.800 m, YF = –0.270 m, XH = 1.1 m, YH = –0,800 m, CE = 0,770 m, CD = 0,870 m, EF = 0,900 m; CG = 0,330 m;
c) phase working times: t1 = t2 = t3 = t4 = 5 sec,
d) initial position of the mechanism: S230 = 0.833 m, S560 = 0.667 m;
e) hydraulic cylinder piston: stroke 23 = 0.600 m, stroke 56 = 0.400 m;
f) hydraulic cylinder piston road length: d2 = 0.700 m, d5 = 0.550 m;
g) the mathematical function used to actuate the hydraulic cylinder: sinusoidal function Isin;
(h) masses of the elements of the mechanism: m1 = 10,0 kg, m2 = 5,0 kg, m3 = 10,0 kg, m4 = 20,0 kg, m5 = 5,0 kg, m6 = 10,0 kg, m7 = 20 kg; m8 = 20 kg
(i) the position of the centres of mass: DG1 = CD/2, CG2 = d2/2 m, AG3 = 0,4 m, CG4 = CG/2 m, CG5 = d5 / 2 m, AG6 = AD/2 m, FG7 = 0.3 m, EG8 = 0.3 m;
j) the moments of inertia of the elements: IG1 = 0.6 kgm2, IG2 = 0.2 kgm2, IG3 = 1.1 kgm2, IG4 = 0.2 kgm2, IG5 = 0.3 kgm2; IG6 = 0.35 kgm2, IG7 = 1.0 kgm2; IG8 = 0.9 kgm2;
(k) technological resistances:
- Q = 1000 N, for branches cb and cd of the diagram in fig.5.11;
- Q = 0 N, for the branches ab and yes of the diagram in fig.5.11;

In Fig.5.13 and fig.5.14 show the hodographs of reactions in joints D and A.

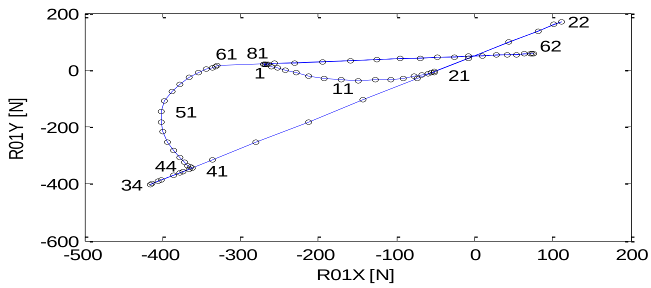


Fig.5.13. Reaction hodograph in the D-joint [55, 72,a]

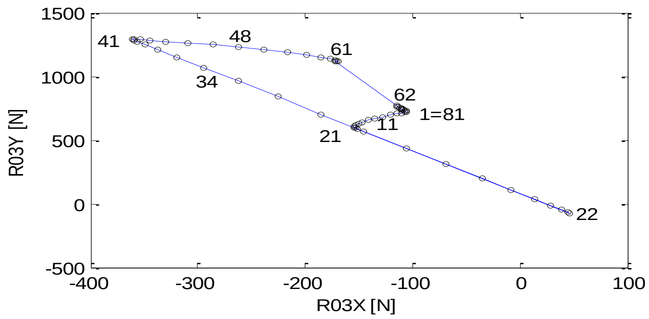


Fig.5.14. Reaction hodograph in joint A, [55, 72,a]

The diagrams of the drive forces in the hydraulic cylinders formed with elements 2 and 3, respectively 5 and 6, depending on the position of the mechanism, are shown in fig.5.15,a,b.

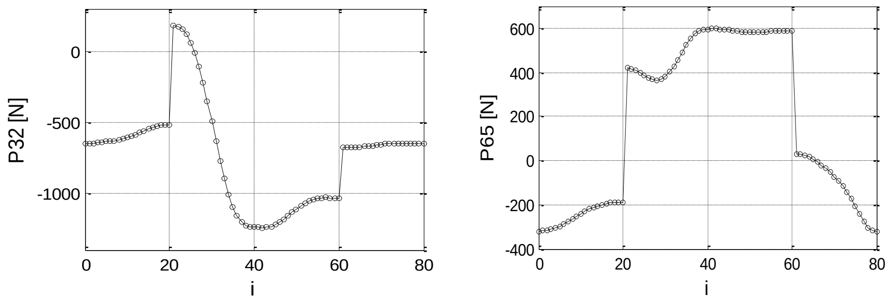


Fig.5.15. Diagram of the driving forces[55, 72,a] (a) from hydraulic cylinder 2-3; (b) from hydraulic cylinder 5-6

Table 5.1 shows the size of the components on the coordinate axes of the reactions in the kinematic couplings D and H, depending on the position of the mechanism.

Table 5.1

POZ	R03X	R03Y	R01X	R01Y	R06X	R06Y
0	-109.94	741.26	-270.33	21.23	319.51	133.34
1	-109.47	738.49	-269.12	21.12	318.27	133.21
2	-108.83	735.68	-267.31	20.18	316.04	134.08
3	-107.95	732.80	-264.33	17.71	311.97	136.80
4	-106.91	729.80	-259.54	13.26	305.42	141.96
5	-106.03	726.56	-252.32	6.71	296.07	149.74
6	-105.84	722.86	-242.13	-1.57	283.88	159.90
7	-106.92	718.33	-228.63	-10.84	269.10	171.86
8	-109.70	712.50	-211.86	-20.03	252.22	184.80
9	-114.27	704.89	-192.29	-27.98	233.84	197.85
10	-120.37	695.14	-170.84	-33.67	214.68	210.20
11	-127.38	683.21	-148.70	-36.45	195.53	221.19
12	-134.53	669.45	-127.21	-36.18	177.19	230.38
59	-171.60	1118.15	-329.85	14.84	-550.33	-111.01
60	-172.11	1121.07	-329.41	15.15	-550.80	-110.73
61	-114.07	766.47	75.80	56.85	-21.98	72.42
62	-114.00	766.04	74.42	56.71	-20.20	72.94
79	-109.81	740.44	-267.56	21.52	316.33	132.87
80	-109.94	741.26	-270.33	21.23	319.51	133.34

From the performed analyses, the values obtained for the reaction forces through the kinematic analysis of the mechanism allow the transition to the next stage, i.e. the real design of the kinematic elements.

In order to verify the results obtained by kinematic analysis, the driving forces in hydraulic cylinders and the method of virtual exponents were determined, and the results were identical to those in the kinetic calculations. Depending on the driving forces in the hydraulic cylinders, cylinders can be chosen from the manufacturers' constructive offer. For the collection and compaction of waste, the constructive form of kinematic elements can be chosen by machine designers.

5.4. Simulation with finished elements of the resistances of the compaction / discharge plate from the mobile municipal waste collection systems

In the case of mechanical stress, the most common method of analysis is finite element analysis. Many such analyses can be found in the literature, even in the case of machines for collecting municipal waste, [56].

This 3D numerical simulation with finished element actually aims to simulate the behavior of the compression plate structure of a Valu€ Pak Lift 1000 waste collection and transport machine following the requests that arise during the household waste compaction process, considering that the plate is made of three different materials (Hardox 400 steels, Hardox 450 and S355J2).

The waste compaction system of such a machine consists of two basic parts, a metal plate with an articulated support that takes the material from the supply area of the machine, having a complex movement, and a backpressure plate arranged in the parallelepipedic collection container

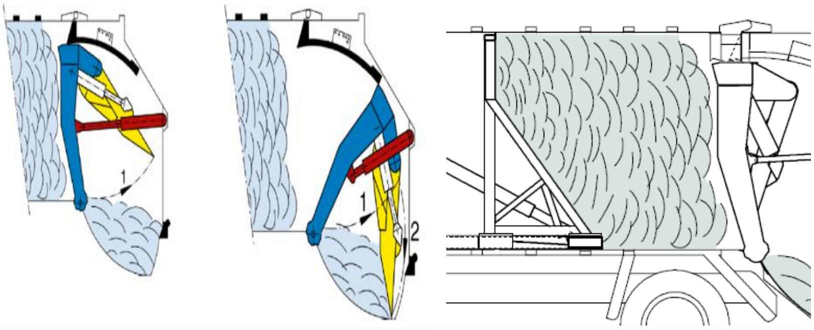


Fig.5.16. Waste compaction system in waste machines Valu€ Pak 1000, [56]

In both parts, important stresses occur during the collection and compaction process, but much higher in the pushing and pick-up piece when refueling the container. When unloading, the backpressure plate shows high loads because it has to push the entire amount of material from the container, all the more uneven as the material is more inhomogeneous on the cross-section of the collection container.

In the first stage of the analysis, the three-dimensional geometrical model of the assembly components (compression plate, backpressure plate, wear piece and garbage truck bucket) was performed. For this purpose, an ASUS K55V model laptop was used, containing an Intel Core i5-3210M processor, 2.5 GHz, an NVIDIA GeForce GT 630M graphics card with its own memory of 2 Gb, the laptop's RAM being 8 Gb. 3D modeling was achieved using the solid works premium 2016 S.P. 0.0 parameterized design program.

The three-dimensional modeling of the assembly components was performed in the "Parts" module of the design program, in fig.5.17 being presented the isometric view of the compaction plate, as well as the solid works program interface.

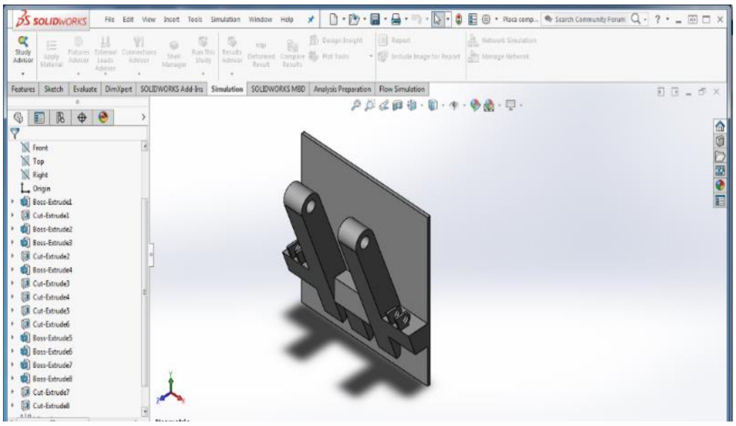


Fig.5.17. Isometric view of the compression plate, [56]

The pieces were introduced in the Assembly module of the program where they were positioned by adding geometric relationships between their entities (relations of concentricity, coincidence and parallelism between edges and faces). For the dynamic simulation of the household garbage compaction process, the compaction material was also modeled between the two plates (compaction and backpressure). For this we chose a thickness at the bottom of about 580 mm, see fig.5.18.

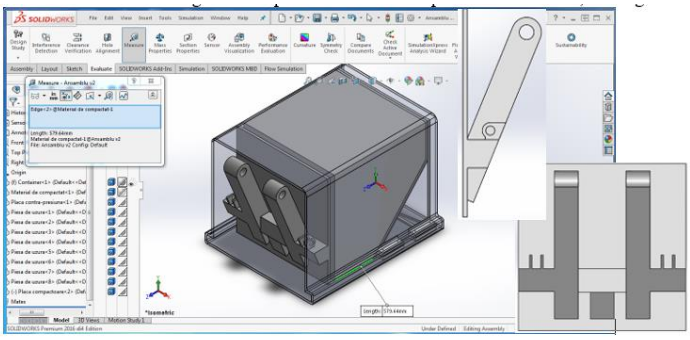


Fig.5.18. The assembly introduced in the Motion Study module, [56]
(with side and rear view of the pressure plate)

The entire assembly from fig.5.18 was introduced in the Motion Study module to perform the dynamic simulation of the household garbage compaction process. For this purpose it was considered that the backpressure plate is fixed together with the compacting material, and the compactor plate moves towards it. According to Manring N et al. [56] the displacement speed of the compaction plate without load is a maximum of 150 mm/s, at the beginning of the compaction process the travel speed is 75 mm/s and reaches the end of compaction at 20 mm/s. Thus, a linear variable-speed motor was attached to the compaction plate (see Fig. 5.19). It should also be noted that the calculation period (dynamic simulation) was 12 s

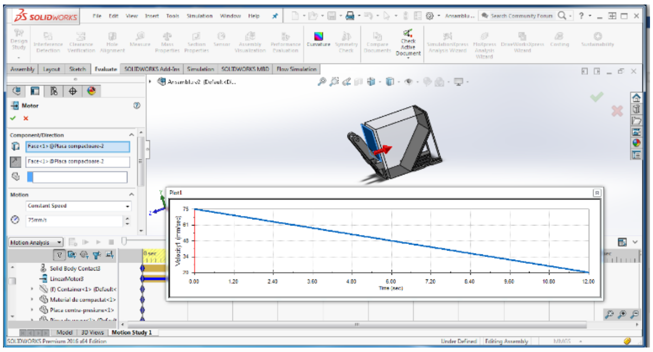


Fig.5.19. Linear motor attached to the compactor plate, [56]

After this stage was completed, we proceeded to the next stage, which consisted of importing the requests for the 3D geometric model of the compaction plate into the "Simulation" module of the Solid Works design program.

According to the technical sheets of the manufacturers, the materials most often used in the manufacture of compression plates are Hardox 400, Hardox 450 and S355J2 steels. Fig.5.20 shows the fatigue resistance curves of the three materials.

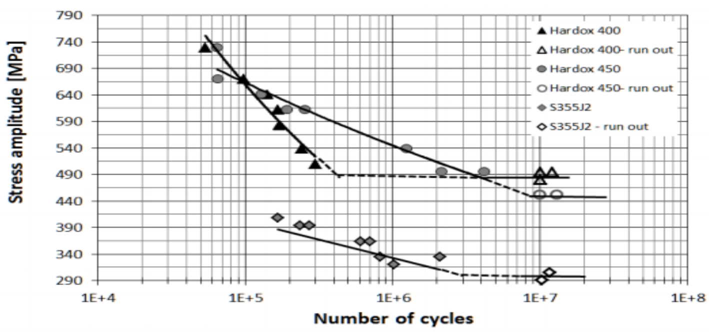


Fig.5.20. Fatigue curves for Hardox 400, Hardox 450 and S355J2 steels[56,66]

The discrete finished pattern of the compression plate is shown in Fig.5.21. After the discretization of the finite element network, the simulation was run, the results of which were presented below. It should be noted that the simulation was carried out with the "Large displacement" option selected.

Following the simulation, the design programme provided the results obtained in graphical form; the geometric pattern is divided into areas of a certain color, each area comprising the region of the geometric pattern in which the size analysed has the value specified in the chromatic legend on the right-hand side of the screen. It should be noted that three simulations were run, one for each of the three steels chosen (Hardox 400, Hardox 450 and S355J2).

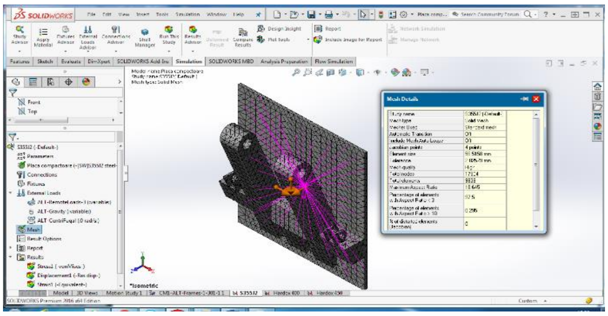
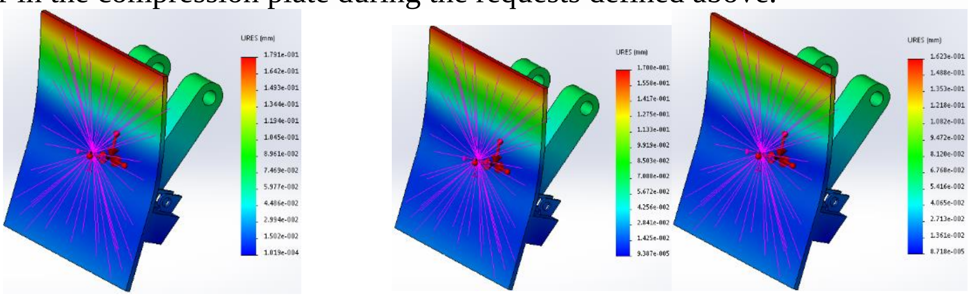


Fig.5.21 Finite element discretisation of geometric pattern, [56]

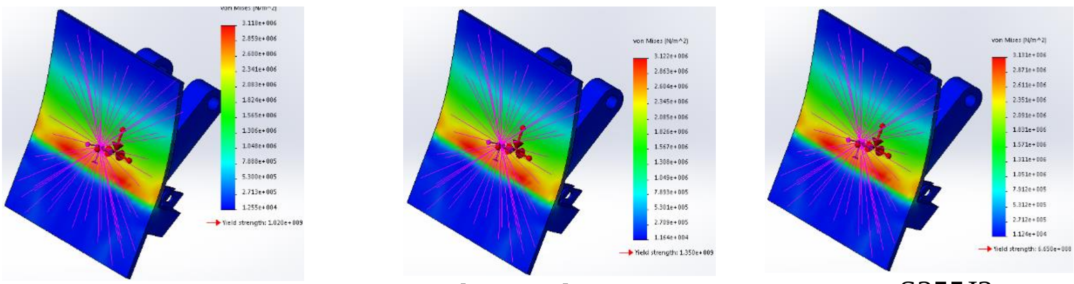
For the modeled and analyzed compression plate model, the results obtained from the simulation in Solid Works are presented below. Thus, fig.5.22 shows the values of the displacements that appear in the compression plate during the requests defined above.



a. Hardox 400 b. Hardox 450 c. S355J2

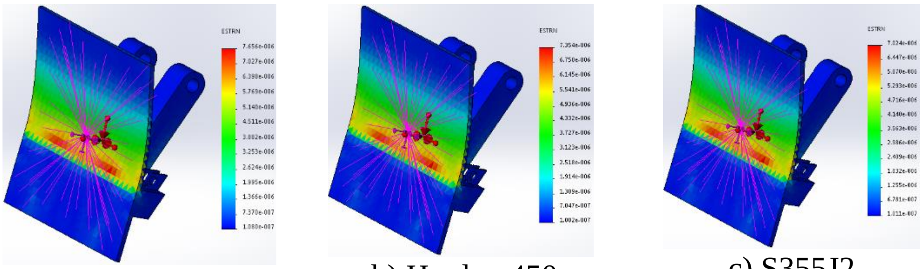
Fig.5.22. Displacement values occurring in the compression plate, [56]

Analyzing these data, it can be seen that the displacement values are close (179 µm for Hardox 400, 170 µm for Hardox 450 and 162 µm for S355J2). Although S355J2 steel is not necessarily a harder material than Hardox 450, it has the lowest displacement during the compaction process. For all three materials, the maximum displacement occurs at the top of the compaction plate.
In Fig.5.23 shows the values of the equivalent voltages in the compaction plate for the two analyzed cases, voltages calculated according to the von Mises criterion.



a. Hardox 400 b. Hardox 450 c. S355J2

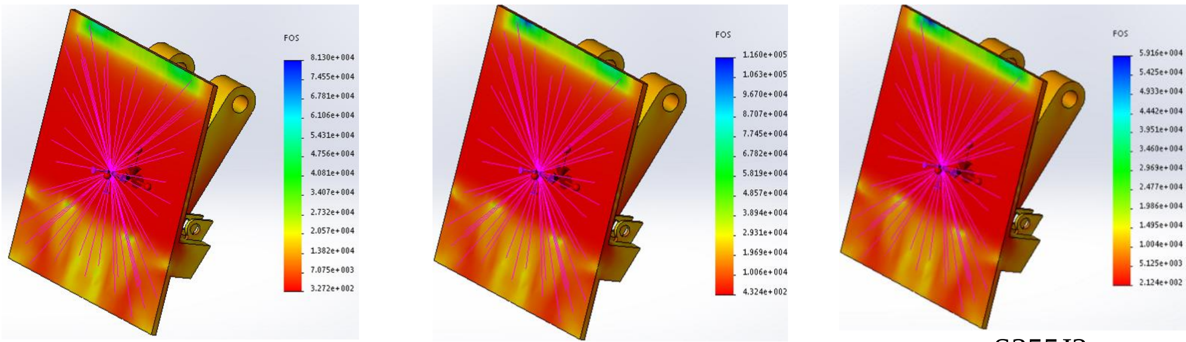
Fig.5.23. (a,b,c) Values of equivalent voltages according to the von Mises criterion, [56]



a) Hardox 400 b) Hardox 450 c) S355J2

Fig.5.24. Values of equivalent deformations occurring in the compression plate, [56]

Analyzing fig.5.23 it can be seen that the highest equivalent voltages occur in the middle zone of the compression plate structure, and their values are well below the breaking voltages of the three materials. From the analysis of fig.5.24 we can see the values of the equivalent deformations that appear in the compression plate following the request to which it is subjected. Thus, the maximum equivalent deformation also arises in the middle zone of the compression plate, the value of the deformations for the three considered materials being presented in the figure.
Fig.5.25 shows the oscillation of the safety coefficient in the compression plate for the three considered materials.



a. Hardox 400 b. Hardox 450 c. S355J2

Fig.5.25. Variation of the safety coefficient for the three materials considered, [56]

In conclusion, the minimum values of the safety coefficient are 327 for Hardox400, 432 for Hardox 450 and 212 for S355J2. It can be said that this compression plate is either oversized, or it is made to work in much heavier conditions than those provided for by this analysis, or to withstand even overloads (impact with materials that are difficult to compact, excessive friction, etc.). The analysis also showed that in the structure of the compression plate appear voltage concentrating points, located in the areas where the plate is welded to the supports that connect with the yoke (drive system). The maximum voltage values calculated with the von Mises criterion are 3.118·106 MPa for Hardox 400, 3.122·106 MPa for Hardox 450 and 3.131·106 MPa for S355J2, values somewhere half the breaking limit of these materials.

5.5.Structural analysis with finished elements of the wear parts in the guides of the backpressure/compaction plate

In this subchapter, the structural analysis of these wear parts is presented. In the first phase of the analysis, the three-dimensional parameterized modeling of each part of the assembly (compaction plate, bucket, compaction material, backpressure plate and wear parts) was performed. After assembly, a dynamic simulation of the household waste compaction process inside the bucket was performed, and the mechanical stresses from the wear parts, resulting from the dynamic simulation, were imported into the Simulation finite elements analysis module of the SolidWorks

2016 software. Here the actual analysis was performed, resulting in the values and dispersion for the equivalent voltages (calculated with the von Misses criterion), the displacements, the safety coefficient and the relative deformations for these wear parts.

The purpose of the 3D numerical simulation analysis with finite elements was to establish the mechanical behavior of the eight wear parts on which the backpressure plate rests at the bottom, following the requests that occur during the household waste compaction process on a municipal solid waste truck Valu€ Pak 1000 (Norba, Sweden), considering for this that the wear parts are made of two different plastics (Nyaltron GSM and Nylon 101).

In the first stage of the analysis, the three-dimensional geometric model of the assembly components (compression plate, backpressure plate, wear part and garbage truck container) was made. for this purpose, a laptop with an Intel Core i5-3210M processor, 2.5 GHz, an NVIDIA GeForce GT 630M graphics card with 2 Gb of its own memory was used, the laptop's RAM being 8 Gb. 3D modeling was carried out using the solidworks premium 2016 S.P. 0.0 parameterized design program.

The three-dimensional modeling of the overall components was performed in the "Parts" module of the design program, from fig.5.27 showing the isometric view of the wear part, as well as the solid works program interface

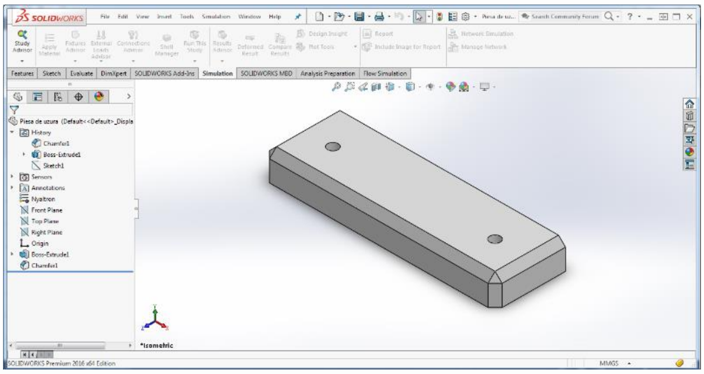


Fig.5.27. Isometric view of the wear part as well as of the interface of the software used, [54]

The pieces were introduced in the Assembly module of the program where they were positioned by adding geometric relationships between their entities (relations of concentricity, coincidence and parallelism between edges and faces). It is worth noting that the wear part has been introduced eight times in the Assembly, since so many parts are actually in the car model analyzed. For the dynamic simulation of the household waste compaction process, between the two plates (compaction and backpressure) the compacted material was also parameterized, fig.5.28. For this, a bottom thickness of about 580 mm was chosen.

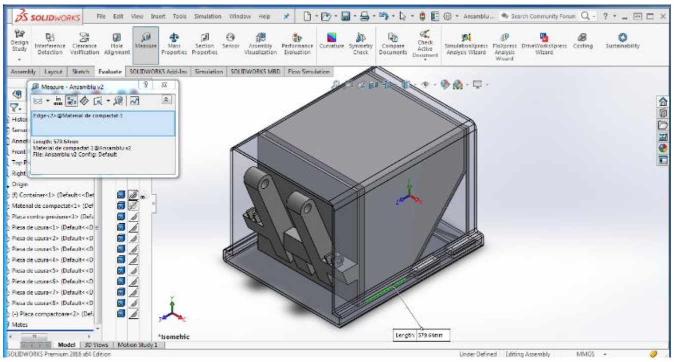


Fig.5.28. The assembly introduced in the Motion Study module, [54]

The entire assembly in fig.5.28 was introduced in the Motion Study module to perform the dynamic simulation of the waste compaction process.

For this purpose it was considered that the backpressure plate is fixed, together with the compaction material, and the compaction plate moves towards it. According to [64,RRM] the displacement speed of the compactor plate without load is a maximum of 150 mm/s, at the beginning of the compaction speed it is 75 mm/s and reaches the end of compaction at 20 mm/s. Thus, a linear variable-speed motor was attached to the compaction plate (see fig.5.29). It should also be noted that the calculation period (dynamic simulation) was 12 s.

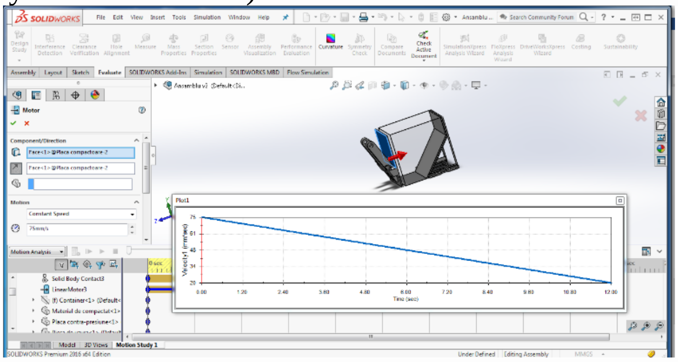


Fig.5.29. Linear motor attached to the compactor plate, [54]

Following the dynamic simulation, the values of the voltages in the parts of interest (wear parts) were obtained. So, fig.5.30 shows the variation curve of the reaction force between the material and the backpressure plate. On the variation curve of the reaction force, peaks are observed due to uneven compaction of the material.

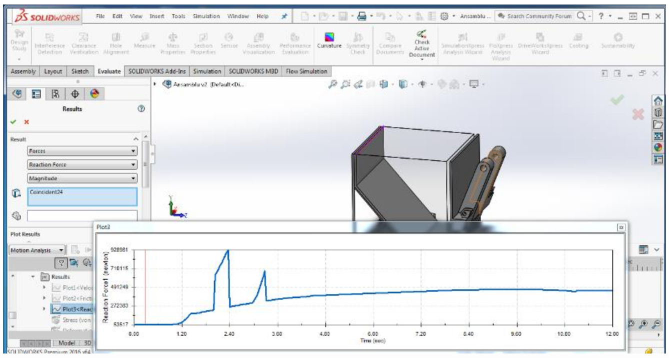


Fig.5.30. Variation of the reaction force in the backpressure plate, [54]

After completing this step, we moved on to the next step which was to import the voltages for the 3D geometric models of the eight wear parts into the "Simulation" module of the Solid Works design program.

According to the technical sheets of the manufacturers, the materials most often used in the manufacture of wear parts are nyaltron GSM and Nylon 101 polyamides. Fig.5.31 shows the fatigue curve of these plastics and Table 5.4 shows the characteristics of the material.

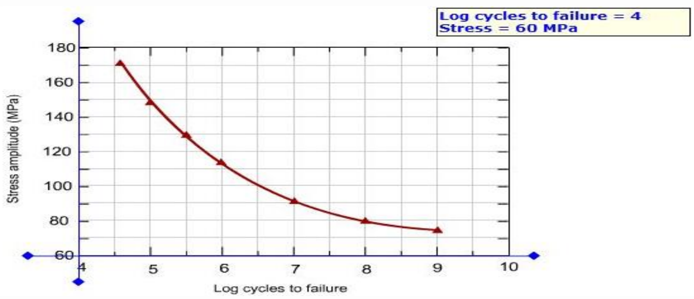


Fig.5.31. Fatigue curve for the two plastics used in the execution of the wear part, [54]

Before the analysis with finished elements, the numbering and positioning of the analyzed wear parts was made. There were a total of eight, on which the backpressure plate was supported in moving it inside the collection container, both when loading the container with household waste and when unloading it. They are fixed with screws to the bottom of the backpressure plate and are arranged four on one side and another four on the other side. Behind the backpressure plate is the cab, so it can be said that wear parts 5, 6, 7 and 8 are on the left side of the garbage machine and wear parts 1, 2, 3 and 4 are on the right side.

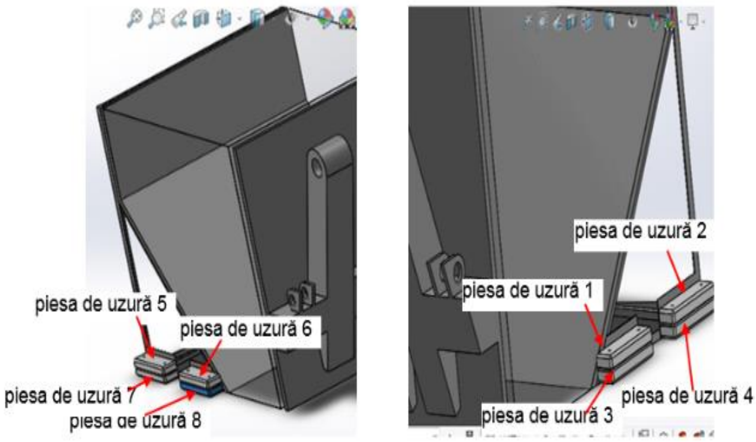


Fig.5.32. Arrangement of wear parts,[54]

Înainte Before presenting the results of the analysis it should be noted that 16 analyses were performed for the eight wear parts (for requests from the dynamic simulation for each of the two types of materials considered - Naltron GSM and Nylon 101).

The discrete finished element model of one of the wear parts is shown in fig.5.33.

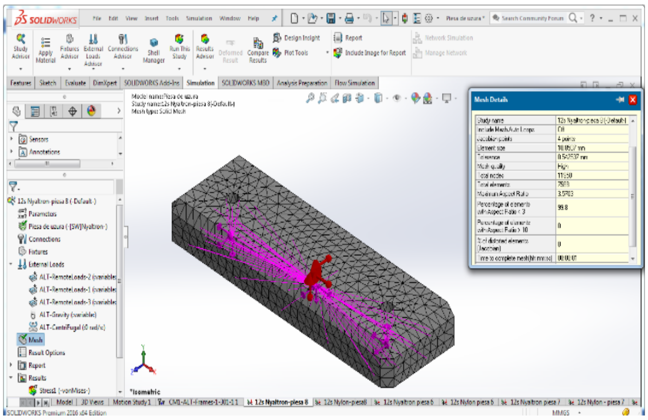


Fig.5.33. Discretization of the geometrical model with finite elements, [54]

Following the simulation in SolidWorks, the design program provided the results obtained in graphic form; the geometric pattern is divided into areas of a certain color, each area comprising the region of the geometric pattern in which the analyzed size has the value specified in the color legend on the right side of the screen. For a modeled and analyzed wear part, fig.5.34 shows the values of the displacements that appear in its structure during the previously defined requests

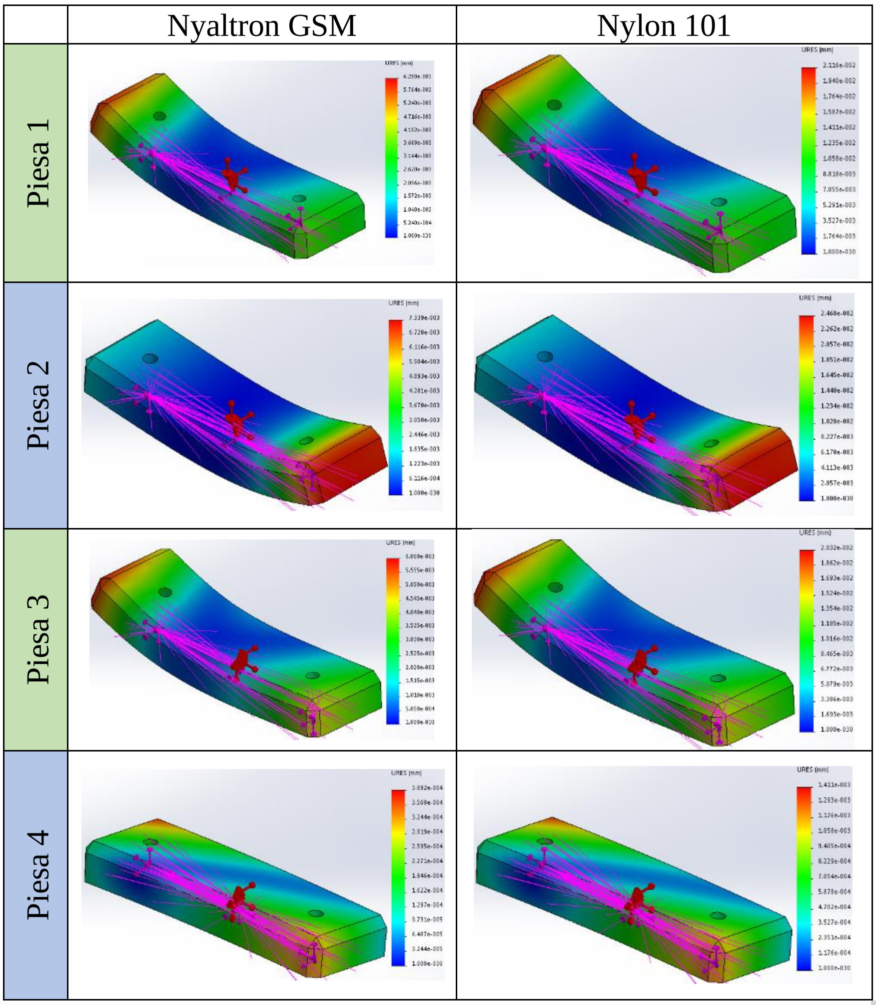


Fig.5.34. Displacement values occurring in the first four wear parts, [54]

The minimum values of the safety factor are 454 for Nyaltron GSM and 340 for Nylon 101, thus resulting in wear parts operating in quite difficult conditions and their failure rate is quite high. The analysis also showed that in the structure of the wear parts appear voltage points, generally located in the areas where the assembly of the screw and nut is made on the backpressure plate.

The maximum values of the equivalent voltage calculated with the von Mises criterion are reached in the case of part 1, 1.77·10-1 MPa for Nyaltron GSM and 1.76·10-1 MPa for Nylon 101, values below the flow limit of these materials. After obtaining these values, a design analysis can still be done, with the same software used in the analysis, to reduce the voltages in the wear parts and thus increase the service life.

Analyzing these data (fig.5.34), it can be seen that the displacement values are close and small, for the two types of materials considered the maximum value of the displacement is found in the case of part 2, 7.34·10-3 mm for Nyaltron GSM and 2.47·10-2 for Nylon 101. Fig.5.35 shows the values of the equivalent voltages of the eight wear parts for the two considered materials, voltages calculated according to the von Mises criterion.

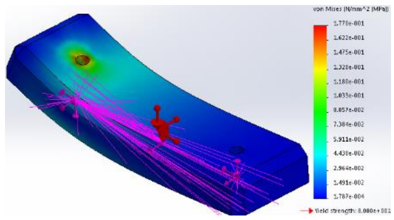
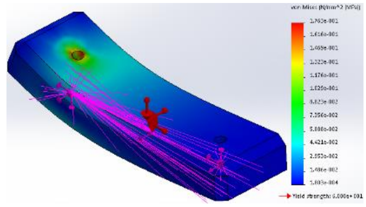
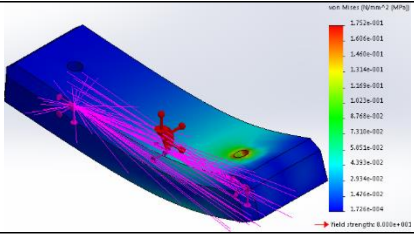
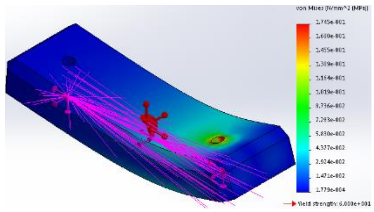
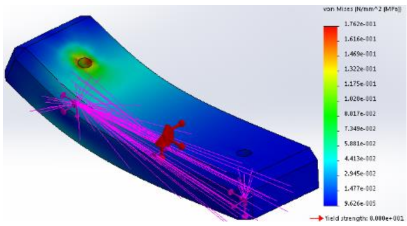
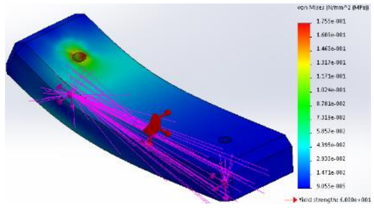
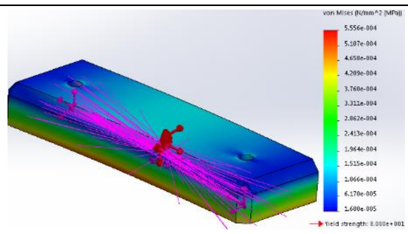
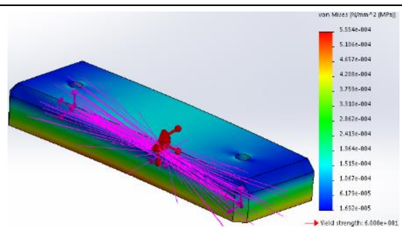
	Nyaltron GSM	Nylon 101
Piesa 1		
Piesa 2		
Piesa 3		
Piesa 4		

Fig.5.35. Voltages equivalent to von Mises criterion in the first four wear parts, [54]

Analyzing fig.5.35 (and the corresponding Annex) it can be seen that all eight pieces behave differently in the same regime, and the values of the voltages are well below the breaking voltages of the two materials. The maximum equivalent voltage value is reached for the first wear part, respectively 1.77·10-1 MPa for Nyaltron GSM and 1.76·10-1 MPa for Nylon 101.

This reaches the minimum value of the safety factor for part 1, shown in fig.5.37. By comparison, for agricultural ploughing machines, the safety factor takes values in the range of 1,8 to 2,2, [21,54].

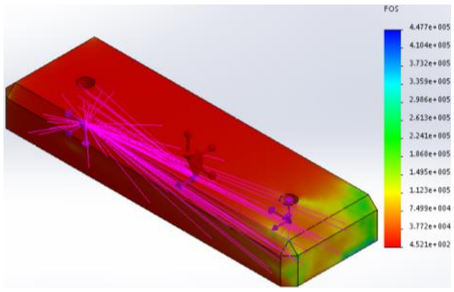
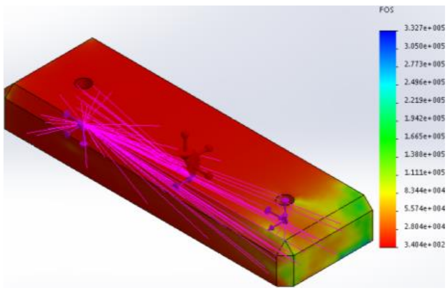
	Nyaltron GSM	Nylon 101
Piesa 1		

Fig.5.37. Minimum values of the safety coefficient, [54]

In conclusion, the minimum safety factor values are 454 for Nyaltron GSM and 340 for Nylon 101. We infer from this that wear parts operate in quite difficult conditions, hence their high failure rate. In addition to having to support the weight of the backpressure plate plus an additional weight of household waste resting on this plate, the wear parts must also withstand the friction given by the slippage of the backpressure plate (compaction of garbage and emptying) of the machine.

5.6. Modelling and simulation in FLUIDSIM of hydraulic systems of stationary waste baler presse[53]

The drive systems of these compaction balers are hydraulic systems. A hydraulic drive system is a technical system consisting of several elements that convert mechanical energy into hydraulic energy and which it transmits to various places by converting it again into mechanical drive energy. The transmission of hydraulic energy can be done directly or following a manual or automatic control

Hydraulic drive systems (fig.5.38) generally consist of a pump, which converts the mechanical energy of a thermal or electric motor into hydraulic energy, of various control elements (various valves, hydraulic manifolds, etc.) that direct the working fluid on various routes, of one or more hydraulic motors that convert hydraulic energy into mechanical drive energy, and of various auxiliary elements (such as filters, oil tank, pipes, connections, hydraulic accumulators, measuring elements, etc.).

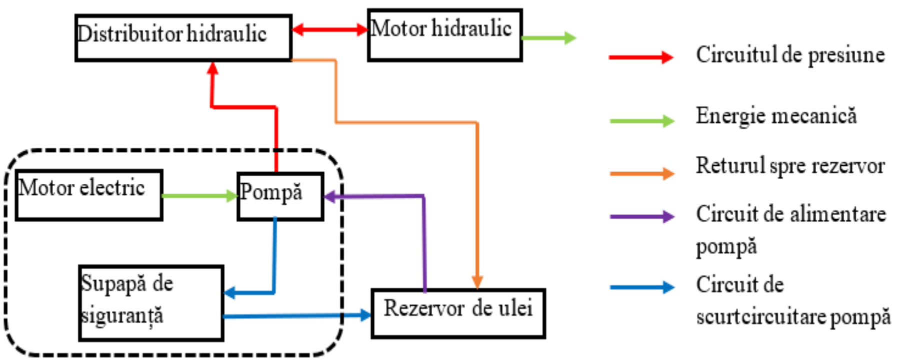


Fig.5.38. Simplified scheme of a hydraulic circuit, [10]

One of the most used software for simulations and modeling of hydraulic and pneumatic systems is FESTO FluidSIM. The mathematical equations behind the simulations in FluidSIM are presented in several papers in the literature, [80].

In this subchapter is presented the modeling and simulation of hydraulic systems of two stationary presses (HSM V-605 and Strautmann PP-1208), as well as the experimental validation of the results obtained from simulations. For the press HSM V-605 the maximum force was calculated in the simulation with an error of 0.53 % compared to the actual maximum force, and for the Strautmann PP-1208 press the maximum force was calculated in the simulation with an error of 1.15 % compared to the actual maximum force. At the same time, the profile of the hydraulic oil pressure curves for the two presses was established, as well as the mathematical laws that best represent the variation of the force with the displacement of the piston.

The hydraulic system of the stationary press HSM V-605 (made in FluidSIM) is shown in fig.5.50. It is composed of a drive unit (consisting of an oil tank, a hydrostatic pump with a theoretical flow rate of 3.9 l/min driven by a 1.5 kW electric motor powered by 380 V and a safety valve opening at 290 bar), a hydraulic manifold with three positions and four paths, a direction valve and a hydraulic double-acting cylinder, [120].

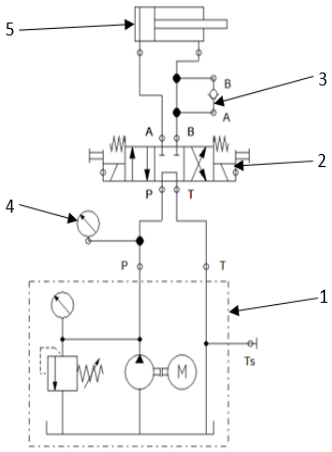


Fig.5.39. Hydraulic diagram of the stationary press HSM V-605
1.drive unit; 2. hydraulic distributor; 3.sense valve; 4.pressure gauge; 5.hydraulic cylinder with double action

The hydraulic manifold is one with electrical control by electromagnet (with a coil) and spring return. In the left position it will drive the hydraulic oil from the pump to the chamber in front of the piston and the oil from the back of the piston to the tank, so the piston will come out of the cylinder. In the position on the right will drive the oil from the pump behind the piston and the oil from the front of the piston to the tank, so the piston will enter the cylinder.

Fig.5.40 shows the hydraulic system of the Strautmann PP-1208 stationary press (also made in FluidSIM). It is composed of two drive units (each consisting of an oil tank, a hydrostatic pump, driven by a 4 kW electric motor powered in 380 V and a safety valve), a three-position and four-way hydraulic manifold, two direction valves and a double-acting hydraulic cylinder.

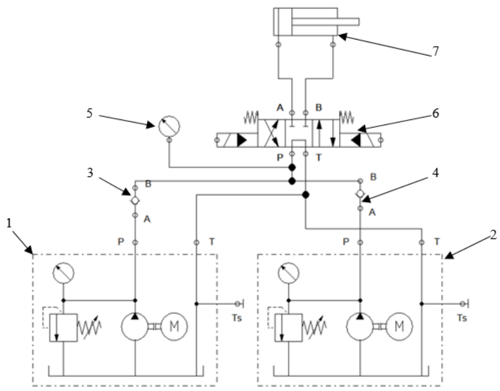


Fig.5.40. Hydraulic diagram of strautmann stationary press PP-1208
1.drive unit 1; 2.drive unit 2,3,4.direction valve; 5.pressure gauge; 6. hydraulic distributor; 7.Hydraulic cylinder with double action

The hydraulic manifold in this hydraulic system is one with indirect external control with a piloted manifold, driven by increasing the pressure, and the return is also springed here. In the left position it will drive the hydraulic oil from the pump/pumps to the chamber behind the piston and the oil from the front of the piston to the tank, so the piston will enter the cylinder. In the right position it will drive the oil from the pump in front of the piston and the oil from the back of the piston to the tank, so the piston will come out of the cylinder

In Fig.5.40 shows that this stationary press has two drive units working in parallel. Drive unit 1 has a flow rate pump of 11.2 l/min and a safety valve of 230 bar, and the drive unit has a flow pump of 38 l/min and a safety valve of 60 bar. Initially, both drive units pump oil to the hydraulic cylinder in the same pipe (connecting to the pump) of the hydraulic manifold. At the moment when the oil pressure they exit on the pump outlet pipe from the drive unit 2 reaches (and exceeds) the value of 60 bar, the safety valve will short-circuit the oil towards the tank. Thus, it will further introduce oil into the system only the drive unit 1 (with the safety valve of 230 bar).

In the present modeling, the variation of the force with the displacement of the piston was determined, the conditions of experimentation being presented in the chapter of experimental research together with the complete experimental data. In simulations, the hydraulic cylinder of the HSM V-605 press was set to move a mass of 7.75 kg, and that of the Strautmann PP-1208 press to move a mass of 80.5 kg, in order to comply with the experimental conditions carried out.

After modeling the two hydraulic systems, the simulation was run, the results being shown in fig.5.41 and fig.5.42. The results of the simulation are presented in graphical form, from the two figures being able to visualize the variation in time of the position, speed and acceleration of the piston, of the force exerted by it when moving the load, the position of the manifold and the pressure of the hydraulic oil at the entrance to the distributor from the hydraulic pump.

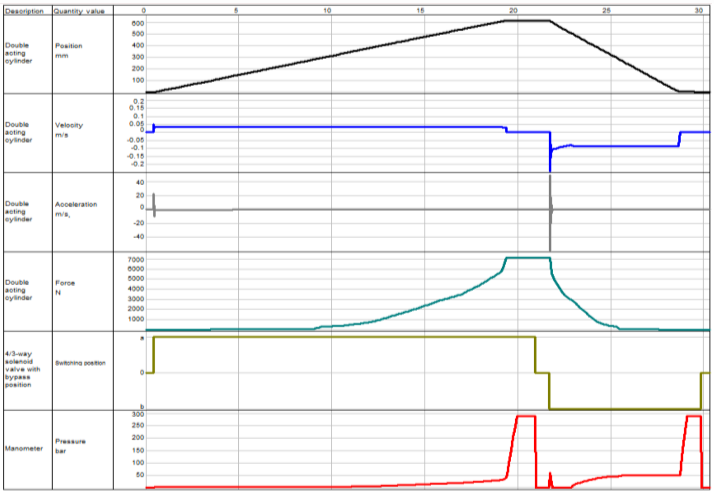


Fig.5.41. Simulation results of stationary press HSM V-605

Fig.5.41 shows that the speed at the output of the piston from the cylinder is lower (0.03 m/s) than the speed at the cylinder inlet (0.09 m/s) for the HSM V-605 press. This is mainly due to the compacted material that tends to loosen by pushing the piston into the cylinder and thus increasing its speed when retreating. On the contrary, in the Strautmann PP-1208 press (fig.5.53) the two speeds are equal and considerably lower than in the first press (0.01 m/s).

Extracting the three speeds (maximum, minimum and average) from the time speed variation chart (fig.5.41 and fig.5.42) the unevenness of the oil flow was calculated. Thus, at the output of the piston from the cylinder the unevenness is of maximum 86.2%, and at the inlet of the piston into the cylinder is 93.1% for the HSM V-605 press, and at the Strautmann press the unevenness is on both strokes of 70%.

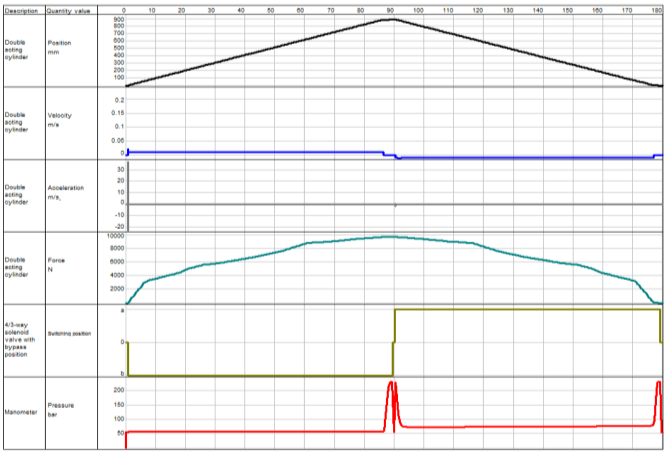


Fig.5.42. Results simulation of strautmann stationary press PP-1208

It should be noted that this flow unevenness lasts a maximum of 1,5 s at the beginning of each stroke of the piston (either output or withdrawal from/into the cylinder), and then becomes uniform and the speed constant. This happens, in general, due to the starts in the task.

The graphs of time force variation for the two presses on both piston strokes show exponential variations up to the maximum force of 7118.2 N for the HSM V-605 press and 9702.1 N for the Strautmann PP-1208 press (simulated values).

As mentioned above, the simulation data were validated by the experiments presented in chapter 6 of the thesis [57] In Table 5.4 are presented the data from the experiments and those extracted from the simulation for the variation of the force correlated with the piston stroke for the two presses.

Table 5.4

Variația forței față de cursa pistonului la presele staționare HSM V-605 și Strautmann PP-1208

HSM V-605	Experim	Deplasare piston, mm	275	294	323	351	383	419	463	502	537	575	605	620
		Forța, N	51,7	147,1	283,8	455,9	787,6	1191,1	2006,6	2884,5	3473,2	4258,0	5690,3	7156,2
	Simulare	Deplasare piston, mm	281	300	326	363	391	420	468	504	541	575	612	620
		Forța, N	60	327,3	347,3	572,7	818,2	1309,1	2127,3	2863,6	3436,6	4418,2	5727,3	7118,2
Strautmann PP-1208	Experim	Deplasare piston, mm	42	120	188	254	325	401	462	544	613	693	782	890
		Forța, N	4021,8	4690,5	5193,2	5714,6	5900,6	6337,5	6874,7	7669,1	8757,7	8960,3	9325,7	9591,3
	Simulare	Deplasare piston, mm	63	186	210	264	317	386	451	538	627	703	801	890
		Forța, N	3201,5	4498,6	5003,8	5600,3	5834,7	6340,4	6807,4	7623,7	8821,9	8998,1	9436,5	9702,1

Using MS Office Excel, the force variation curves with the displacement of the piston were drawn, correlated experiments / simulation, for the two stationary presses, with various mathematical laws to determine which is the mathematical law that best represents the pressing process of each of the two stationary presses analyzed. Thus, in fig.5.43 and fig.5.44, these variation curves are presented for the two presses, along with the functions that best represent the variation of the force with the displacement of the piston for experimental data and simulation data.

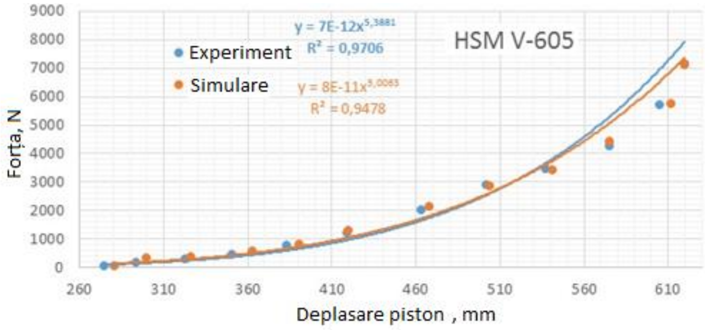


Fig.5.43. Graph of force variation with piston displacement at HSM press V-605

It can be noted that in the HSM V-605 press the best represents the data an exponential law, reaching values of the correlation coefficient (R2) of 0.971 for the experimental data and 0.948 for the data in the simulation, while in the Strautmann PP-1208 press the mathematical law that best represents the data is the linear function, obtaining values of the correlation coefficient of 0.978 for the experimental data and 0.975 for the simulation data.

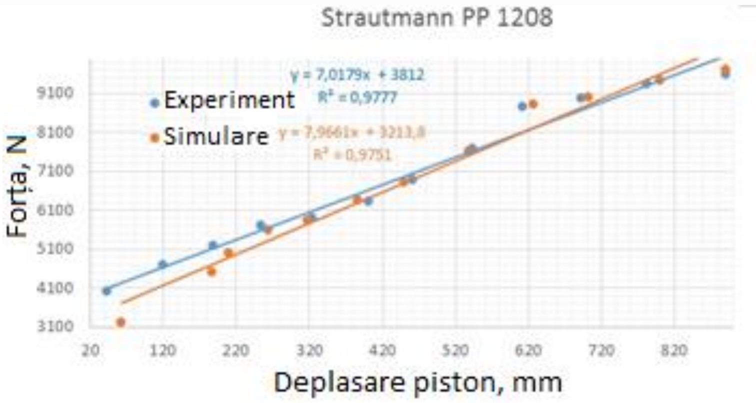


Fig.5.44. Graph of force variation with piston displacement at Strautmann press PP-1208

Taking into account what is presented in this subchapter it can be said that the simulation in FluidSIM for the two stationary presses is very close to reality, for the HSM V-605 press the maximum force was calculated in the simulation with an error of 0,53 % compared to the real maximum force, and for the Strautmann PP-1208 press the maximum force was calculated in the simulation with an error of 1,15 % compared to the actual maximum force. Thus, it can be concluded that modeling and simulation in FluidSIM software for hydraulic systems can be used with confidence.

5.7. Conclusions

The finite element 3D numerical simulation of the behavior of the compression plate structure of a Valu€ Pak Lift 1000 waste collection and transport machine was performed considering that the plate is made of three different materials (Hardox 400, Hardox 450 and S355J2 steels).

It can be said that the analyzed compression plate is either oversized, or is made to work in much heavier conditions than those provided by this analysis, or to withstand even overloads (impact with materials that are difficult to compact, excessive friction, etc.). However, in the structure of the compression plate appear some voltage concentrating points, located in areas where the plate is welded to the supports that connect with the yoke (drive system). The maximum voltage values calculated with the von Mises criterion are 3.118·106 MPa for Hardox 400, 3.122·106 MPa for Hardox 450 and 3.131·106 MPa for S355J2, values at about half the breaking limit of these materials.

The 3D numerical simulation analysis with finished elements was also used to establish the mechanical behavior of the wear parts on which the backpressure plate rests at the bottom, due to the stresses that occur during the household waste compaction process in a ValuE Pack machine, considering two different plastics (Nyaltron GSM and Nylon 101).

The minimum values of the safety factor are 454 for Nyaltron GSM and 340 for Nylon 101, thus resulting in wear parts operating in quite difficult conditions and their failure rate is quite high

The modeling and simulation of hydraulic systems in FluidSIM of the stationary presses HSM V-605 and Strautmann PP-1208, used in experimental research, found the presence of maximum forces in the system, through this analysis being established the profile of the hydraulic oil pressure curves, as well as the mathematical laws that best represent the variation of the force with the displacement of the piston.

CHAPTER 6. EXPERIMENTAL RESEARCH ON THE COMPACTION OF WASTE IN PRESSES WITH STATIONARY OR FURNITURE LOCATION

6.1 Objectives of experimental research

The general objective of the thesis is to create a set of research procedures and systems for measuring, collecting and processing/analyzing data, regarding the physico-mechanical behavior of waste in the interaction with the working organs in the compaction systems by translation. based on the data we can determine mathematical models for the compaction process according to each system.

The secondary objectives are oriented towards the study of moving or static organs of compaction systems by translation, by collecting/analyzing and interpreting data and identifying solutions for improvement.

In the thesis were configured systems of measurement, data collection and interpretation / analysis for translation pressing systems (press with vertical flow), a measurement and data collection system for mobile compaction systems was designed and realized and the simulation was treated by the finite element method of the mechanical resistance of some active organs of mobile compactors (garbage trucks).

6.2. Working apparatus and equipment for experimental research on waste compaction systems

6.2.1. Fixed presses and mobile compaction systems for municipal waste used in experimental determinations

Translation compaction systems can have a waste feed stream of a continuous type (with supply band) or with discontinuous supply, and the operating flow can be positioned vertically or horizontally and are important aspects in the identification and positioning of measurement and data collection systems

For experimental determinations, the following were used: the stationary press from the laboratory of the ISB Faculty – Politehnica, of the type HSM VPress – 605, the system for determining and purchasing the resistances to the compaction of waste,

6.3 Methodology of experimental research on waste ccompaction

The determinations in practice show that for PET container waste there is a specific mass of 25-35 kg/m^{3,} paper waste has a specific mass of 100-150 kg/m^3, and for urban solid waste it has a specific weight of 250-350 kg/m^3. So, a container of 40 m^3 contains 1-1.2 t of PET or 10-14 t of solid urban waste

In order to record the data on a filling of the compaction chamber, sort the waste collected in advance is carried out so that they are of the same type and that there are no differences that influence the results. Check the hydraulic system of the press for its correct operation and the electronic data recording system (pressing plate stroke and press-resistant force).

Next, the operation of the press is checked in the void, and then with the power door open, the supply of material, possibly previously weighed, is made to the top of the press enclosure.
With the power door closed, slowly lower the pressure plate until the moment of touching the material. Basically, this is where the recording and collection of data to be processed later begins. If recordings are made at regular intervals of 1 second, basically the number of recordings coincides with the time interval between two recordings (1 s).
The system acquires the compaction force in kgf, which must then be converted into N or daN. The travel of the pressure plate is recorded in millimeters, so at the end for the calculation of the energy consumed at compaction it is necessary to make the necessary transformations

6.4. Experimental determinations on compaction by means of fixed presses

6.4.1. Determination of compaction resistances to plastic waste

This subchapter presents experimental aspects and results regarding the compaction of PET botles of the same capacity, related to the variation of the compaction force with the displacement of the pressure plate, in several successive compressions, as well as the energy consumed in the compression process, for each compression-recompression, but also the total of this energy consumption.

Experiments on the physico-mechanical characteristics of the compacted material and the forces resistant to compaction were carried out on a vertical flow press of type HSM-V 605 (GmbH, Germany) fig.6.1. The determination of the data was done by mounting the equipment for remote data collection, recording and transmission, indicated in fig.6.3 and fig.6.4.

The experimental flow on the determination of the physico-mechanical characteristics and the behaviour of plastic container waste was made by:

- weighing and counting the botles in the samples introduced; the introduction of material successively,
- sorted on the criterion of dimensional uniformity (botles of 2 liters) in the pressing chamber;
- measurement of the deformations of the volume of waste in plastic botles;
- scaling of the physical characteristics obtained (force, time, length of the pressing piston).

In the first stage, 2-liter PET botles were used (with a lid, but pricked with the tip of a knife in the middle area), undeformed, weighed both individually and in a group, which were compacted to the lowest limit reached by the pressing plate.

The pressing process went as follows: enough botles were loaded into the pressing chamber to cover the volume of the chamber (77 botles, 3,696 kg), after which a continuous pressing followed, until reaching the lower limit detected by the system and automatically lifting the pressure plate, followed by a recompression and return of the pressure plate to the upper point, filling in the remaining free volume with another 52 botles (26 botles - 1,620 kg + 26 botles – 1,280 kg) and a new compression to the limit detected by the system, then a recompression for better compaction. Then followed another addition of the free volume of the pressing chamber (with 26 botles – 1,180 kg) and a three-stage compaction, for a compact laying of the bale for further binding. The pressure plate had a free movement until reaching the top level of the botles, after which its displacement followed a curvilinear variation, depending on the size of the compaction force at that time

The experimental data obtained were stored in tabular form, which were generated continuously as long as the press was in operation (Table 6.2). the table shows the variations in the compaction force depending on the distance of movement of the compaction plate from a fixed upper point on the press cover, as well as the number of 2-liter PET botles existing in the pressing chamber in each of the three groups of compactions, respectively their mass. Data processing can bring favorable results in order to shape the process of pressing waste plastic botles.

Table 6.2. Variation of pressure forces with compaction piston displacement

Compactare succesivă a recipientelor PET de 2 litri													
P01.01		**P01.02**		**P02.01**		**P02.02**		**P03.01**		**P03.02**		**P03.03**	
77 recipiente / 3.696 kg				129 recipiente / 6.596 kg				155 recipiente / 7.776 kg					
Deplasare (mm)	Forță (daN)	Deplasare (mm)	Forță (daN)	Deplasare (mm)	Forță (daN)	Deplasare (mm)	Forță (daN)	Deplasare (mm)	Forță (daN)	Deplasare (mm)	Forță (daN)	Deplasare (mm)	Forță (daN)
0	0	0	0	0	0	0	0	0	0	0	0	0	0
462	4,76	459	1,71	0	0,52	98	6,09	272	1,03	0	0,89	275	5,17
493	17,44	488	13,53	0	0,65	120	21,00	291	2,24	4	0,94	294	14,71
544	37,87	527	39,52	0	3,01	140	40,03	321	15,82	49	0,95	323	28,38
581	73,95	561	75,87	17	8,64	180	59,26	347	39,85	80	1,02	351	45,59
615	127,74	596	122,23	46	15,76	210	75,14	383	75,74	106	1,12	383	78,76
651	139,14	638	179,21	79	26,26	243	89,32	415	125,68	130	1,13	419	119,11
				123	46,52	267	91,94	457	204,53	164	1,13	463	200,66
				163	70,54	295	136,73	512	287,70	205	1,16	502	288,45
				193	98,63	336	215,26	539	382,13	232	1,20	537	347,32
				227	120,62	381	257,95	582	504,94	260	1,43	575	425,80
				249	150,03	413	361,58	615	651,47	287	4,11	605	569,03
				280	192,17	511	600,85	659	567,11	315	9,96	646	715,62
				325	246,07	608	730,64			343	27,37	675	219,37
				367	277,63	657	518,07			375	46,65	595	29,10
				416	348,68					405	73,08		
				470	380,30					436	108,35		
				512	421,80					482	138,99		
				553	500,86					524	205,23		
				619	586,82					565	406,97		
										602	521,61		
										639	700,23		
										670	170,92		
131,553 J		**134,065 J**		**1471,718 J**		**1729,953 J**		**1009,440 J**		**856,255 J**		**857,403 J**	

Table 6.3. Additional details for sample P03.01

Cod probă	**Recipiente**	**Masa**	**ID înregistrare**	**Δt**	**Timp**	**Cursa**	**Forța**
	buc	kg		s	s	mm	daN
P03.01	155	7,776	10111	34	12	659	567,11
			10110	34	11	615	651,47
			10109	33	10	582	504,94
			10108	32	9	539	382,13
			10107	32	8	512	287,70
			10106	31	7	457	204,53
			10105	30	6	415	125,68
			10104	30	5	383	75,74
			10103	29	4	347	39,85
			10102	28	3	321	15,82
			10101	28	2	291	2,24
			10100	27	1	272	1,03
	0	0	0	0	0	0	0

Based on the graphs drawn in the MS Office Excel program, the surfaces under the force-displacement curve (by the trapeze method) that represent the energy consumed at each stage of the compaction process have been determined, and its values are presented at the bottom of table 6.2.

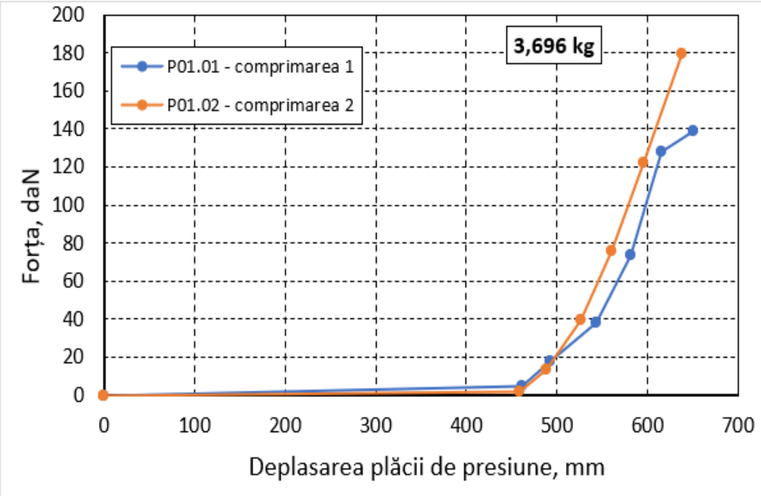


Fig.6.6. Force variation – displacement to the pressure plate when loading the press with 77 PET botles (2 L)

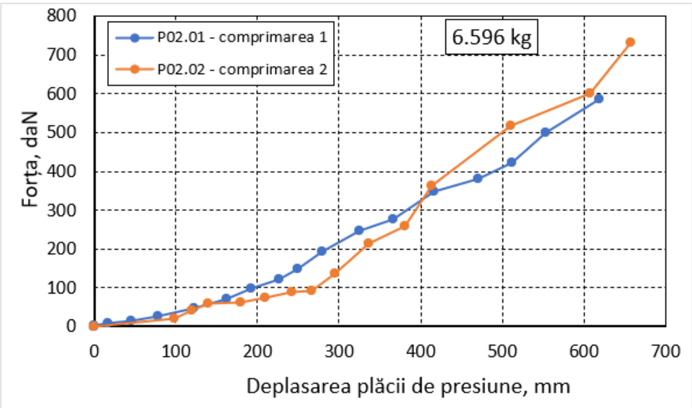


Fig.6.7. Force variation – displacement at the pressure plate when loading the press with 77 +52 PET botles (2 L)

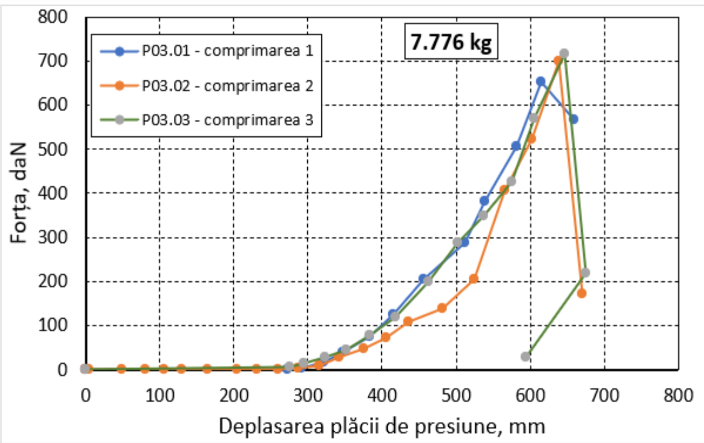


Fig.6.8. Force variation – displacement to the pressure plate when loading the press with 77+52+26 PET botles (2 L)

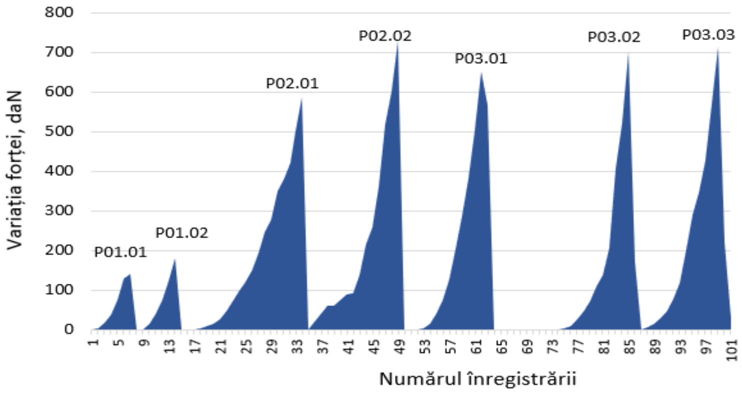


Fig.6.9. Variation of the downforce in the seven phases of the compaction process of 2 liters PET botles P01 – 77 botles, P02 – 77+52 botles; P03 – 77+52+26 botles

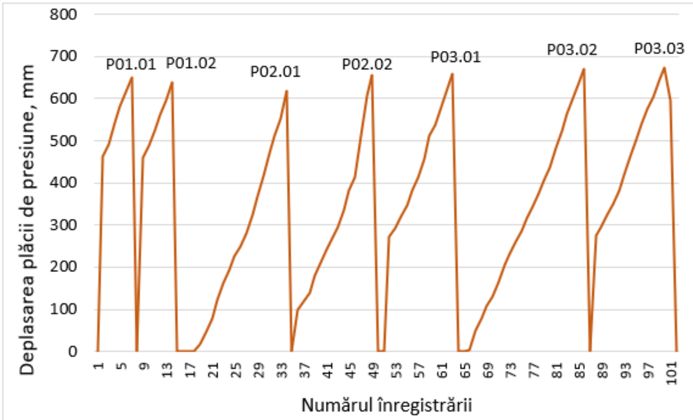


Fig.6.10. Variation of the displacement of the pressure plate in the process of compaction of 2 liters PET botles P01 – 77 botles, P02 – 77+52 botles; P03 – 77+52+26 botles

From the analysis of the data from table 6.2, but also of the graphs presented, it is found that the pressure plate travels, at the beginning, in idle, a certain distance until it comes into contact with the material to be compacted and, only from here on, the recording of the values of the compressive forces follows, which increase relatively exponentially as the pressure plate descends and the maximum lowest position of the piston is reached (respectively the maximum compaction force that it presents the press). The lower the level of the material inside the press, the later it will begin to record the value of the compressive force.

Thus, the variation of the compressive forces depending on the displacement of the piston can be traced in Table 6.2, for all seven stages of compaction of the 2-liter PET botles. What is mainly found is that the force recording system begins to show values all the earlier as the press is loaded as close as possible to the top of the pressing chamber, as can also be seen from fig.6.7. Moreover, the greater the amount of material in the pressing chamber, the higher the pressing forces, both at the first compression and at recompression.

In addition to the data that can be seen directly from the data table or from the graphs presented, it could be found that the speed of the pressing plate during the compression of the botles (i.e. as long as the plate is in direct contact with the compacted material, and the force continuously increases) is different from one press to another. Thus, it presented values from 47.3 mm/s at the first pressing to about 53.0 mm/s at the last pressing, with variations between these values at the other stages of the pressing. However, the value of the speed of the pressing plate is dependent on the force resistant to compression of the material.

Analyzing the energy consumption values in the three stages of compression, it can also be found that the highest values are presented by the second stage (pressings P02.01 and P02.02), when the number of botles to be compacted has increased significantly compared to the first stage (P01). If at the first stage, the energy consumption is at low values (131.5 J and 134.1 J respectively), in the second stage the energy consumed at compression reached 1471.7 J and 1729.9 J respectively. In the third stage of compaction, the energy consumed decreases, although 26 more botles have been added to the pressing chamber. What seems logical, however, are the decreasing energy values at the two recompressions that follow (subtracting from about 1009.4 J to P03.01, to about 856-857 J at the compressions P03.02 and P03.03). Overall, the total compressive energy (the sum of the consumptions from the seven compressions) reaches about 6190 J, which in relation to the mass of the botles in the pressing chamber (7.776 kg) determines the specific pressing energy, i.e. 796.1 J per 1 kg of compacted botles.

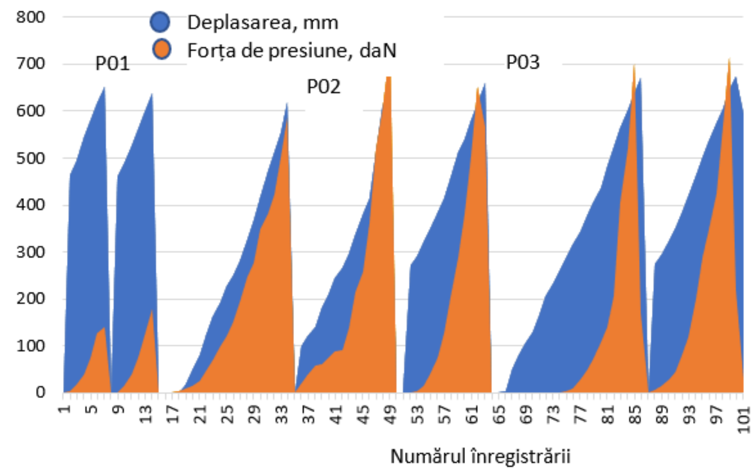


Fig.6.11. Variation of pressure forces and displacement of the pressure plate when compacting 2-liter PET botles

If we plot the displacement of the pressure plate in relation to time, the speed of its displacement is obtained and, as seen from the graph of the speed in sample P03.01, based on table 6.3, the speed is approximately linear, mainly after contact with the material inside the press is made (see fig. 6.12). The speed value is about 36.3 mm/s, so a relatively small and constant value.

Although the speed is approximately linear and constant, it is not retained as a value from one sample to another, primarily because of the strong forces due to the material (see Fig. 6.13).

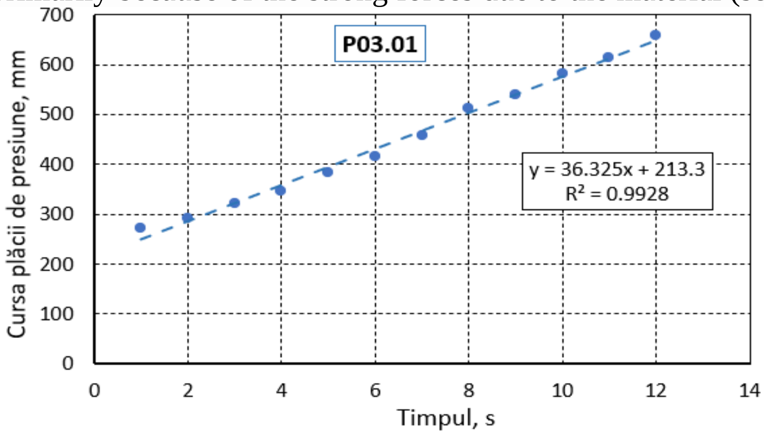


Fig.6.12. Pressure plate speed at compaction P03.01 (compaction 1 – 155 botles)

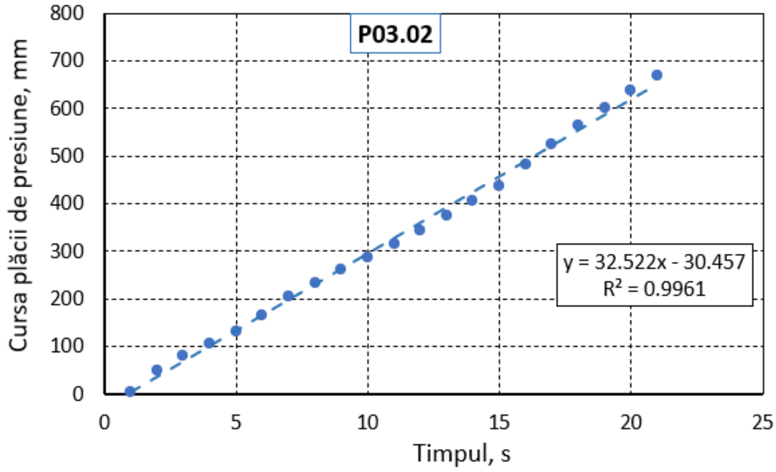


Fig.6.13. Pressure plate speed at compaction P03.02 (compaction 2 – 155 botles)

Therefore, the speed of the pressure plate decreases to compactions 2 and 3, due to the fact that the material is already compacted and the resistors encountered increase.

From the processing of the experimental data, the graph of the energy consumptions can be drawn on each stage of the compaction of the PET botles at 2 liters, so that for the entire quantity of PET waste, a specific energy consumption is obtained for a bale of about 0.821 kJ/kg (fig.6.14).

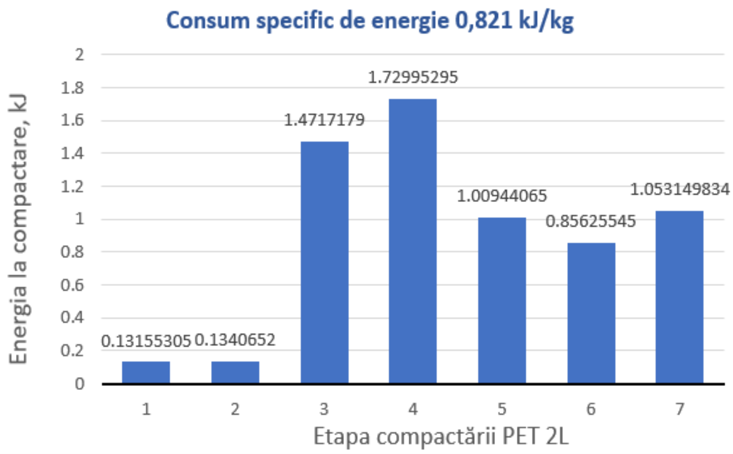


Fig.6.14. Specific energy consumption at 7-stage compaction of 2 L botles

The second part of the experimental determinations was devoted to the compaction of 0,5 liter PET botles'

The same procedure was carried out as compaction of the 2-litre botles and the results of the experimental determinations are concentrated and presented in Table 6.4. The records of the pressure plate stroke and the force resistant to compaction were made with the same recording system as in the case of the 2-liter PET botles.

Initially, the pressing chamber was loaded with 202 0.5 liter PET botles and two compactions were made (P01.01 and P01.02), after which 22 more botles were added and a new registration was made (P02.01), as shown in Table 6.4. The variation of the pressing force depending on the stroke of the piston of the pressing plate, for the 3 stages of compaction, is shown in Fig. 6.15.

Table 6.4. Variation of pressure forces with compaction piston displacement for 0.5 litre botles

P01.01		**P01.02**		**P02.01**	
202 recipiente		202 recipiente		224 recipiente	
Deplasare (mm)	Forță (daN)	Deplasare (mm)	Forță (daN)	Deplasare (mm)	Forță (daN)
0	0	0	0	0	0
404	7.439	400	28.19	480	20.52
429	66.36	403	20.53	521	92.53
476	184.51	451	107.06	548	132.17
551	198.23	489	188.35	610	253.20
601	263.37	518	114.57	675	64.07
662	269.70	586	183.25		
		633	276.98		
		674	10.32		
		522	10.35		

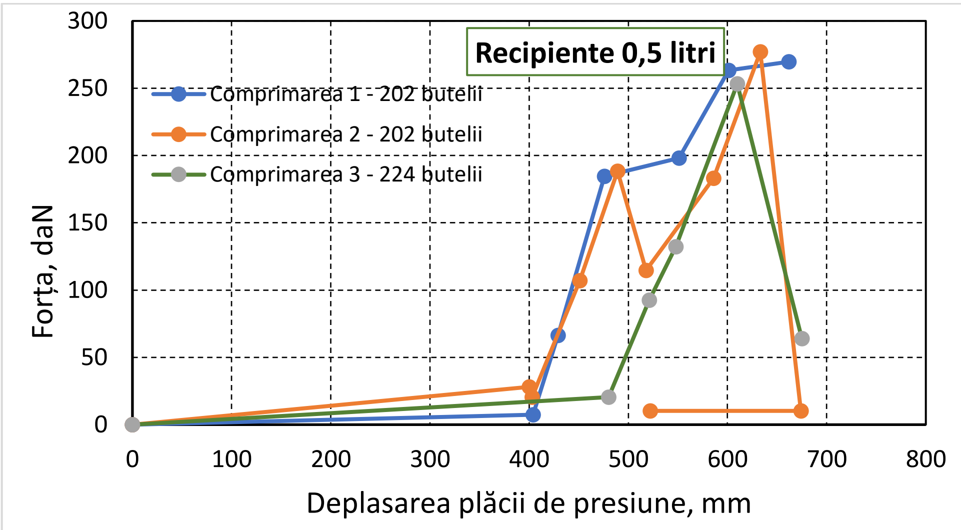


Fig.6.15. Force variation – displacement at pressure plate when loading the press with 202 + 22 PET botles (0,5 L)

From both Table 6.4 and fig.6.15, it is found that the variation in force with displacement is not relatively constant, since the botles compress randomly, and if some have remained uncompacted enough at the first compression there may be important jumps and variations in the force of resistance, as observed in the second compression with 202 botles of 0,5 liters in the press enclosure.

In conclusion, the compaction of used PET botles in small and medium capacity vertical presses is generally carried out at the stage of collecting them before they are routed to the processing companies. Compaction with the help of stationary presses is carried out in several stages, with recompressions and the addition of new material, until it is sufficient for the formation of a parallelepipedic bale with the dimensions of the bottom of the pressing chamber. The bale is then tied with plastic strips, having a much reduced volume compared to the initial free state of the botles.

Compression in several successive stages leads to the repositioning of the material within the pressing chamber and an increase in its volumetric mass. The degree of compaction depends, including, on the pressure in the operating cylinder (or cylinders) of the compaction plate that the machine can develop, but also on the initial condition of the botles. They must be pressed either without a lid or be pricked (pierced) with a sharp body so that the air inside does not resist too much resistance to compression.

When pressing the 2-liter PET botles, with the vertical press of 57 kN, the compressive forces showed generally increasing variations when recompressing or adding new material. For maximum load of the press (according to experiments 7,776 kg of PET botles) the compressive force exceeded the value of 715 daN at the third compression, that is, a pressing pressure of about 15 Pa.

As for the compressive energy, it recorded the highest values when the press was suddenly recharged with a larger amount of material, after the material initially loaded had been compressed in two stages, so that the energy increased more than tenfold when the amount of material in the press almost doubled (from 3,696 kg to 6,596 kg), since the pressing plate was forced to move a greater distance under the action of forces that appeared earlier in the recording system. However, the average value of the specific compressive energy for the whole process was around 0.8 kJ/kg of compressed material.

6.4.2. Determination of compaction resistances to waste paperboard

In Europe, recycling has increased by almost 20% in recent decades, being around 72% in 2012, [87]. With the increase in recycling rates, processes have also been improved, with lower quality paper and cardboard fractions being added.

According to the mediafax.ro, Romania produces 5.8 million tons of waste per year, with an average of 272 kg / year / inhabitant and with a collection rate of 82.35, shows the Waste Atlas study, published by the D-Waste organization. Of these, 56% is organic matter, 9.9% paper and cardboard, 9.9% plastic, and the rest other categories of waste. Of the total waste, Romania recycled only 3% before 2018, (mediafax.ro, accessed October 20, 2021).

Other countries in Europe recycle much larger quantities of waste compared to Romania. For example, Slovenia recycles about 55% of its waste annually, with a collection rate of 100%, but produces only 0.852 million tonnes of waste, with 414 kg/inhabitant/year.

In a circular economy an important practice is recycling, currently considered as the main core for the return of materials to the supply chain, and the main bottleneck in the plastic and paper recycling chains is the lack of continuous separate collection programmes with a focus on environmental education processes, [92]. In this paper it is shown that in 2013, about 57% of the paper used worldwide was produced from recycled fibers (~233 million tons). Although the quantities of recyclable material increase every year, it is difficult to guarantee the homogeneity of separation and avoid contamination.

Laboratory experimental results have shown that chips from recycled cardboard waste mixed with sand can be successfully used in the preparation of concrete for construction, resulting in a more environmentally friendly concrete with reduced costs of disposing of waste from cardboard and with acceptable strength characteristics, [94].

At the same time, waste paper and cardboard can be a major source of cellulosic biomass, which can be used as a potential substrate for cellulose production. Thus, experiments show that cardboard treated with 0.1% sulfuric acid is a good substrate with low costs for the production of cellulase, [6]. To choose the most efficient waste management method, life cycle assessment (LCA) may be used, recommending energy recovery by pyrolysis, gasification and combustion only if the heat produced is used for other applications, [112].

Balers for cardboard are quite versatile and can compress all types of cardboard, regardless of shape, size or use. Normally, in a baler can be baled whole boxes, plates, sheets, tubes, corrugated board and ordinary cardboard.

For the compaction of cardboard waste, a vertical flow press was used and bales with a parallelepipedic shape were obtained. The press is usually used in the compaction of plastic waste, foil, PET botles, cardboard, and is of type PP 1207 production Germany, with the maximum force of 50 tons force. The pressing chamber is front-fed through the median sliding door (see Fig. 6.15).

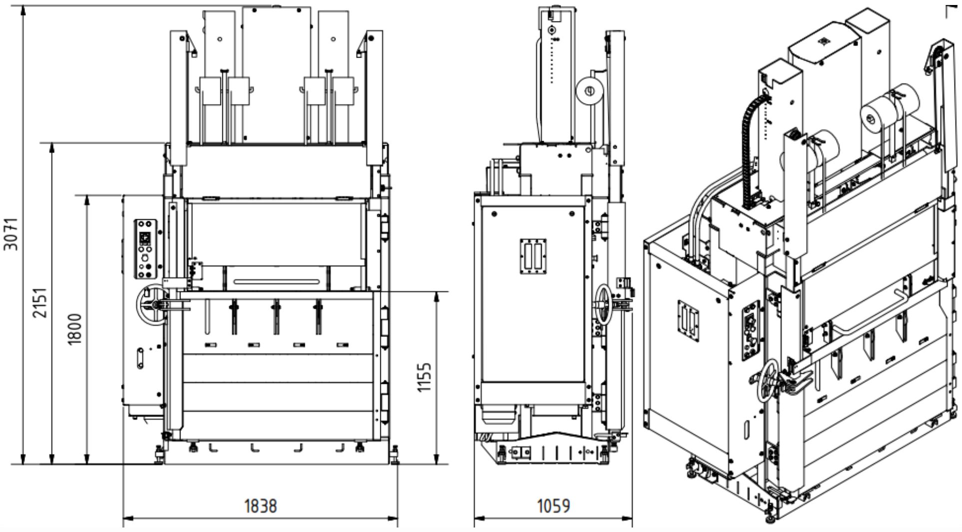


Fig.6.15. Vertical flow baler PP-1207, Strautmann

The bale is formed by successive feedings and compactions and it is connected by 4 lanes, before being discharged from the compaction chamber. The purpose of compaction and bale obtaining is to reduce the volume of waste for economical storage and transport with optimal weight / volume for further processing

The assembly scheme of the equipment is the same as for the compaction of pet botles, but the press used is different, aspects during the experimental determination being shown in fig.6.16.

Fig.6.16. Test press and bound bale obtained after compaction/baling

Fig.6.17. Aspects during the experimental determination when compacting cardboards

In experiments on the compaction of cardboard waste, sorted material consisting of cardboard of various shapes was used, each sample was weighed and placed in the compaction chamber. Humidity was not measured, because in reality, in the desert industry they are stored in covered halls and having the atmospheric humidity given by normal conditions.

The experimental data obtained were stored in tabular form, which were generated continuously as long as the press was in operation (Table 6.5). the table shows the variations in the compaction force depending on the distance of displacement of the compaction plate from a fixed upper point on the press cover for 7 samples, as well as their mass. Data processing can bring favourable results in order to shape the pressing process of cardboard waste.

Estimated 11.5 kg of cardboard waste was initially introduced into the pressing chamber, the volume being calculated based on the transverse dimensions of the pressing chamber and the height of the chamber at the time of reaching the cardboards by the pressure plate, which is about 0.2 m3. Eventually the pressing cylinder was activated. After a first pressing, when the maximum pressure is reached in the system, a sensor reverses the stroke of the piston and in the pressing chamber was added, over the 0.2 m3 of cardboard waste, another 0.2 m3 and 11.5 kg of pressed cardboard waste respectively (see Table 6.5)

Table 6.5

Variation of pressure forces with displacement of the compaction piston for the seven samples

Timp, (s)	P1		P2		P3		P4		P5		P6		P7	
	V= 0,2 m^3 m = 11,5 kg		V= 0,4 m^3 m = 23 kg		V= 0,6 m^3 m = 34,5 kg		V= 0,8 m^3 m = 46 kg		V= 1,0 m^3 m = 57,5 kg		V= 1,2 m^3 m = 69 kg		V= 1,3 m^3 m = 80,5 kg	
	Deplasare (mm)	Forță (daN)	Deplasare (mm)	Forță (daN)	Deplasare (mm)	Forță (daN)	Deplasare (mm)	Forță (daN)	Deplasare (mm)	Forță (daN)	Deplasare (mm)	Forță (daN)	Deplasare (mm)	Forță (daN)
1	1323	457	1234	258	1302	153	1278	193	905	128	915	148	1184	278
2	1244	633	1035	912	1042	914	1235	258	838	390	848	410	985	932
3	1099	705	975	980	991	982	1194	372	760	458	770	478	925	985
4	958	742	896	992	892	992	1111	416	692	510	702	530	846	997
5	810	772	824	980	817	981	1026	521	626	563	636	583	774	985
6	645	960	758	967	748	962	950	586	555	631	565	602	708	972
7	523	955	671	968	668	961	902	632	479	766	489	646	621	973
8	385	968	595	966	602	965	868	662	418	802	428	701	545	971
9	231	980	523	967	510	968	802	706	336	861	346	782	473	972
10	183	979	432	967	422	968	725	803	267	912	277	893	382	972
11			347	966	342	970	630	852	236	983	246	978	297	971
12			271	977	270	975	529	876					221	982
13			233	977	231	977	336	921					183	982
14							237	961						
15							183	979						
Energie	**673 J**		**1544 J**		**1536 J**		**1292 J**		**1065 J**		**1027 J**		**1554 J**	

Having at your disposal the data from Table 6.5, the variable curves of the resistant forces depending on the displacement of the compaction plate were graphically drawn (in Excel) for all the 7 samples mentioned before, so that the resulting bale had about 80.5 kg.

It is found that the variation of the resistant force with the displacement of the pressure plate does not follow a predetermined trajectory, even if in principle it is a curve with an upward slope, the resistant force depending on the mode of random placement of the cardboards in the pressing chamber, with voids unevenly distributed between the cardboards inserted into the press. There are many curves at which, after the maximum resistance force has been reached, it remains relatively constant mainly and the way of achieving the hydraulic circuit of the press.

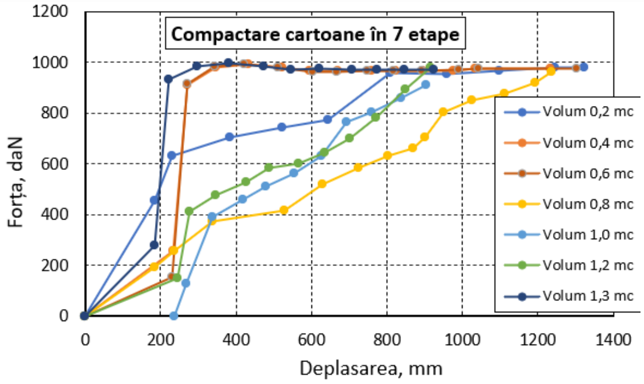


Fig.6.18. Force variation – displacement when loading the press with pressed cardboard in 7 similar steps

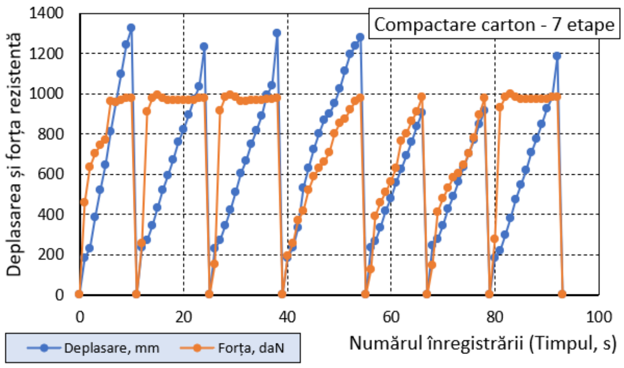


Fig.6.19. Variation of pressure forces and displacement of the pressure plate when compacting the cardboards

From the analysis of the data in the table and of the graphs in fig.6.19, it can be seen that the displacement of the pressure plate reaches relatively high values not only at the first stages of compaction, but also in the final phase of compaction, even if the highest value of the displacement was reached at the first compression (about 1323 mm), the stroke from which the records of the force resistant to compaction begin having minimum values of about 183-236 mm.

The values of the force resistant to compaction are between 977 – 983 daN, which means that at higher values the resistance sensor from the hydraulic circuit comes into operation and it gives the signal of withdrawal of the pressure plate.

Based on the graphs drawn in the MS Office Excel program, the areas under the force-displacement curves (fig.6.18) that represent the energy consumed at each stage of the compaction process have been determined, and its values are presented at the bottom of table 6.5.

It is found that the lowest energy consumption is at the first compaction, when there is a small amount of cardboards inside the press, in the next stages the energy consumed increasing with the amount of cardboards added and with the parameters of the process – force-displacement. However, the placing of cardboards in the press also has a decisive role, which is random in nature.

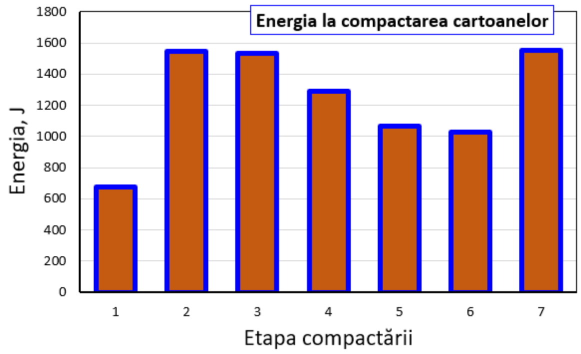


Fig.6.20. Energy variation in cardboard compaction in the 7 stages of compaction

At the separate representation of the pressure plate stroke, simultaneously for the 7 stages of compression, the upward slope of the stroke is better observed in correlation with the increment time, which has been set to 1 second (fig.6.21).

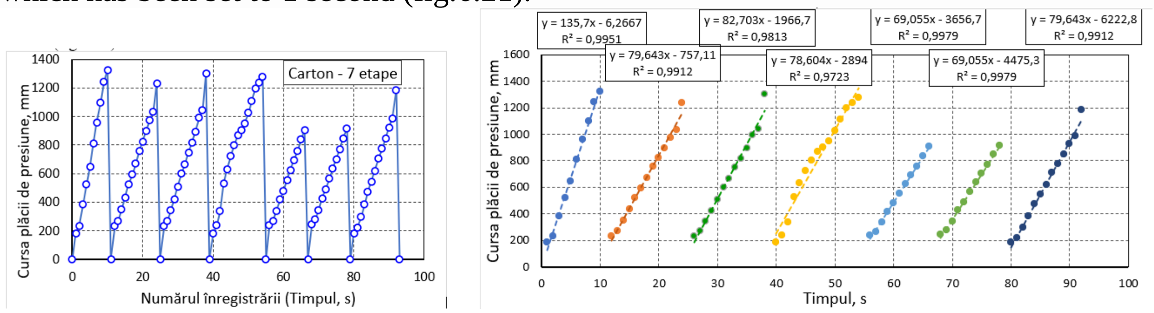


Fig.6.21. Variation of the pressure plate stroke when compacting the cardboards in the 7 steps

At the same time, even if the trend is clearly linear (as shown by the values of the regression coefficient R2 (0.9723), the speed of movement of the plate is not a constant one, depending on the resistance encountered during compaction and the random placement of the cardboards, and the hydraulic circuit adjusts the speed according to the perceived force. It is found that the speed has a value between 69 mm/s (steps 5 and 6) and 135,7 mm/s (at the first stage of compaction). Basically, the compaction itself begins from the moment of notification of the material by the pressure plate in its downward stroke.

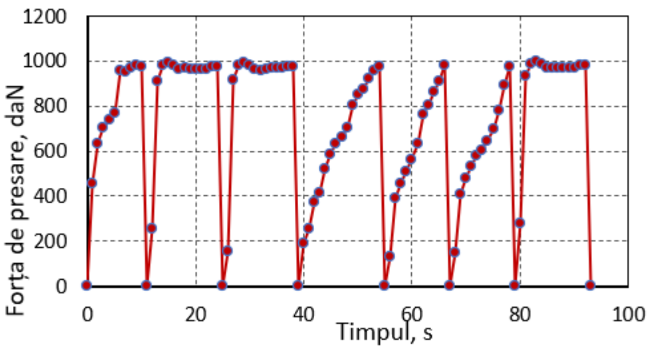


Fig.6.22. Variation of pressure forces in compaction of waste paperboard

In both Fig.6.19 and Fig.6.22, the differences between the variations in the pressing force during the seven stages of compaction of the cartons until the bale is tied are observed.

The data records show the constancy of the volume of cardboard waste inserted/added into the pressing chamber at each stage of compaction, i.e. the constant increase in the quantity introduced.

Based on the volume of material in the pressing chamber and its volume in the bulk state (placed in the pressing chamber), the constancy of the bulk mass of the material is also observed (Fig.6.23).

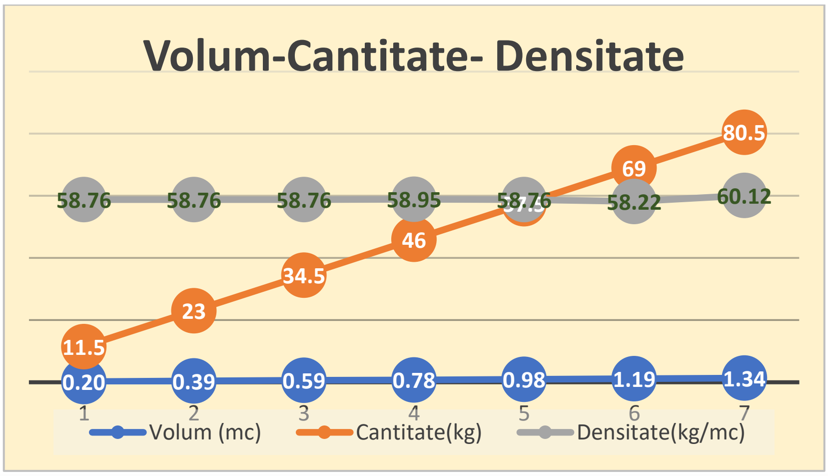


Fig.6.23. Variation in the quantity of material, volume and volume mass at the initial moments of the stages of compaction of waste paperboard

6.5. Experimental determinations of compaction of waste using fixed horizontal flow presses

Horizontal presses for compaction and baling of bulky, recyclable waste are designed to provide all the necessary flow, from the supply of bulk waste to the disposal of tethered bales.

Fig.6.25. Overview of the horizontal press for bales of recyclable waste

The MAC 107/1 horizontal press (fig.6.25), used in our experiments, is a baler for municipal solid waste, commercial and industrial waste. It can bale both recyclable plastic waste (PET bottles or various foils), cardboard and aluminum, but also unsorted municipal solid waste with various contents of organic materials or bulky waste. The press shall show an optimum ratio between the thrust force and the rate of compaction, having a mechanism on the exhaust channel provided to regulate the density of the bale. It is used, as a rule, in transfer stations and landfills, where these materials are recovered in the final phase. Of course, the baling of waste can also be done to make the most of a deposition space.

If we analyze the forces in the hydraulic cylinder during a working cycle, in relation to the distance travelled, we can identify the energy consumed in the process. Consequently, the area below the two curves (ascending – descending) represents the energy on the compaction phase, respectively on the piston retraction phase. The energy stored in the bale that is formed is represented by the area of the surface between the two curves, obtained by the difference between the surface area under the ascending curve and the area of the curve under the downward curve

For the P5 bale formation cycle, the respective curves are shown in Fig.6.29 and 6.30

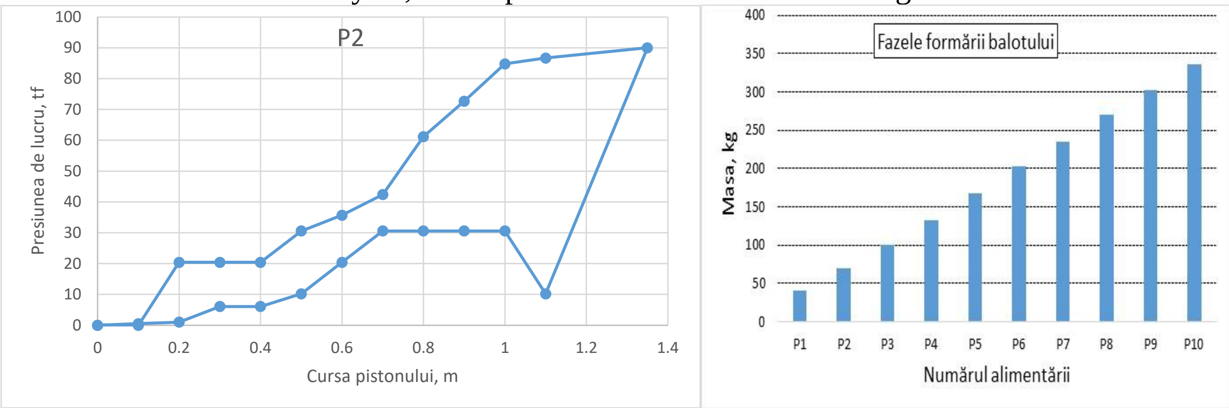


Fig.6.29. Variation of the force in the working cylinder during a compaction-retraction cycle

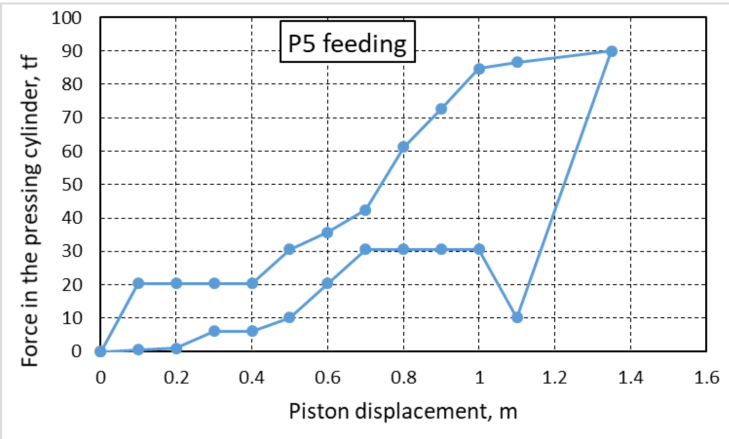


Fig 6.30 Variation of the force in the working cylinder in relation to the displacement of the compaction piston

From those mentioned in the paper it can be seen that the force in the hydraulic cylinder for pressing the material continuously increases in the active stroke (pressing stroke), and after reaching the maximum value (at the end of the pressing stroke) it suddenly decreases to a minimum value, but due to the relaxation of the material it returns to a slightly higher value, keeping it relatively constant over a length of about 0.3 m, and then it decreases continuously until the piston is permanently withdrawn and a new race resumes, respectively a new refuelling with a new charge of material

From our experiments, the specific energy consumption for the baling of food cylinders in PET was about 1.12 kJ(kg-1, for bales formed in ten cycles, with a net mass after binding of over 335 kg. This value is indicative because for other categories of recyclable baled waste and other horizontal press panel adjustments it is very likely that the value of this specific energy will be different.

6.6. Dimensional optimization of the wear parts of the pressing plate guidance system

Since the component with the highest failure rate in the household waste compaction assembly is the wear part (introduced 8 times in this assembly), it was considered appropriate that the dimensional optimization study be carried out on it. The purpose is in fact to increase its service life, leading to a lower maintenance cost of the garbage truck.

Thus, under the given conditions, it was considered that the dimensional improvement should be made in the sense of reducing the equivalent voltage in the wear part.

For this purpose, in the "Design Study" module, the dimensions that can be variable were selected, in this case the dimensions of length (300 mm), width (100 mm) and thickness (40 mm) of the wear part. Fig.6.24 shows the interface of the module "Design Study", the dimensions that can be variable, the constraints and the objective of the study.

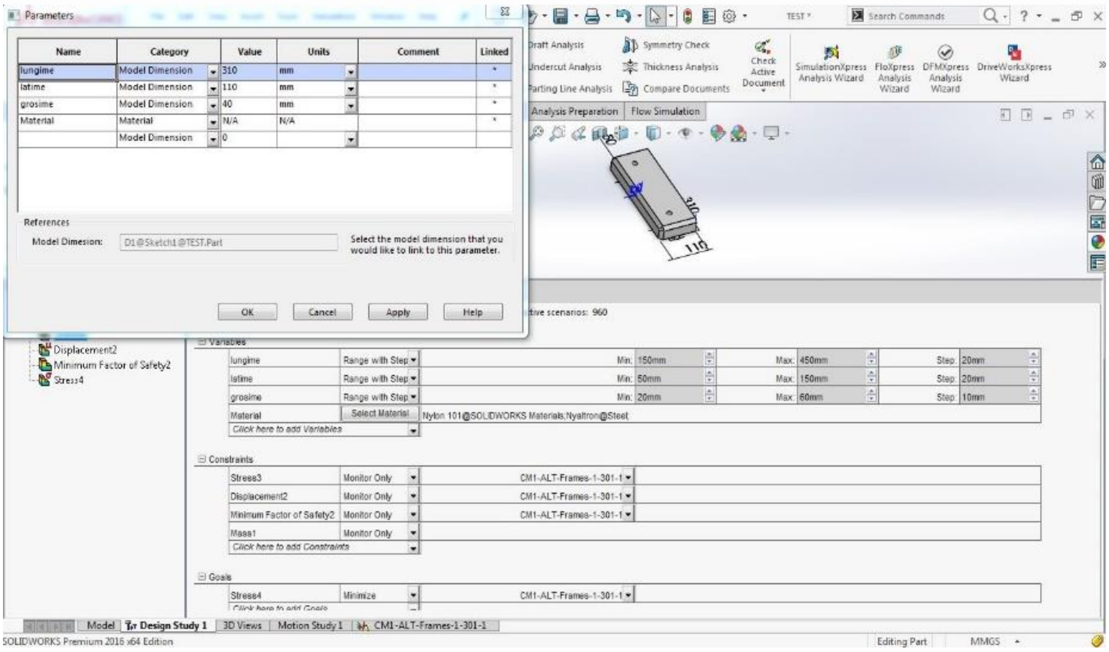


Fig.6.24. Interface of the "Design Study" module in SolidWorks 2016

After selecting the allowances, the sensors (specific name of the program used) were specified for monitoring the mass of the wear part, the von mises equivalent voltage, the safety factor and the displacement in the wear part body, which will use the data from the finished element analysis. Subsequently, in the module "Design Study" was established the field in which the selected quotas and their step can vary. Thus, the length elevation was set to vary between 150 mm and 450 mm with the step of 20 mm, the width of the wear part (elevation of 100 mm) to vary between 50 mm and 150 mm with the step of 20 mm, the thickness of the wear part (elevation of 40 mm) to vary between 20 mm and 60 mm from 10 to 10 mm. In addition, it was also required that the material vary by selecting nyaltron and nylon 101 materials.

Also, the constraints set were only monitoring for: the mass of the wear part, the von mises equivalent voltage, the safety factor and the displacement in the wear part body. The objective of the study is to minimize the von mises equivalent voltage.

After specifying all the parameters and settings, the program used established 962 possible scenarios, obtained by combining the 3 variable odds in the imposed areas and taking into account the set step, but also by considering the two types of material for the wear part.

After running the simulation, the program established the optimal combination of the values of the three variable quotas and the two materials, taking into account the constraints and the stated objective.

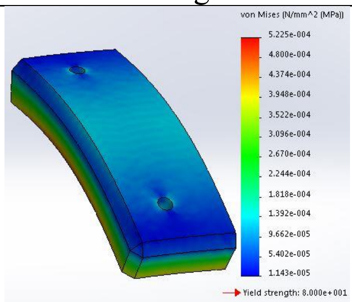
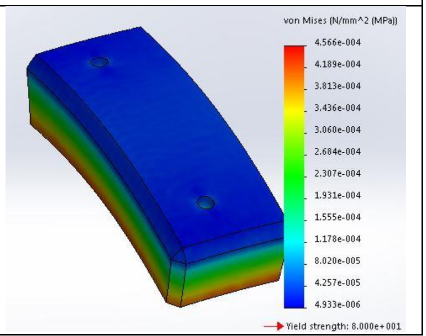
802 of 962 scenarios ran successfully. Design Study Quality: High

		Current	Initial	Optimal (960)	Scenario 903	Scenario 904	Scenario 905	Scenario 906	Scenario 907	Scenario 908	Scena
lungime		290mm	150mm	450mm	270mm	290mm	310mm	330mm	350mm	370mm	390mm
latime		90mm	70mm	150mm	90mm	90mm	90mm	90mm	90mm	90mm	90mm
grosime		60mm	20mm	60mm	60mm	60mm	60mm	60mm	60mm	60mm	60mm
Material	List of Materials	Nyaltron @Steel	Nyaltron @Steel	Nyaltron @Steel	Nyaltron @Steel	Nyaltron @Steel	Nyaltron @Steel	Nyaltron @Steel	Nyaltron @Steel	Nyaltron @Steel	Nyaltron @Steel
Stress3	Monitor Only	0.0006 N/mm^2	0.0042 N/mm^2	0.00024 N/mm^2	0.00064 N/mm^2	0.0006 N/mm^2	0.00056 N/mm^2	0.00053 N/mm^2	0.0005 N/mm^2	0.00047 N/mm^2	0.00045
Displacement2	Monitor Only	7.73e-005mm	4.054e-005mm	1.139e-005mm	4.109e-005mm	7.73e-005mm	1e-005mm	1e-005mm	1e-005mm	1e-005mm	2.475e-(
Minimum Factor of Safety2	Monitor Only	133589.937500	19048.250000	340040.031250	124393.523438	133589.937500	143076.750000	151332.656250	160569.343750	169324.046875	178180.
Mass1	Monitor Only	1759.29 g	217.807 g	4624.49 g	1635.17 g	1759.29 g	1883.41 g	2007.53 g	2131.65 g	2255.77 g	2379.89
Stress4	Minimize	0.0006 N/mm^2	0.0042 N/mm^2	0.00024 N/mm^2	0.00064 N/mm^2	0.0006 N/mm^2	0.00056 N/mm^2	0.00053 N/mm^2	0.0005 N/mm^2	0.00047 N/mm^2	0.00045

Fig. 6.25. Dimensional improvement simulation results

In fig. 6.25 An extract from the simulation results is presented. As expected, the optimal scenario suggests increasing the elevations to the maximum of the range (450 mm long, 150 mm wide and 60 mm thick) with the use of Nyaltron material. Obviously, this will lead to a stiffening of the wear part resulting in a better behavior under conditions of dynamic stress (extracted from the dynamic simulation in subchapter 5.4). However, it has the disadvantage that they will increase the production prices of the wear part, being used more material in its body.

Unfolding, however, through the possible scenarios, we are drawn to the 904 scenario, which foresees a 10 mm reduction in the length and width of the wear part (length 290 mm and width of 90 mm) simultaneously with an increase in the thickness of the wear part (from 40 mm to 60 mm). The figure below shows comparatively the von Misses voltages, the safety factor and the displacements for the original track and the piece from the 904 scenario.

<table>
<tr><td></td><td>Piesa originală</td><td>Piesa din scenariul 904</td></tr>
<tr><td>Tensiunea von Misses</td><td>
</td><td>
</td></tr>
</table>

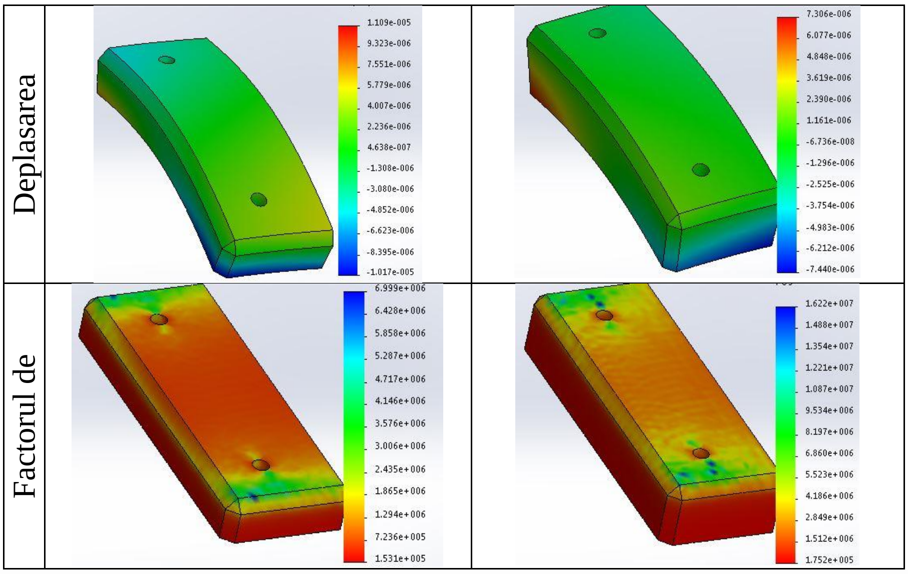


Fig. 6.26. Von Misses tension, displacement and safety factor for the original track and the song from scenario 904

It can be seen that if the geometry of the part is slightly changed, the maximum von Misses voltage of the wear part will decrease from 5,225 · 10-4 MPa at 4,556 · 10-4 MPa, the maximum movement in the piece will decrease from 1,109 · 10-5 mm to 7,306 · 10-6 mm and the minimum safety factor of the part will increase, the result being that the service life of the wear part will be increased.

It should also be noted that the material recommended by the software is Nyaltron, and the mass of the wear part will increase by about 170 g.

In order to ensure the safety in operation, a cyclic fatigue study of the newly obtained model with the data resulting from the optimization study was also carried out. For the study, the fatigue curve in the fig was used. 4.

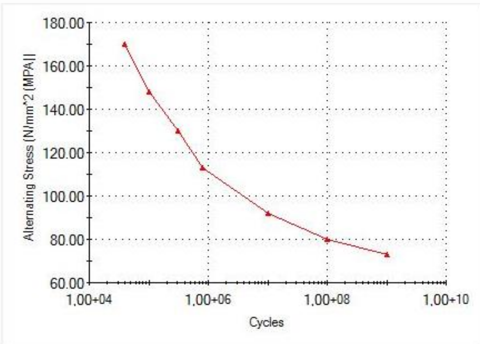


Fig. 6.27. Nyaltron fatigue curve [128]

The requirements in the dynamic simulation were considered and for the determination of the wear degree of the part it was considered a number of 105 operating cycles. It can be seen from the figure below that in the area of screw grip the wear is 90% after 105 operating cycles, and on the lower face, mainly due to the frictional stress, it reaches about 75% after the same number of cycles

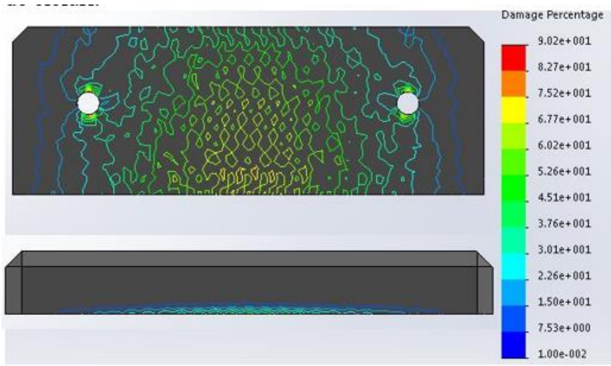


Fig. 6.28 . Wear percentage of the wear part, obtained from the dimensional optimisation study, after 105 operating cycles (side view and bottom view)

For comparison, after the same number of operating cycles, the original part reached the same areas (and on the same layers on its thickness) at 250% wear, about 3 times more, see fig. 6.29

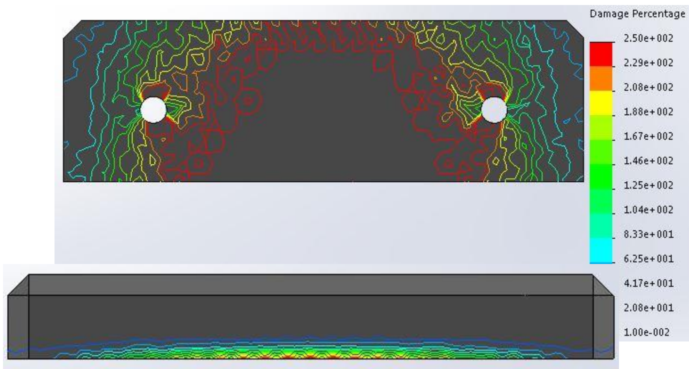


Fig. 6.29 Wear percentage of the wear part with the original dimensions, after 10^5 operating cycles (side view and bottom view)

The conclusion from the optimization calculation is: if the length of the wear part is reduced from 300 mm to 290 mm, the width from 100 mm to 90 mm, and the thickness is increased from 40 to 60 mm, von Misses voltages and displacements in the part will be reduced, reducing the wear of the part by up to 3 times at the same number of operating cycles.

CHAPTER 7. FINAL CONCLUSIONS. PERSONAL CONTRIBUTIONS. RECOMMENDATIONS AND RESEARCH PERSPECTIVES

7.1. Final conclusions on theoretical and experimental research

The process of mechanical compaction of waste is done with the purpose of:

- volume reduction
- densification
- baling
- liquid extraction (dehumidification).

The determination and analysis of the movement of the working organs of these mechanisms is necessary for the good understanding of their functioning, but especially in order to redesign and improve their functional parameters for an operation without loss of material and with low energy consumption.

From the studies carried out, we seek to determine the relationship between the pressure applied to the material(s) in the compaction chamber and the density (densification) of the material .

The dynamic simulation brought results that are verified in reality, regarding the mechanical behavior of the studied components.

In the future, we must make a complex analysis of the compaction equipment, this being necessary for a system with dynamic data, also taking into account the influence of the chassis on the movement of the active organs.

7.2. Recommendations and research perspectives

For future research activities in the field it is recommended:

1. Continue the research of the work process of the waste compaction machines in order to establish the influence of the different structural and functional parameters of the systems on the process parameters (energy consumption, compacted material quality) of them.
2. Continue and expand research on the behavior of the material to be compacted during the compaction process, through specific laboratory analysis.
3. Development of working models of the waste compaction process

SELECTIVE BIBLIOGRAPHY

1. Afzalinia S., Modeling and validation of the baling process în the compression chamber of a large square baler, Ph.D thesis, 2005, University of Saskatchewan, Canada
2. Afzalinia S., Roberge M., Modeling of the pressure-density relationship în a large cubic baler, Journal of Agricultural Science and Technology, 2013, 15(1), pp. 35-44.
3. Akcaozoglu S., Atis C.D., Akcaozoglu K., An investigation on the use of shredded waste PET bottles as aggregate în lightweight concrete, Waste Management, 2009, 30(2), pp. 285-290.
4. Akinola A., Adeyemi I., Adeyinka F., A Proposal for the management of plastic packaging waste, Journal of Environmental Science Toxicology and Food Technology, 8(1), 2014, pp.71-78;
5. Akkaya A.V., Effect of bulk modulus on performance of a hydrostatic transmission control system, Sadhana, 2006, vol.31, Part. 5, 543–556, https://doi.org/10.1007/BF02715913.
6. Al Azkawi A.S., Sivakuma N., Al Bahr S., Bioprocessing of cardboard waste for cellulase production, Biomass Conversion and Biorefinery, 2018, vol.8, pp.597–606, https://doi.org/10.1007/s13399-018-0309-7
7. Antonescu N.N., Antonescu N., Stanescu P., Popescu L., Gestiunea și tratarea deșeurilor urbane. Gestiunea regionala, Ed.MatrixRom, București, 2006
8. Archna A., Moses V., Sagar S., Shivraj V., Chetan S., A Review on processing of waste PET (Polyethylene Terephthalate) plastics, International Journal of Polymer Science Engineering, vol. 1, iss. 2, 2015, pp.1-13.
9. Arlosoroff S., Developing countries struggling with waste management policies, Waste Management & Research, 1991, vol.9(1), pp.491-494, doi: 10.1177/0734242X9100900169
10. Babiciu P., Scripnic V., Frățilă Al., Sisteme hidraulice ale tractoarelor și masinilor agricole, Ed. Ceres, 1984, Bucuresti
11. Brubaker J.E., Pos. J., Determining static coefficients of friction of grains on structural surfaces, Transactions of the ASAE, 1965, 8(1), pp.53-55.
12. Fang H.-Y., Chaney R.C., Introduction to environmental geotechnology, 2nd Edition, CRC Press, 2017, Boca Raton, Fla.
13. Feher G., Evacuarea și valorificarea reziduurilor menajere, Editura Tehnică, 1982
14. Ferrero A., Horabik J., Molenda M., Density-pressure relationship în compaction of straw. Canadian Agricultural Engineering, 1990, 33(1), pp.107-111.
15. Fitch E.C., Hong I.T., Hydraulic component design and selection, 1998, Oklahoma, BarDyne Inc.,

https://books.google.ro/books/about/Hydraulic_Component_Design_and_Selection.html?id=aMy9AAAACAAJ&redir_esc=y
16. Foolmaun R.K., Ramjeawon T., Disposal of post-consumer polyethylene terephthalate (PET) bottles: Comparison of five disposal alternatives în the small island state of Mauritius using a life cycle assessment tool, Environmental Technology, 2012, 33(4-6), pp.563-572.
17. Gabr M.A., Valero S.N., Geotechnical properties of municipal solid waste, Geotechnical Testing Journal (ASTM International)-Vol. 18, Iss. 2, pp 241-251.
18. Gavali S., Patil R.J., Design, Analysis and Manufacturing of Garbage compactor, International Engineering Research Journal (IERJ), Special Issue, 2015, pp.2796-2799.
19. Gulseven O., Ashkanani S., Abdullah S., Ismaeil H., Alkandari H., Baroun M., A sustainable model for enhancing road quality with recycled plastic bags, Kuwait Journal of Science, 2019, 46(4), pp.112-119.
20. Ivanova T., Muntean A., Havrland B., Pobedinsky V., Theoretical modelling of the briquetting process with different pressing equipment, Agronomy Research , 2013, 11 (1), pp.47–52.
21. Jankauskaite V., Lygaitis G., Lygaitis R., Polyethylene terephthalate waste recycling and application possibilities: a Review, Materials Science, 2008, 14(2), pp.119-127;
22. Jankovic Pantic J., Rakic D., Basaric Ikodinovic I., Tina Duric, Hadzi-Nikovic G., Geotechnical effects of municipal solid wastedestruction with different compaction, Engineering Sciences, 2022, Vol. 75, iss. 1, https://proceedings.bas.bg/index.php/cr/article/view/13
23. Koneczny K., Pennington D.W., Life cycle thinking in waste management: Summary of European Commission’s Malta 2005 workshop and pilot studies, Waste Management, 2007, vol.27, iss.8, pp. S92-S97.
24. Kuhlman T., Farrington J., What is Sustainability?, Sustainability, 2010, vol.2, 3436–3448.
25. Lawton P.J., Marchant J.A., Direct shear testing of seeds în bulk. Journal of Agricultural Engineering Research, 1980, 25, pp.189-201
26. **Lazea M.-B.**, Constantin G.-A., Voicu Gh., Mușuroi G., Stefan E.-M., Munteanu M.-G., Zăbavă B.-S., Using hydraulic presses for finding the stiffness variation of the waste materials - experiments for calibrating simulations, U.P.B. Sci. Bull., Series D, 2022, Vol. 84, Iss. 4, 251-262.
27. **Lazea M.-B.**, Constantin G.A.. Stoica D, Voicu Gh, *FEM structural analysis for wear parts supporting counterpressure plate from a municipal solid waste truck*, Romanian Journal of Materials – RRM, 2020, 50(2), pag. 283-293
28. **Lazea M.-B.,** Sisteme de compactare a deșeurilor prin translație, în amplasare mobilă sau staționară, Raport științific 1 la doctorat, Universitatea Politehnica din București, 10 iulie 2018
29. **Lazea M.-B.,** Sinteza cercetărilor teoretice și experimentale pe plan mondial cu privire la parametrii constructivi, funcționali și energetici ai sistemelor de compactare prin translație a deșeurilor, Raport științific 2 la doctorat, Universitatea Politehnica din București, 12 decembrie 2018
30. **Lazea M.-B.**, Voicu Gh., Constantin G.A., Tudor P., Zabava B.S., *Some aspects regarding compaction of plastic bottles în stationary vertical presses,* 20th Int. Sci. Conference Engineering for Rural Development Proceedings, 2021, Vol. 20, Jelgava, Latvia, pp.174-180
31. **Lazea M.-B.**, Voicu Gh., Constantin G.-A., Zabava B.-S., Tudor P., Translation compaction systems used în waste collection and transportation, Acta Technica Corviniensis - Bulletin of Engineering, 2021, Tome XIV, Fasc. 1, pp. 97-100.
32. **Lazea M.-B**., Aspecte și contribuții teoretice privind proiectarea, construcția și procesul de compactare a deșeurilor prin translație în structuri cu secțiune dreptunghiulară, Raport științific 3 la doctorat, Universitatea Politehnica din București, 27 iunie 2019
33. **Lazea M.-B.,** Cercetari experimentale privind compactarea mecanica a deseurilor în prese cu amplasare fixă sau mobilă, Raport științific 4 la doctorat, Universitatea Politehnica din București, 12 decembrie 2019

34. **Lazea M.-B.,** Cercetari experimentale privind compactarea mecanica a deseurilor. Prelucrarea datelor experimentale, Raport științific 5 la doctorat, Universitatea Politehnica din București, 18 iunie 2019
35. Lela B., Barisic M., Nizetic S., Cardboard/sawdust briquettes as biomass fuel: Physical-Mechanical and thermal characteristics, Waste management, 2016, Vol. 47, Part B, pp.236-245,
111,b. Voicu Gh., **Lazea M.-B.**, Constantin G.A., Stefan E.M., Munteanu M.G., *Finite element analysis of the compaction plate from a garbage truck*, 9th International Conference on Thermal *Equipment, Renewable Energy and Rural Development - TE-RE-RD 2020*, 2020, E3S Web of Conferences, 180(60): 04006
111,c. Voicu Gh.**, Lazea M.-B.**, Tudor P., Zabava B.St., Moise V., Comparative analysis of the municipal waste collection and pre-compacting systems, Proc. of the Sixth International Conference "Research People and Actual Tasks on Multidisciplinary Sciences", 2019, pp. 354-359, Lozenec, Bulgaria.
111,d. Voicu Gh.**, Lazea M.-B.**, Zabava B.-S., Tudor P., Moise V., *Cinematical analysis of the pre-taking and pre-compacting mechanisms of some garbage trucks,* Journal of Engineering Studies and Research, 2019, Vol. 25, No. 2, pag.56-62.
111,e. Voicu Gh., **Lazea M.-B.**, Constantin G.-A., Tudor P., Stefan E.M., A*spects regarding the compaction of cardboard waste in vertical presses with discontinuous flow*, INMATEH - Agricultural Engineering, 2022, *Vol. 68, No. 3,* doi: 10.35633/inmateh-68-63

Curriculum Vitae

Personal Information

Nome/Prenome **Mircea Bucur Lazea**
Adress Pitesti, Vasile Militaru street , 12 no, Arges County
mircealazea2005@yahoo.com
Date of birth 1 August 1967

2016-present
Function Oparational Manager
Name of employer RLG WASTE MANAGEMENT SYSTEMS ROMANIA
Managementul Deseurilor Bucuresti

2011-2016
Function Director Logistica
Name of employer COMPANIA ROMPREST SERVICE

2000-2011
Function Logistics Director
Name of employer VEL PITAR
1995-1999
Functia Mechanical Engineer
Name of employer SILVA GRUP Pitesti

Education and training

Universitatea Politehnica din Bucuresti	Facultatea de Mecanica Agricola	1988-1993	Mechanical Engineer

	Universitatea Politehnica din Bucuresti	Facultatea de Sisteme Biotehnice	2017-2023	PhD student

Personal competences and skills

Native language Romanian

Other

Language	Read	Spoken	Written
Engleza	4	3	4

**List of papers - ** eng.Mircea Bucur LAZEA

1. **Lazea M.-B.**, Constantin G.-A., Voicu Gh., Mușuroi G., Stefan E.-M., Munteanu M.-G., Zăbavă B.-S., Using hydraulic presses for finding the stiffness variation of the waste materials - experiments for calibrating simulations, U.P.B. Sci. Bull., Series D, 2022, Vol. 84, Iss. 4, 251-262.

2. **Lazea M.-B.**, Constantin G.A.. Stoica D, Voicu Gh, *FEM structural analysis for wear parts supporting counterpressure plate from a municipal solid waste truck*, Romanian Journal of Materials – RRM, 2020, 50(2), pag. 283-293 (indexat ISI), WOS: 000538152900016, ISSN: 1583-3186, FI=0.542

3. **Lazea M.-B.**, Voicu Gh., Constantin G.A., Tudor P., Zabava B.S., *Some aspects regarding compaction of plastic bottles în stationary vertical presses*, 20th Int. Sci. Conference Engineering for Rural Development Proceedings, 2021, Vol. 20, Jelgava, Latvia, pp.174-180

4. **Lazea M.-B.**, Voicu Gh., Constantin G.-A., Zabava B.-S., Tudor P., Translation compaction systems used în waste collection and transportation, Acta Technica Corviniensis - Bulletin of Engineering, 2021, Tome XIV, Fasc. 1, pp. 97-100. Prezentat la 8^{th} Int. Symposium Agricultural and Mechanical Engineering ISB-INMA Teh'2019, Bucharest, 31 October - 01 November 2019, și publicat în volumul simpozionului, pag.763-768, BDI – CABI, COPERNICUS, EBSCO;

5. **Lazea M.-B.,** Voicu Gh., Constantin G.-A., Tudor P., Aspects regarding the technological process of cardboard waste baling, Annals of Faculty Engineering Hunedoara, International Journal of Engineering, Tome XX, 2022, Fasc. 3, pp.185-190.

6. Moise V., Voicu Gh**., Lazea M.-B.**, Popa L., Tudor P., Dugăeșescu L., Ungureanu L., Kinetostatic analysis of the precompaction mechanism in municipal solid waste collecting equipment, INMATEH-Agricultural Engineering, 60 (1), p.295-302, 8p, indexat WOS:000535690100033, prezentat la *8th Int. Symposium Agricultural and Mechanical Engineering ISB-INMA Teh'2019*, Bucharest, 2019, pp.317-324

7. Voicu Gh., **Lazea M.-B.**, Constantin G.A., Stefan E.M., Munteanu M.G., *Finite element analysis of the compaction plate from a garbage truck*, 9th International Conference on Thermal

Equipment, Renewable Energy and Rural Development - TE-RE-RD 2020, 2020, E3S Web of Conferences, 180(60): 04006, doi:10.1051/e3sconf/202018004006, BDI – Scopus

8. Voicu Gh**., Lazea M.-B.**, Tudor P., Zabava B**.**St., Moise V., Comparative analysis of the municipal waste collection and pre-compacting systems, Proc. of the Sixth International Conference "Research People and Actual Tasks on Multidisciplinary Sciences", 2019, pp. 354-359, Lozenec, Bulgaria.
9. Voicu Gh**., Lazea M.-B.**, Zabava B.-S., Tudor P., Moise V., *Cinematical analysis of the pre-taking and pre-compacting mechanisms of some garbage trucks,* Journal of Engineering Studies and Research, 2019, Vol. 25, No. 2, pag.56-62, indexat Index Copernicus, ERIH PLUS, Google Academic, Publons
10. Voicu Gh., **Lazea M.-B.**, Constantin G.-A., Tudor P., Stefan E.M., A*spects regarding the compaction of cardboard waste in vertical presses with discontinuous flow*, INMATEH - Agricultural Engineering, 2022*, Vol. 68, No. 3,* doi: 10.35633/inmateh-68-63
11. Voicu Gh., Moise V., Popa L., **Lazea M.,** Tudor P., Niculae L., Polena A., Kinematic analysis of mechanism, with articulated precompaction bars, of municipal solid Waste collecting machines, INMATEH-Agricultural Engineering, Vol. 59, No. 3, 2019, pp.93-100, DOI: 10.35633/INMATEH-59-10, WOS:000504038200011, prezentat la 8th Int. Symposium Agricultural and Mechanical Engineering ISB-INMA Teh'2019, Bucharest, 31 October - 01 November 2019, și publicat în volumul simpozionului pag.626-634, indexat BDI – CABI, COPERNICUS, EBSCO
12. Voicu Gh., **Lazea M.-B.**, Constantin G.-A., Tudor P., Zabava. B.S., Plastic waste behavior during compaction in horizontal press with continuous feeding, prezentat la 49th Int. Symposium Actual Tasks on Agricultural Engineering, 28 February – 2 March 2023, Opatija, Croatia (acceptat pentru publicare în volumul simpozionului)