drawing used, that point is moved forward on 20 mm. It creates situation of the eccentric column compression.

Central column bowing in the forward direction. Top forward sides of central columns are the most stressed region (***-1.01*** MPa) in the façade. Rounded concentrators ***SCC-1*** are placed there. However, they acquired arcuate shape due to eccentric compression. As for 11th drum of a central column, minimum principal stress σ_3 is 2.7 times lesser on the rear side than on the forward one.

Corner columns compressed half as weak (***-0.51*** MPa) than central ones. End columns are loaded mainly by their own weight and are just a little stressed (***-0.21*** MPa). A comparison of stress-strain states for different columns points out the importance of the stone fronton gravity.

Openings in the drum junctions are observed only for the end columns. The facade itself is monolithic and stable enough in spite of eccentric loading from above, due to the mentioned shift of the fronton point of mass. That conclusion is relevant only for precisely vertical column positions.

Conclusions:

1. Parthenon's façade was simulated by FEA as a contacts-in-focus load-bearing system of FPS type. Fronton eccentricity (20 mm forward) is taken into account. Stress-strain state is depicted, including smooth lowering (in ~1.35 times) of the average compression stress during descending from echinus to the stylobate.
2. Sequences of the contact openings and slides are described. Different contact interaction patterns are revealed. The adaptive character of the contact slippage picture was considered. The presence of numerous contact gaps in the compressed system is stated as natural feature for FPS.
3. Eccentric compression of the columns caused due to fronton eccentricity is simulated. Drum contact pairs response on eccentricity is discovered.
4. A special class of stress concentrators – surface compression concentrators (SCC) – is depicted. These concentrators are tied to block/drums edges, occupying both free and contact neighboring surfaces. Rounded and arcuate SCC easily transforms into each other. SCC is potentially dangerous for compressed material at least for local overstressing. The significance of that class of concentrators is possibly underestimated.
5. SCC may be compatible (under some conditions) with structure longevity and durability (Parthenon temple e.g.). Column ends, near echinus and near stylobate, are the places for SCC. The periodical transition from SCC to stress leveled regions and back again is revealed along column height. Moderate self-focusing of the compression stress is stated inside stylobate under column.
6. The simulation predicts Parthenon's façade vulnerability to the inclination from vertical. Uncontrollable deformation by sliding and local crashing is expected, beginning from 3° level. Slippage localization on the column bottoms, about abacus, and in the fronton corners is the predictor of the upcoming instability.

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FEA SIMULATION OF THE BIOMECHANICAL STRUCTURE OVERLOAD IN THE UNIVERSITY CAMPUS PLANTING

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Abstract. *FEM investigation of the branch collapse is provided for the huge healthy chestnut tree. Strong wind gust (24 m/s) is assumed. Thus, simulation has as engineering so methodic value to improve the FEM-teaching of students. The geometry was recovered by the photos and sketches. It includes roots, trunk, branch and conditional crown. Static simulation is provided both in the linear formulation and in the geometrically nonlinear one. Branch under-*

goes bending with a moderate portion of the twisting. Near uniform stress dispensation is stated along the branch. There are no stress concentrators at all. The trunk-branch junction is steady enough and self-optimized. The branch has grown with the implementation of the idea of „equal-strength console". Transforming of the branch section provides constant stress level along the branch. Collapse is caused by a severe accidental wind gust. Work stresses have exceeded twice the allowable level (16 MPa) along the main part of the branch. The tree should be taken as an example of an effective bionic design for the load-bearing system. Simulation confirms the effect of self-reinforcing during tree growth. Tree simulation may be methodologically useful. It is understandable and interesting for students.

Keywords: *FEM, biomechanics, tree, branch, wind, overload, wood cracking, bionics.*

There is a group of trees on the border of the BNTU university campus. That is chestnuts. Tree 1 became the object of the simulation. It is a part of two-row planting. A huge branch of the mentioned tree has collapsed on a windy day, causing some material damage. Breakage took place across the healthy, quality wood fibers at the distance from trunk-branch junction. The tree remains standing and continues to grow. Branch had developed crown, withstanding against the wind. However, there was not a storm upon a summer city. According to the data of a weather station (5 km distance from campus), wind speed was equal 12 m/s only. The weather is regarded as stormy if the wind exceeds 15 m/s.

University authorities make the decision to investigate the collapse event. Two groups were formed: experts in the area of computed flow dynamics (CFD-group) and analysts of the load-bearing systems (SA-group). The last group was an international collective of experts and students, joined under the auspices of Mechanical engineering faculty and department "Technological machines".

CFD-group has provided computer simulation of airflows nearby the tree (0.3 km vicinity) and revealed a strong local wind amplification. It turned out, that the tree is placed in the focus of the double-wedged air manifold. The slot between buildings is continued by the gap in the double-row planting just before the tree. In sum north-east wind is speeding up above university stadium and creates in the manifold stormy flow with the velocity of 24 – 25 m/s.

SA-group (authors of this paper) has simulated the tree as a load-bearing system under wind pressure. Pressure value was extracted from CFD-group proceeding. Here below normal pressure level is equal $p_{norm}^{wind} = 380$ Pa. Simulation has shown interesting results in two fields: engineering of biomechanical load-bearing system and methodical improvement of teaching students FEA.

The tree with a broken branch was measured and sketches by gardeners just after the event, in the vacation time. Sketch information is relatively scarce. That is why SA-group members have provided parallel 3D- modeling of the same tree to bring variability of shapes and reduce the subjectivity of simulation. Scope of simulation embraces tree's trunk, huge collapsed branch and crown.

Finite element mesh paid special attention to the branch and to the branch-trunk junction. The branch itself was meshed by hexahedral elements. It brings better accuracy in the critical part of the model. The tree's crown was represented by a separated mesh of volume finite elements. Crown and tree meshes were conjugated by contact pair.

The simulation was provided in the static form. Stepped loading and large displacement accounting were completed at the end of simulation, as an additional check. The ground is simulated as a rigid base. Wind pressure is uniformly distributed upon the windward side of the crown. Gravity force is dispensed through all materials accordingly to their densities.

The concentration of maximal principal stress σ_1 so minimal stress σ_3 are disclosed. There aren't local stress concentrators, discontinuities, high-gradient regions on the tree surface. The bottom part of the branch is the only place with relatively high stresses. There is

Strip of Strong Tension SSTe. It is “tensioned fiber” from classic theory of bending. Just branch is most tensioned part of the tree. It happens from windward far away trunk-branch junction. The trunk is a slightly stressed object.

Stress-strain pictures, shown above, points out that branch collapse under wind pressure $p_{norm}^{wind} = 380$ Pa is highly likely possible. Nonlinear geometry effects amplify branch deformation and overloading. Wind displaces the crown’s center of mass to leeward. Gravity force starts to create a bending moment relatively to trunk’s rest (eccentrical compression). That moment even more raised crown and branch deviation from the vertical axis.

Comparing the linear and nonlinear solutions was provided. In the last case, the crown’s top displacement has risen about twice. Stresses along SSTe and SSCo have grown approximately in a quarter. Nonlinear effects aren’t strong for the trunk part of the tree.

Thus, stormy wind pressure overloads tree branch up to fracture. It happens with a large margin above allowable stress level. There isn’t concentrators or damaged places along the branch for collapse event explanation. The branch has to fall under influence of the strong bending and twisting moments.

Engineering conclusions:

1. Investigated branch undergoes during the storm mainly bending with some portion of twisting. Gravity compression didn’t take a significant part in the formation of the stress state.
2. Narrow Strip of Strong Tension (SSTe) is forming from windward in the bottom third of the branch. From leeward opposing Strip of Strong Compression (SSCo) is revealed.
3. Strong stresses rise in a smooth and uniform manner only along SSTe and SSCo in a bottom third of the branch. Working tension and compression stresses reach 30-34 MPa for the moderate crown (*RectCrown* model). It exceeds allowable stress (16 MPa) with a great margin. For developed crown (*CurlCrown* model) stress rises up to 67 MPa, partially for the eccentric action of the gravity.
4. There is no stress concentrators along the branch. Destruction occured due to severe overloading. Predicted bending stress exceeds twice allowable stress for the chestnut tree.

Methodical conclusions:

1. The university campus tree is a part of the environment, interacting with students. Therefore, the simulation of such an object arises keen interest among students.
2. The tree branch suddenly became a good illustration of the “equal strength console” idea. Tree simulation teaches students to create models of load-bearing systems without stress concentrators, according to bionic design ideas.
3. Mechanical students generally know that different junctions are usually the most stressed and damaged places into machines. The trunk-branch junction is the counterexample. It shows the potential of bionic-style reinforcements.

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МОДЕРНИЗАЦИЯ ПРИВОДА ГОРИЗОНТАЛЬНО-КОВАЧНОЙ МАШИНЫ МОДЕЛИ В1234

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Abstract. *In this work, the modernization of the start – protection equipment of the horizontal forging machine model B1234 was carried out.*

Горизонтально-ковочная машина модели В1234 оснащена главным приводом асинхронным трехфазным электродвигателем с фазным ротором типа 5АМ315S8Еу3, пневмоаппаратурой марки У7 126А УХЛ4-28В и пускозащитной аппаратурой марки АП50-3МГ [1]. Изучив устройство ГКМ В1234, сделал следующие выводы по его модернизации:

1. Замена электродвигателя главного привода асинхронного двигателя с фазным ротором на асинхронный двигатель с короткозамкнутым ротором.