

CAD-based strength analysis of EK-18 excavator bucket construction for mounting of anti-adhesive devices

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Abstract. 3D rigid-body model of a bucket of power shovel EK-18 was built using modern CAD-software. Tetrahedral grid with 10-node second-order elements was chosen, and the given model was imported to APM WinMachine - model preparation preprocessor for finite element analysis. The finite element model was based on the geometrical model, imported from KOMPAS-3D to APM Studio. Calculation of stressed-strained state of the bucket was carried out under the forces emerging while digging with “back hoe” equipment. Shift, deformation and tension charts were planned and the most and the least strained areas were pointed out. Wet coherent soil excavation deals with soil adhesion to working bodies of power shovels and leads to reduced performance. The performance decrease is caused by a reduction of useful bucket capacity and partial unloading, increased front resistance to cutting (digging) caused by wet soil adhesion to a working body, increased bucket entry resistance, increased idle time caused by necessity to clean working bodies. Also energy losses increase and quality of work drops because friction forces go up. Friction force occurs while digging and levelling account for 30...70 percent of total digging resistance while performance decreases 1.2...2 times and more. Vibrothermal exposure creates new technological effect which involves a wider humidity range of efficient application and a reduction of friction forces. Disintegrating adhesion bonds with heating requires less driving force from the vibrator. Vibration boosts up heating of the contact layer, which reduces thermal energy losses. However, the question of piezoelectric ceramic actuators location on the excavator bucket needs to be dealt with. The most suitable spots for mounting piezoelectric ceramic devices for reducing soil adhesion to the excavator bucket were defined. Their efficiency is derived from combined (vibrothermal) methods of exposure. Such devices eliminates soil adhesion to the bucket and increases efficiency of using power shovels with wet coherent soils.

1. Introduction

Successful functioning of enterprises depends on output of products which should meet certain demands, application area or purpose, cater to customer needs, conform to accepted standards and technical specifications, meet society interests, take into account environmental requirements, be available to customer at competitive price and be cost-effective.

To deliver competitive products, an enterprise needs to release new products as soon as possible, cut production costs and improve quality. This process becomes easier with the application of modern automated design engineering systems, which streamline the whole production designing process – from concept formation to prototype building to commercializing it. Therefore, the process of developing new products becomes significantly faster without loss of quality.



Computer aided design (CAD) systems enable one to carry out tridimensional and two-dimensional geometric modelling, reverse engineering, design decision assessment, technical drawings generation.

The objective of CAD is to improve designing quality, lower material costs, reduce the time needed and prevent the increasing number of engineers who performs designing and development.

2. Research subject

Excavating machinery operation shows that soil freezing over and adhesion to working bodies significantly reduces machinery performance.

Abovementioned performance reduction is caused by a reduction of useful bucket capacity and partial unloading, increased front resistance to cutting (digging) caused by wet soil adhesion to a working body, increased bucket entry resistance, increased idle time caused by necessity to clean working bodies. Also energy losses increase and quality of work drops because friction forces go up. Friction force while digging and levelling account for 30...70% of total digging resistance while performance decreases 1.2...2 times and more [1-7].

Piezoelectric ceramic actuators (transducers) are proposed as a solution to a soil adhesion problem. Such transducers provide combined (vibration and thermal) exposure and can be mounted in the areas with the strongest adhesion. This effect is based on an inverse piezoelectric effect.

Combined application of vibration and heating of working surface was researched [8]. Vibrothermal exposure causes a new technological effect which results in wider efficient humidity range and significantly less friction force. There is less vibrator driving force required for disintegrating adhesion bonds. Vibration boosts the contact layer heating which leads to reduced thermal energy costs.

However, at this point one needs to deal with the question of proper placement of piezoelectric ceramic transducers on the excavator bucket.

3. Research objective

The given paper discusses the calculation of stressed-deformed state of the EK-18 excavator bucket using CAD system APM WinMachine in order to locate the least stressed areas to place piezoelectric ceramic transducers.

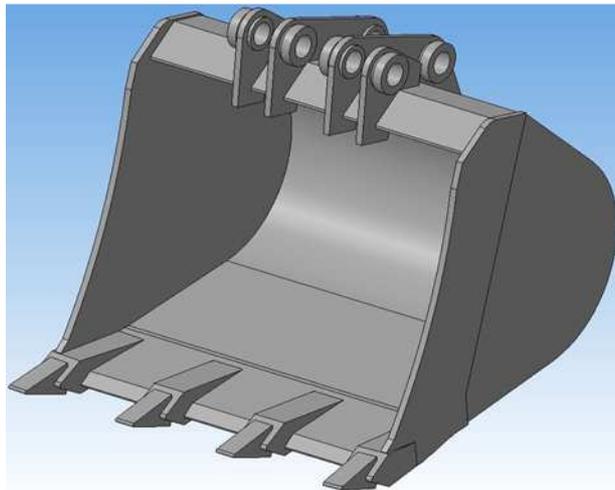


Figure 1. Tridimensional bucket model.

APM WinMachine is a system for automated analysis and designing mechanical equipment and machinery constructions. The system taps into latest achievements in computational mathematics, numerical methods and programming, theoretical and experimental engineering solutions. The system meet all the requirements of state standards and regulations that control design documents execution as

well as computational algorithms [9].

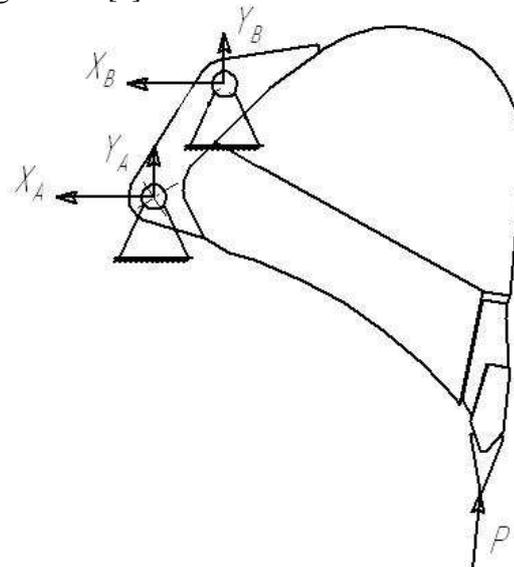


Figure 2. A chart for forces which affect the bucket.

Despite rich functional capabilities of APM WinMachine, creating tridimensional rigid-body models of parts and complex geometry constructions in this environment is quite demanding. This disadvantage is compensated by enabling the user to import files from other systems, where creating tridimensional models is easier and takes less time. Figure 1 presents a tridimensional model of the EK-18 excavator bucket, created using KOMPAS-3D software. The model was imported into preprocessor of model preparation for finite element analysis APM WinMachine. Then fixing points were selected and all the loads were applied according to the chart in figure 2. The load pattern complies to the bucket position at the moment of digging into soil. X_A , X_B , Y_A , Y_B – bucket fixing (reactions of bearing), force P (excavator maximum digging effort), affecting the bucket via its teeth, was taken as 100 kN in accordance to technical specifications [10].

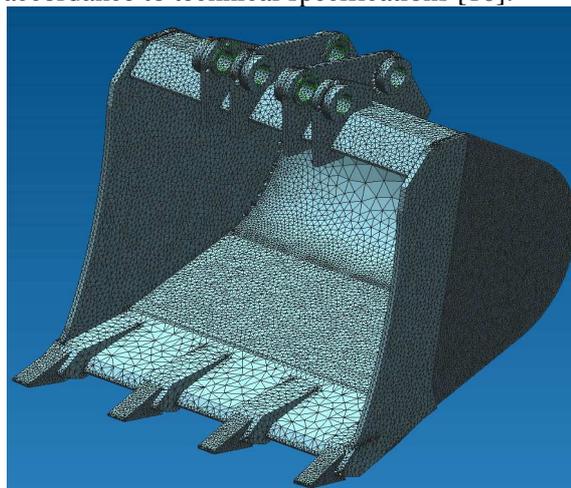


Figure 3. Bucket breakdown into finite elements using the rigid-body modelling module in APM Studio.

The finite element model was generated in APM Studio and based on the geometrical model imported from KOMPAS-3D (figure 3). The grid chosen was a tetrahedral one consisting of 10-node

second-order elements. The number of finite elements equalled 210103, the number of nodes – 60465.

APM Studio includes tools for assembling preparation for calculation, border conditions and loads setting, as well as integrated finite element grid generators (both with fixed and varied pitch) and a post-processor. This functional kit enables one to model a rigid-body object and conduct complex analysis of design model behaviour in different conditions based on statics, eigenfrequencies, stability and thermal stress right in the APM Studio module.

The given paper considers major loads affecting the excavator bucket for different positions. The case of maximum load application is also analysed while the load is evenly distributed along the cutting edge and each of the teeth.

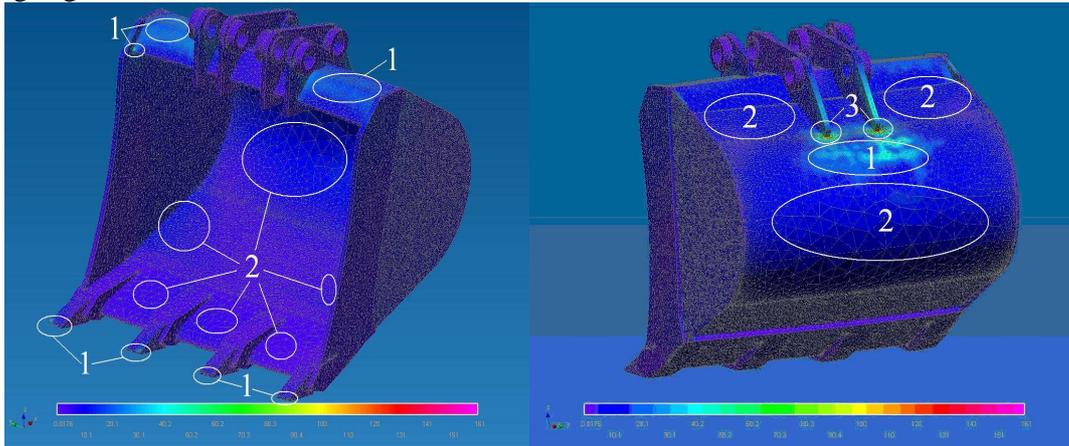


Figure 4. Bucket stress chart.

Component fields of stress tensors were obtained and relative shifts in the EK-18 excavator bucket were identified using APM Studio software package for finite elements analysis under the suggested problem statement within contact interaction mechanics.

4. Results analysis

Figure 4 shows tensions in a bucket with 25 kN load on each of the teeth; the chart corresponds to the moment of digging. Principally tensions in the bucket equal 5-10 mPa (areas without highlight). Areas highlighted under number 1 have tensions 30-40 mPa, under number 2 – 10-20 mPa, number 3 – up to 160 mPa.

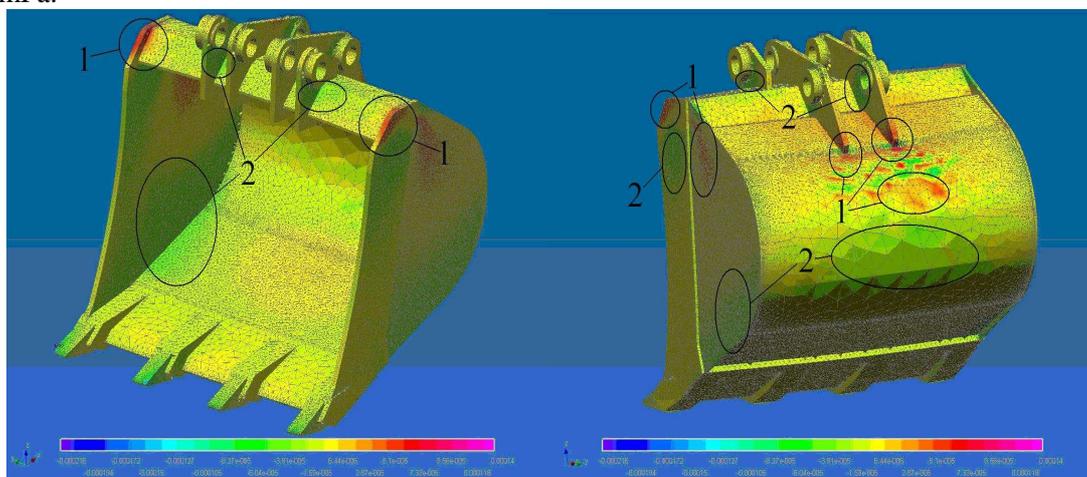


Figure 5. Bucket intermixtures chart.

The most stressed areas of a bucket are stress raisers – spots where stop blocks are mounted to the back wall (number 3).

Figure 5 shows shifts with relation to fixture points: number 1 – 1.2-1.4 mm; 2 – 0.8-1 mm; 3 – 0.6-0.7 mm; 4 – 0.1-0.2 mm; 5 – 0-0.2 mm. The biggest shift can be seen near the teeth which can be explained by concentrated load from the soil applied in these spots.

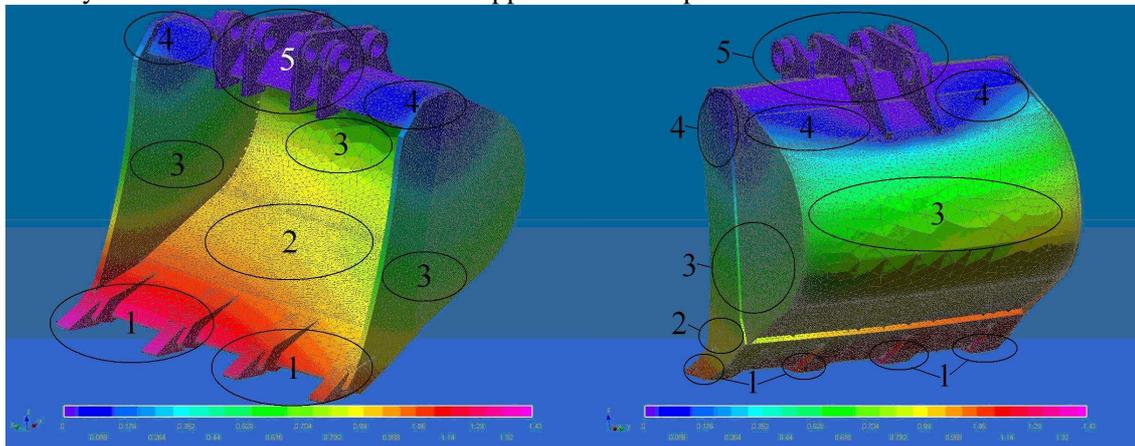


Figure 6. Bucket deformation chart.

Figure 6 shows deformations: 1 – 0.000070-0.000080 stretching; 0.000040-0.000080 shrinkage. Areas without a number experience a 0.000006-0.000010 stretch.

The results obtained present an opportunity to modify the design to balance tensions in a bucket and avoid excess tension in some areas.

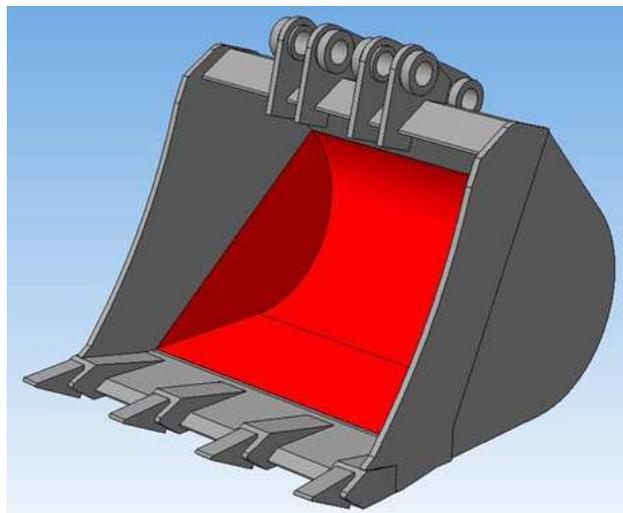


Figure 7. 3D Model excavator bucket.

Possible areas to mount piezoelectric ceramic transducers are the bucket back wall on either side of stop blocks fixing spots (Fig. 6) and areas where the bucket back wall meets the bottom.

Figure 7 shows the 3D model of the bucket of the excavator EK-18; the red color indicates the places most prone to sticking with the soil.

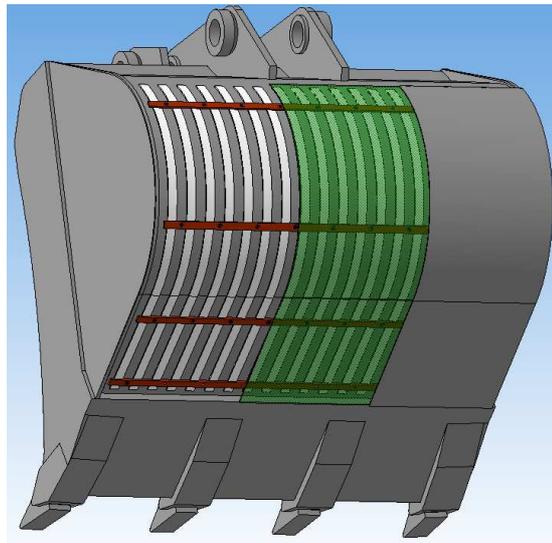


Figure 8. 3D Model excavator bucket.

Figure 8 shows the 3D model of the bucket of the excavator EK-18 with flexible electric heating elements ENGL-1 24V. The specific power of electric heaters is $1000 \text{ W} / \text{m}^2$.

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