Analyse of dynamic operation mode for drilling machine equipped with drill for pits digging

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Abstract. The working part of drilling machine is the drill. It is the one that performs soil dislocation, crushing, evacuation and depositing around the pit. Drilling machines with a drill operate according to dry rotating drilling method, where dislocation and evacuation of drilled soil are performed by the drill. To perform this, the drill is subject in the same time to rotation and vertical push-down. Milling cutter type equipment for pits digging was 3D generated in Mechanical Desktop. Cutter model was introduced in Algor medium and automatically digitized by this. After digitization, the user introduces in Algor the supporting set and loading set for all situations. The user has only available the possibility to refine the digitization within the entire model and not only in areas of interest (as it is mostly wanted). Two real situations were considered and analysed wherein the work equipment during digging process can be found: front stress on the cutter teeth performing material cutting and front stress on cutter teeth and body that go inside material and perform centring. In both situations, supporting has tried to follow real situations wherein work equipment components subject to analysis can be found. In both loading situations, it is noticed that the operating part is not at risk to crush under stress. It is also noticed that displacements of the knots belonging to analysed structures do not have greater values in either situations.

1. Introduction
Drilling machines with a drill operate according to dry rotating drilling method, where dislocation and evacuation of drilled soil are performed by the drill. To perform this, the drill is subject in the same time to rotation and vertical push-down.

The working part of drilling machine is the drill. It is the one that performs soil dislocation, crushing, evacuation and depositing around the pit. The drill (figure 1) consists of a shaft (hollow, usually) whereon an helical coil for soil transport is found.

On lower side drill tip 5 is mounted through a dismantable joint, and topside connection element 1 (flange, sleeve or thread) is mounted for fixin on the drive shaft, or on the previous drill segment. The cutters 4 are monted either directly to lower side of the coils (figure 1(a), (c)), or to dismantable tip of the drill after a short coil was previously welded (figure 1(b)).

For drilling at high depths there are drill segments with variable lengths (oscillating around 1m length), that are added to initial drill as this goes deep in the soil (figure 2).

The drill may have one, two or even three starts, and the pitch may be variable or constant (usually, constant). The drill tip is intended to ease the drill entering the soil and further on align the drill [1].
There is a wide range of constructive types of drill tips. The tips are different depending on the kind of drilled soil, the purpose aimed, materials they are made of and technology used by producer company.

Among all types of tips, the tips with helical cutters and chisel or forked head are multipurpose and more frequently used. Generally and especially for big diameters (over 600 mm), helical tips with forked head are recommended.

The main cutting parts of the drill are the cutters. Their shape and constructive parameters have influence on soil cutting in optimum conditions.

Working process of the drill is as follows: when drilling, the drill goes first in the soil, making the hole for drill shaft passing through, then, this soil layers cutting by drill cutters follows, cut soil transport and crushing on the surface of the drill coils and soil throwing outside from the drill.

Cut soil is driven into rotation movement by the friction forces between soil and surface of the drill, as well as due to inclination of this surface from horizontal plan. Under action of centrifugal force, soil particles rotating together with the drill, are pressed on to the pit wall, resulting in occurrence of friction forces on the pit wall, which brakes soil rotation contributing to its slipping upwards. This happens in the same way as axial displacement of a nut prevented from rotation when the screw rotates. Cutter equipment is intended to make the pits with diameter Φ 750 mm and maximum depth 1750 mm.

The equipment can be mounted on a range of small excavators in the place of jib, by means of clamping elements existing on equipment and with an additional hydraulic installation needed for tool feed drive.

Cutter (tool) rotation driving is performed by coupling of hydraulic motor which was driving the tilting cylinder of the bucket.

The main dimensional features in operation are: Maximum digging depth: 1750 mm; Pit diameter: 750 mm; Time for digging cycle (with cylinder of 1200 mm – with cutter of Φ 750 mm: 320 ÷ 340 sec in three passes; with cylinder of 1750 mm; with cutter of Φ 750 mm: 700 ÷ 730 sec in five passes).

2. 3D modelling of cutter type equipment for pits digging
Cutter type equipment for pits digging (figure 3) was 3D generated in Mechanical Desktop.

Modelling was performed by complying with the following work stages:

- A circle was generated and EXTRUSION control was used to generate the central shaft of the cutter;
- In continuation of the central shaft we generated a polygon which was also extruded to generate the solid with hexagonal shape;
A helical curve was generated representing the way and using SWEEP control the helical surface of the cutter was done;

I copied part of the helical surface, it was rotated by 180° and inserted among the coils previously generated using COMBINE control; it was necessary to use this control because the cutter has two material cutting surfaces, positioned at 180° one from another;

I generated the teeth that perform material cutting on the final part of the coil;

I used FILLET and CHAMFER controls to finalize the details of the model.

3. Study of stress and deformations condition that come up on cutter type equipment for pits digging during operation

I considered and studied two real situations wherein the work equipment may be found during digging process:

- Front stress on the cutter teeth performing material cutting;
- Front stress on the teeth and part of the cutter that goes into material and performs alignment [4].

3.1. Case study when the stress comes up frontal on the teeth

I took the cutter from Mechanical Desktop and analyzed it in ALGOR, a specialized media for finite elements analyze [5].

The performed analyze aimed to emphasize what stress and deformation conditions develop in the equipment in considered stress situations.

Mention is made that from initially generated model in Mechanical only tip part was taken over, where the cutting teeth and cutter alignment surface are found, because the complete 3D model needs a bigger work volume and powerful resources of the computer [6].
It is considered that the cutter goes deep in the soil and is frontally stressed on the cutting teeth by an equivalent pressure to specific strength during digging.

Cutter model was inserted in Algor and automatically digitized by it.

After digitizing operation was performed, the user inserts the seating set and loading set in Algor.

Seating was considered of embedded type and was done on the surface for cutter fixing in clamping device (figure 4).

The pressure on cutter teeth is equivalent to specific strength when digging and was taken over as value from the tables shown within specialty literature. In this situation, the value $0.25 N/mm^2$ was chosen for pressure.

![Figure 4. Cutter digitized model, with seating and loading sets applied.](image1)

![Figure 5. View on stress condition in case of front stress on teeth.](image2)

From the set of results obtained the view on stress condition that comes up on the cutter (figure 5) as well as its displacement under proposed action (figure 6) are of interest.

![Figure 6. View on cutter displacement in case of front stress on teeth.](image3)

3.2. Case study when the stress is frontal on teeth and alignment part of the cutter

In this condition the cutter is considered as going deep in the soil and it is frontal stressed on the cutting teeth by a pressure equivalent to specific strength when digging and also frontal on cutter’s end surface that makes alignment.

Cutter model was inserted in Algor and automatically digitized by it.

After digitizing operation is done, the user inserts the seating and loading sets in Algor.
Seating was considered of embedded type and was done on the surface for cutter fixing in clamping device (figure 7).

The pressure on cutter teeth is equivalent to specific strength when digging and was taken over as value from the tables shown within specialty literature. In this situation, the value $0.25\,N/mm^2$ was choosen for pressure.

**Figure 7.** Cutter digitized model, with seating and loading sets applied in the second stress condition.

From the set of results obtained the view on stress condition that comes up on the cutter (figure 8) as well as its displacement under proposed action (figure 9) are of interest.

**Figure 8.** View on stress condition in case of front stress on teeth and alignment area.

**Figure 9.** View on cutter displacements in case of front stress on teeth and alignment area.
4. Conclusions
Digitizing was automatically performed by Algor, in all situations. The user has only available the possibility to refine the digitization within the entire model and not only in areas of interest.

In both situations, the seating has tried to follow real situations wherein work equipment components subject to analysis can be found.

The finite element analysis was a static analysis and led to obtaining of the stresses from the structure and of the displacements for the structure nodes.

From the analysis of the stress state, the user can visualize the dangerous areas in the structure (those areas in which the stresses take maximum values) and can take measures in useful time to reduce them.

The finite element analysis has the following advantages:
- very low costs (the making of a 3D model and then the analyze of this in a specialized software - both phases are performed on a computer);
- low time consumption (compared to the time periods when the prototypes of structures and machines were practically realized in workshops);
- low material consumption (the structure model is executed in the computer and not in reality).

The present paper can be used by specialists from the domain of construction machinery design to improve the working performance of such equipment.

5. References
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