THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XIV MECHANICHAL ENGINEERING, ISSN 1224-5615
2020

ANALYSIS OF THE DYNAMIC REGIME OF THE TRENCHER

Prof. Carmen Nicoleta DEBELEAC
University “Dunarea de Jos” of Galati,
Engineering and Agronomy Faculty of Braila

ABSTRACT

The main objective of the research carried out in this work consists in the design of a trencher equipment with knife chains used in digging soils (mounted on a multifunctional base machine) based on criteria such as: strength, operational and energy efficiency. Thus, the work contains information with a direct impact on increasing the productivity of the machine, the quality of the works performed, the increase in reliability and profitability, under conditions of optimal exploitation and minimal energy consumption.

KEYWORDS: trencher equipment, digging soils, dynamic, working regime

1. INTRODUCTION

The execution of works on construction sites is carried out with the help of specialized machines (such as the one that is the subject of this work) whose choice is conditioned by a number of factors, such as:

- type of wasted material (soil, granular and powdery materials, ores and coal products);
- the volume of works and the time of execution (with influence in the choice of the capacity of the equipment of the machine and, respectively, of its act power);
- economic efficiency.

A performance requirement imposed on trencher equipment is the precision with which it works and, implicitly, maintaining the digging depth at a constant value, imposed by the technical project of the work to be executed.

In practice, this is done using a sole that can be adjusted reaching several positions, thus maintaining the cutting angle at the selected value (according to the technical project) and, implicitly, the required digging depth similarly.

The digging resistance of soils depends on the one hand, on their physical-mechanical characteristics and, on the other hand, on the specific parameters of the work tool with which the digging is carried out.

Constructive chain solutions are available on the specialized market in a varied range of different tooth configurations to execute trenches in material categories as efficiently as possible, such as: soft, hard, and mixed soil.

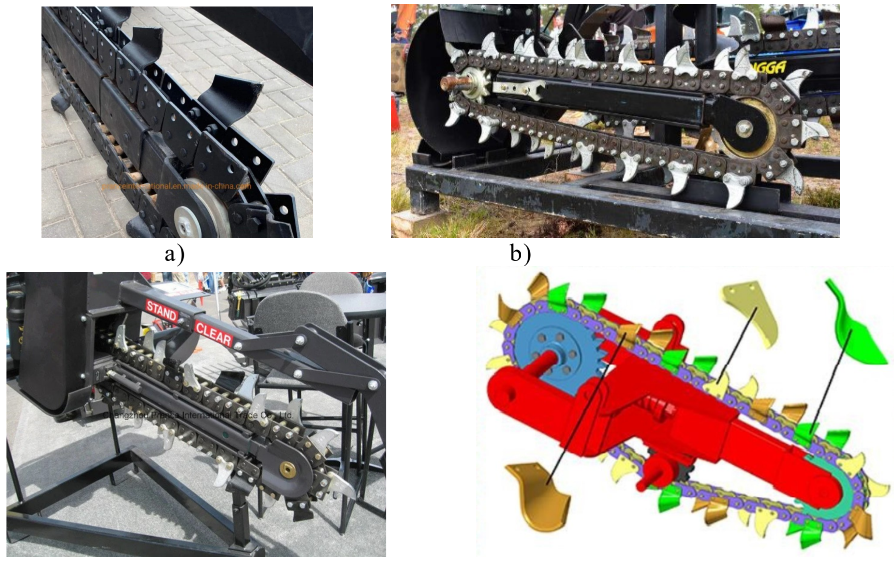
Among the characteristics of soil, which greatly influence the digging process and the size of the resisting forces, are listed: volume weight, granulometric composition, degree of loosening, humidity, internal and external friction, plasticity, and cohesiveness.

2. CONSTRUCTIVE ASPECTS OF TREHCHER EQUIPMENT

Basically, a trencher equipment is constructed from a constructive point of view as shown in figure 1. All component mechanisms are powered by the heat engine of the base machine.

To ensure a wide range of movement speeds of the excavator during the work process, hydrostatic displacement actuation systems, equipped with variable flow pumps, are currently used. When the behavior of the chain is a vibrating one, but of low intensity, the energy consumed is minimal, which is desirable for the builders of this type of technological equipment.

The lifetime of the product is prolonged if the working regime is characterized by a dynamic behavior of low intensity.



a) b)

c)

Fig. 1. Constructive examples for trenchers [1, 2, 3]:
a) with chain with knifes; b) with chain with scrapers; c) with chain with knifes and scrapers.

The handling of the work equipment is also done hydraulically, and the chains are actuated in older models, by mechanical transmission, and currently with fully hydraulic actuation (fig. 2).

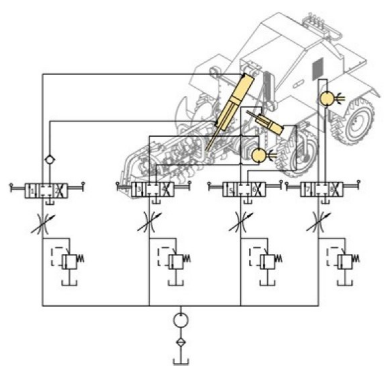


Fig. 2. Hydraulic scheme for driving the working equipment of the trencher

Equipping ditch diggers with scrapers or chain picks ensures their good operation when working in hard (stony) terrain as they are able to make a uniform grinding / shredding of the excavated material. In this way, it can be said that these types of equipment are versatile and powerful, very reliable, have protected working technologies and provide a complex digging and crushing procedure. In addition, the excavated ground shows no changes except in the area of the trench, and the excavation work process is done faster than other common excavation methods.

The vidia spiked chain trencher is designed for stony terrain when crushing rocks of various strength levels. Some modern constructive variants carry out a laser control when installing the cables in the desired place, thus guaranteeing the quality of the execution of the respective work.

Figure 3 shows the 3D model of the excavator on which the longitudinal digging equipment with knife chains was mounted (instead of the standard bucket). The model was made in the dedicated program Inventor 2020. The parameters of the basic machine must ensure the range of travel speeds so that the digging of the trench is carried out with maximum productivity and the work is effective from the point of view of costs. In the case of this project, the excavator must have a power reserve for driving the trenching equipment around the value of 14 kW.

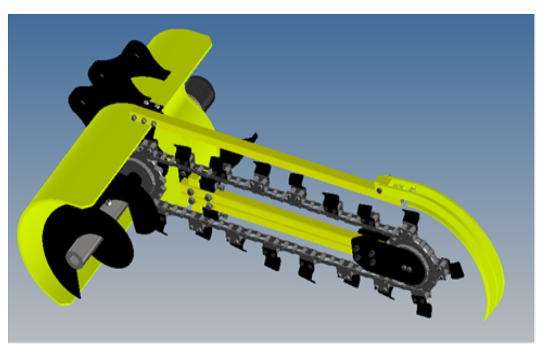


Fig. 3. 3D Modeling of the trench digger equipment

Having established the basic machine, starting from the attachment elements of the bucket on the arm, we then proceed to the design of the equipment that will replace the standard bucket.

3. ANALYSIS ON THE STATE OF STRESS AND DEFORMATIONS FROM A KNIFE

From a static point of view, the evaluation of the demands from a knife will be made in a real case of demand which can be the one in which it is considered to hit it following the impact with an obstacle that appeared during the execution of the technological process of digging a ditch. To start the finite element analysis of the knife, information is needed about its geometry (3D model), the material used for its manufacture, as well as the specific request case (respectively, the value of the force and its application point positioned on the contour of the knife).

Three-dimensional models are used for the computer representation of product models in three dimensions, that is, the geometry of an object is represented in a computer using three coordinates: X, Y and Z. This allows the reconstruction of axonometric projections of object models in different systems of coordinates of the user, as well as obtaining axonometric views of them from any point of view or viewing as a perspective.

So, three-dimensional geometric models have significant advantages over two-dimensional models and can significantly improve design efficiency.

The elements that constitute the working organs of the equipment are the ones that are most subject to the wear process and for this reason they must be designed and manufactured to withstand the harsh conditions in which the digger works with knife chains and scrapers. Their shape is different, as is the material from which they are made, being in close dependence and correlation with the nature of the terrain where the ditch will be executed.

Thus, in this study, the knife will be made of sheet metal with a thickness of 8 mm, from a quality metal - steel (Steel carbon), which has the characteristic parameters given in the dialog box in figure 4 (Tensile Strength = 1450 daN/cm^2).

The discretization mesh of the model is generated automatically with the Mash View command (Inventor 2020). In this way, the knife was divided into a number of 2242 finite elements, in the shape of a tetrahedron, with a lot of 4255 nodes.

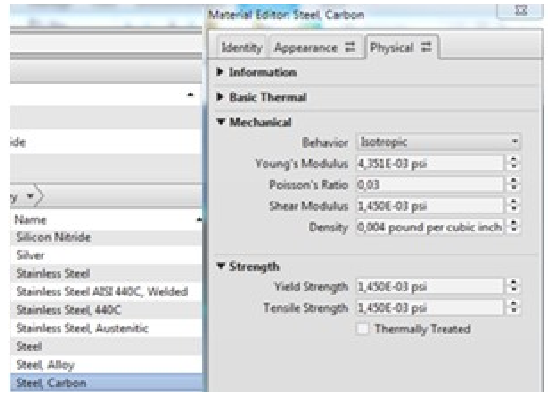


Fig. 4. The properties of the material from which the knife is builded

The support conditions are made up of joints in the two holes of the knife, which added a force acting perpendicularly on its flank (fig. 5), with a value of 10500 N (in the situation were digging in the medium soil and the impact of an obstacle to overcome the fact requires a specific resistance to cutting with twice the value). The lateral force (caused by an obstacle) acts on an area with a surface equal to 35 mm^2.

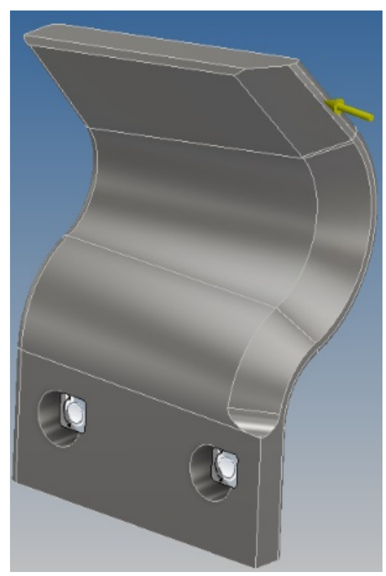


Fig. 5. Knife request constraint

In this study case, the results obtained from the finite element analysis of the knife are presented in figures 6 – 8, in form of tension and deformation states, and safety coefficient of mettalic construction of the material from which it is made.

In conclusion, based on the representations given in figures 6 – 8, it is noted that the maximum stress (165 MPa) does not exceed the elastic limit of the steel chosen for the knife (cutting tools). It is also observed that the maximum displacement of a node reaches a maximum 0,2 mm, and the safety coefficient is at least 2.

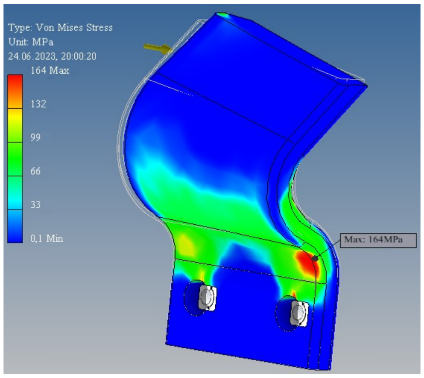


Fig. 6. The von-Mises stress

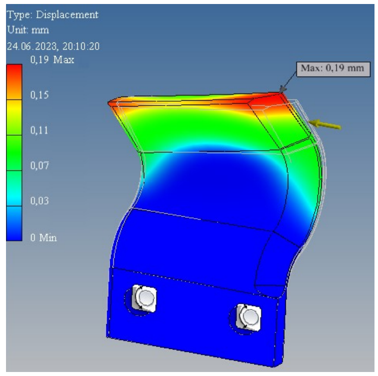


Fig. 7. The deformations state

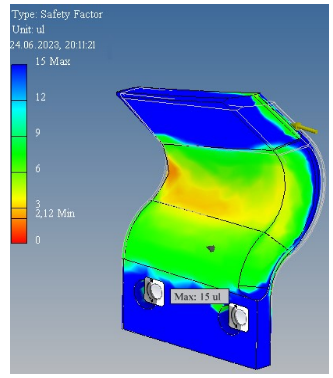


Fig. 8. Safety coefficient

4. MODELING AND SIMULATION OF THE DYNAMIC REGIME OF OPERATION

For the simulation of the mode of operation of the ditch digger, after its 3D model was made, for reasons of simplifying the calculation with the help of the computer a single knife was considered on each branch of the chain, as seen in figure 9. The trajectory of the knife tip is represented by the solid black line in the figure shown previously. Note the closed curve of the trajectory, which represents the operation under identical conditions after several cycles of rotation of the knives.

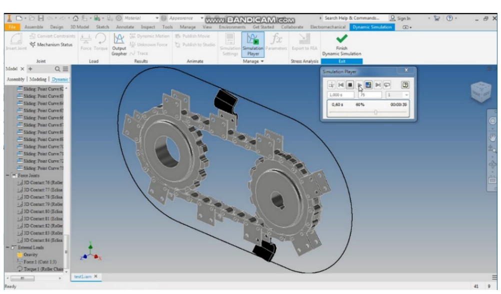


Fig. 9. The trajectory of the tip of a knife on the chain

Each hall was monitored in its movement, and the one with the knife mounted on it was the object of the simulation carried out later, showing interest in the speed with which it moves in the direction of movement of the chain. The variation of this parameter is given in figure 10 highlighting the non-linear character, as well as the periodicity of the analyzed phenomenon and the intense vibratory character of the speed evolution in the direction of the X axis (along the axis).

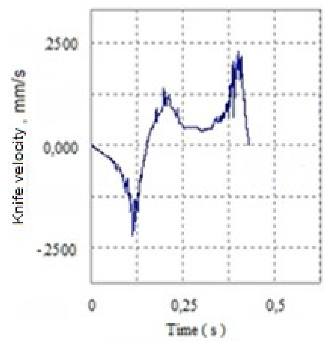


Fig. 10. Speed of a knife chain, in the X direction (along the chain)

5. CONCLUSIONS

When the drive system of the knife chain is set in motion, it starts and then goes into a stabilized motion. At first the speed changes suddenly, after which it behaves non-linearly, but with periodicity. The amplitude of the movement of the knife in the X direction (along the chain) increases slightly due to the oscillations produced by the impact of the rollers, bushings, and rings on the flanks of the teeth of the chain drive wheel. It is concluded that in the running direction, the speed fluctuation is obvious, and the peak value can reach about 2500 mm/s, slightly bigger than the theoretical speed, thus indicating that the chain branch vibrates back and forth, thus increasing the simulated velocity of a knife-bearing chain.

REFERENCES

[1] Jinwu Wang, Yanan Xu, Changyu Wang, Yushun Xiang, Han Tang, Design and simulation of a trenching device for rice straw burial and trenching based on MBD-DEM, Computers and Electronics in Agriculture, Vol.207, 107722, 2023.

[2] www.bobcat.com.

[3] www.kemroc.com.