Exploitation of the software product Pro/MECHANICA in the agricultural research

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ABSTRACT: The program system Pro/MECHANICA is a specific software product designed for solving of different kinds of technical problems in general engineering. We were looking for usage not only in the engineering but also in the terramechanical area. We realized a simulation loading of the soil with a rigid circular table and after the loading we calculated deformations and stresses under the table using FEM (Finite Element Method). This article shows a specific exploitation program Pro/MECHANICA in an unconventional area as well as in the agricultural area.

Keywords: program product; FEM (Finite Element Method); Pro/MECHANICA; deformation and stress of soil; modelling

Soil properties require exact measuring methods making use of computing methods for investigation of deformation strength, establishment of applied progressive mathematical theory and model. The progressive mathematical theory and model lead on verification results or identification parameters, which require difficult systems. One of the difficult system is investigation of stress in the soil, which we analyzed. We investigated a transmission force between tyres and soil. The methods is determinate with a computers and software equipment. In this article the possibility software product Pro/MECHANICA of the software packet Pro/ENGINEER.

DESCRIPTION OF PRO/MECHANICA PRODUCT

Pro/MECHANICA is a product of Parametric Technology Corporation (PTC) company. The software includes static, kinematic and dynamic tools for design optimalization. An excellent design will be achieved when every component behaves and performs adequately and when those components interact correctly with each other in the system. However physical prototyping is not only expensive, it absorbs precious time. With Pro/ENGINEER Simulation Software, engineers can test structural, dynamic, thermal and durability performance and then optimize their designs accordingly. The product can be used for fast modelling of mechanisms and for easy final element analyse (FEM) of designs.

The software product Pro/ENGINEER has tree main modules: Pro/ ENGINEER Simulation, Pro/ENGINEER STRUCTURE and THERMAL, Pro/ENGINEER Mechanism Dynamics.

Pro/ENGINEER Simulation – Pro/ENGINEER Simulation software allows engineers to test and thereby optimize designs for structural, dynamic, thermal and durability performance. By quickly and accurately simulating the mechanical performance of a design, software minimizes physical prototyping, increases creativity and helps to deliver better products in less time. Pro/ENGINEER simulation solutions are used by some of the world largest engineering organizations daily in industries of every market segment, including aerospace, automotive, medical, consumer, and heavy equipment.

With Pro/ENGINEER Structural & Thermal Simulation engineers can easily evaluate product performance using the most essential range of simulation capabilities. Go forward confidently using a unique adaptive technology that will ensure fast, accurate solutions automatically. Of course, as an integral part of Pro/ENGINEER, Structural & Thermal Simulation simplifies the job since there is no awkward data transfer issues common with other systems. Pro/ENGINEER Structural and Thermal Simulation allows product development organizations to meet these challenges, giving engineers the power and comfort of use required to gain early insight into design performance. This provides engineers with the freedom to explore new ideas and alternatives, and even optimize their designs. This freedom gives them the confidence that the new design will behave as expected, requiring fewer changes during physical prototyping and/or real world use.

For simulation to be adopted as an integral component of the product design process, the tools must be fast, give accurate results, and be easy to use. As a Pro/ENGINEER native application, Structural and Thermal Simulation employs the same user interface, workflow, and productivity tools that are prevalent throughout Pro/ENGINEER. Thus, designers leverage their familiarity with and the proven power of Pro/ENGINEER for model creation and collaboration. Additionally, since Pro/ENGINEER model files store simulation-modelling data, data management issues are streamlined.

Pro/ENGINEER Structure and Thermal Simulation has the ability to solve:

– Static analyses to compute stresses and displacements, including contact non-linear effects

– Modal solutions to compute both free and constrained natural frequencies
– Buckling analysis capabilities to compute critical buckling load factors
– Steady-state thermal analyses to evaluate a model's reaction to applied thermal loading and boundary constraints.

In addition, engineers can perform a coupled thermal-structural analysis, applying the results from the thermal analysis as a load for a static analysis.

Pro/ENGINEER Structural and Thermal Simulation works with all types of geometry including solids, shells, beams, or mixed models. It also provides engineers the ability to extract midsurface geometry from solid models, simplifying processing for thin models such as sheetmetal models.

In addition, Structural and Thermal contains a robust library of tools that allow engineers to rapidly built simulation models. These tools include:
– Welded connections, including spot, end, and perimeter
– Simple mass and extensional/torsional spring idealizations
– Rigid connections
– Engineering loads and constraints such as bearing loads and cyclic symmetry constraints
– Isotropic material support.

Pro/ENGINEER Structural and Thermal Simulation features another unique capability – that of interpreting a Pro/ENGINEER assembly and automatically connecting the components at solution time. This capability is particularly important when modelling complex sheetmetal weldments.

Pro/ENGINEER Structural and Thermal Simulation incorporates unique MECHANICA technology to deliver accurate results with minimum effort. Traditional structural analysis products rely on the engineer to guide the system to an accurate solution. In these systems, the engineer must iteratively refine the Finite Element Mesh (FEM) until it accurately represents the CAD geometry and provides converged results.

Pro/ENGINEER Structural and Thermal Simulation handles convergence automatically every time an analysis is performed. Advanced adaptive solution maps precisely to the underlying CAD geometry, and iterates until a quality, converged solution is obtained – no other CADintegrated simulation product available today can match this capability.

In addition, Pro/ENGINEER Structural and Thermal Simulation provide engineers the flexibility of selecting other solvers via its FEM mode. In FEM mode, engineers can output, solve, and postprocess models in either NASTRAN or ANSYS. And, because Structural and Thermal Simulation uses a single simulation model and database, engineers can switch between using the MECHANICA-based solver and FEM mode solvers with no need to recreate modelling entities (properties, loads, etc.).

Mechanism Dynamics Option (MDO), a new addition to PTC Mechanism Design Extension (MDX), greatly expands the Pro/ENGINEER mechanism design environment. While MDX provides fundamental motion (or "kinematic") simulation, MDO simulates dynamic forces of springs, motors, gravity, friction, impact, and so forth. MDO brings real-world forces into your virtual Pro/ENGINEER prototypes. Pro/ENGINEER Mechanism Dynamics adds dynamic functionality to Pro/ENGINEER Mechanism Design to provide a powerful virtual prototyping environment for the simulation and improvement of mechanism operation as part of the design process. Pro/ENGINEER Mechanism Dynamics allows designers to virtually engineer a mechanism without leaving the familiar user interface and workflow of Pro/ENGINEER.

Pro/ENGINEER STRUCTURE uses a precise calculation technology, which accelerates working with the models. It automatically controls convergence and the solution accuracy. The results of analyses and optimization can be conveyed individually: graphic version – like an animation, vector, devise, isoline or iso-surface; text version – like a calculation protocol.

Analysis of deformation and stress in soil

We must identificate mechanical properties of soil between properties of machines *in situ*, following the Bekker's theory – RONAI and LIČEN (1983), BARNES (1996). We can find two results of deformation and stability properties: first is deformation and loading, second is skid force.

The deformation and loading relation:

$$p = (\frac{k_c}{b} + k_\varphi)\, z^m \qquad (1)$$

where: p – normal skid pressure in the soil (Pa, MPa),
k_c – cohesion modul (N/mm$^{(n+1)}$),
k_φ – friction modul (N/mm$^{(n+2)}$),
b – plate width, or plate circular diameter (mm),
z – deformation of soil (mm),
n – exponent (1),
m – Bekker's constant (1).

If we want to designate each parameter we will perform minimally two tests with different plate diameters and with different widths b.

Following theoretical methods enable design principal the measuring device – the bevameter – by which a circular of rectangular plate is depressed into soil.

The shear stress represents functional stress of a touch wheel operating on a base which define the decisive transmission force of the travelling system on base – soil.

The uniform load on a circular plate in axis will produce vertical stress σ_z in accordance with the equation

$$\sigma_z = q\,(1 - \cos^3 \alpha) \qquad (2)$$

For rigid circular plate the stress in vertical axis will be produced in accordance with prof. Hruban (ŠIMEK et al. 1990)

$$\sigma_z = \frac{qr^2}{2}\,\frac{r^2 + 3z^2}{(r^2 + z^2)^2} \qquad (3)$$

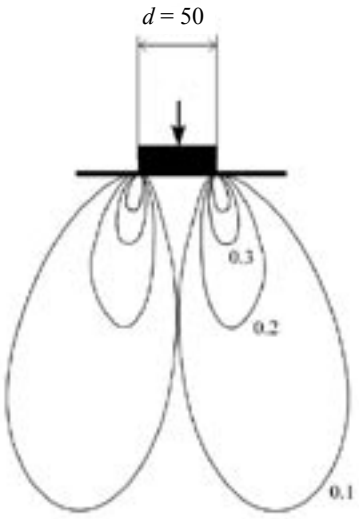

Fig. l. Isobar continuance τ_{xy}

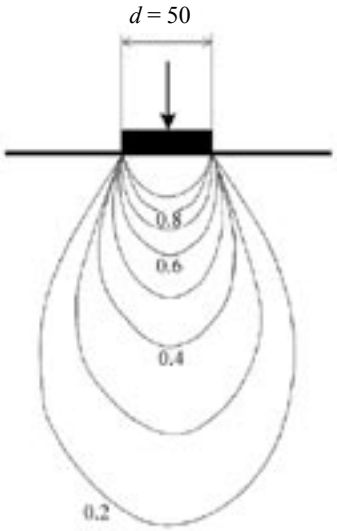

Fig. 2. Isobar continuance σ_z

for each of depth will be $z = a \,.\, r$

$$\sigma_z = A \,.\, q \qquad (4)$$

where: q – charging surface (N/mm^2),
r – diameter of charging surface (mm),
α – angle (deg),
z – deformation of soil at z-axis (mm).

It is possible to determine value of coefficient A from tables, where q characterizes average load on rigid board. Using the same method we can simply determine shear stress τ_{xy} also at investigated point. By creating of a chart with using an isobar lines we express theoretic course of stresses under rigid board, which represents the bevameter plate.

WORK METHOD AND RESULTS

The main purpose of this work was the use of the Pro/MECHANICA module at deformation modelling and stress analyse under bevameter plate. On base of all known theoretic assumptions it is possible to characterize the deformations and stress sources under rigid board with modern calculation methods (FEM) offering exact and precious values of the parameters. The FEM method is using material coefficients of technical materials at calculation, which is simple to define, considering its homogeneity.

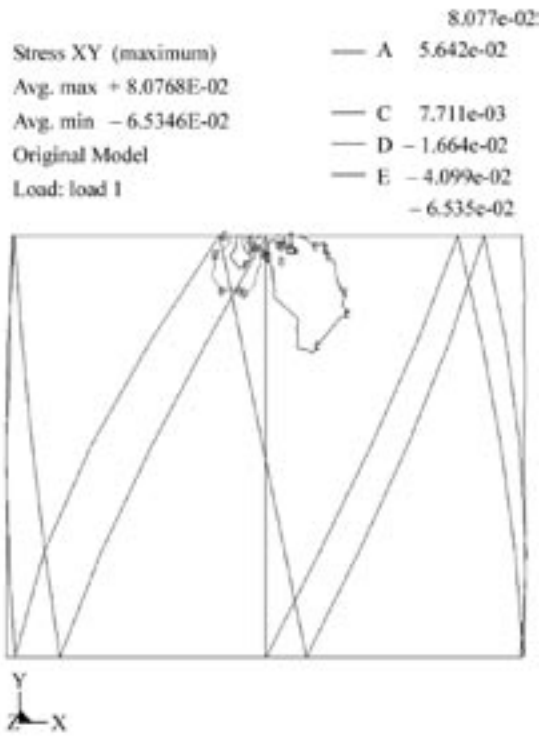

Fig. 3. Skid thrill τ

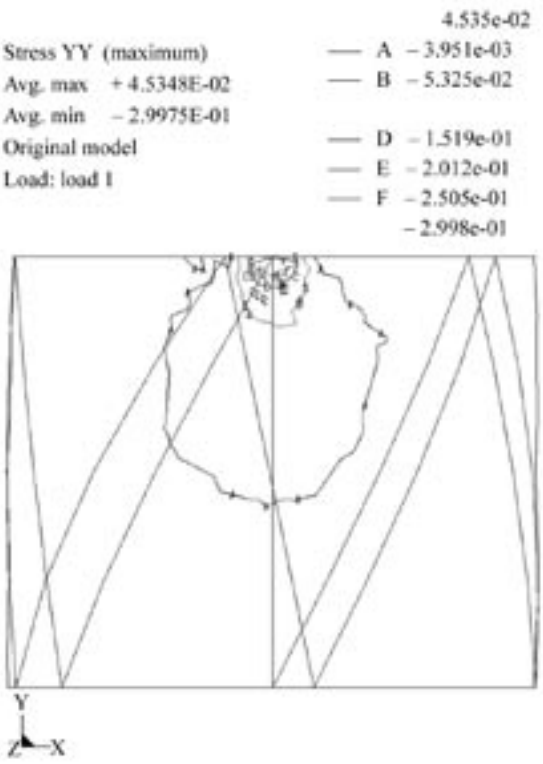

Fig. 4. Normal thrill σ

Soil is generally very unhomogeneous, while the courses of deformations are mostly at unlinaer area. It is very hard to determine material coefficients and to define marginal conditions for different calculations.

In the article we were using following values and coefficients of the soil (BAJLA, MALÝ 1999):

Load force	F	500 N
Diameter of plate	d	50 mm
Soil density	γ	$= 2.6$ t/m^3
Young module	E	15 MPa
Poisson ratio	μ	$= 0.3$

For the verification and convenience of chosen coefficients, there were used known calculations and these were compared with results of calculations using Pro/MECHANICA module. Results of all calculations are represented on Figs. 1–4 in the graphical form.

DISCUSSION

By comparing of both independent ways of the calculations we can see evident coincidence of the results. Absolute values of isoline courses are not identical, based courses of stresses are the same. At lower part of the diagrams are at the results of Pro/MECHANICA module evident some unlinearities, caused by inaccurate specification of marginal conditions. These carefully chosen coefficients sufficiently characterize physical gist (substance) of proceeding deformations and stresses (BILANSKI, L'ESPERANCE 1990). On the base of described facts we will be able to optimize dimensions of loading plates and alternative technical parameters of the hydraulic parts and control systems at a new design of a bevameter apparatus.

CONCLUSION

The measuring methods of soil properties have important influence on possible development of means, tools and technologies, used for tillage of soil. They have influence on evaluation of the soil conditions, their changes and the activity of the external factors of anthropogenic character. At research and investigation work were used many methods and measuring ways, proceeding above all with aid of soil mechanics and utilizing mainly at building trade. The methods defined at standards are enforceable in laboratory conditions and in modified forms are allowed to at field conditions only. There are utilizing theoretical principles elaborated by Bekker and others, for determination discrete deformation-strength characteristics of soil. Despite of bevametric method feasibility we have to observe, that bevameter is a complicated device and it is necessary to design and to prepare this apparatus carefully. At the article there were used methods for comparing two ways of calculating determination stress courses under loading plates with circle cross-section. The calculation of stresses with support of Pro/MECHANICA module demonstrates the possibility to use this software product at untypical applications in soil mechanics. Results are enforceable at different design and research projects.

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Využitie programového produktu Pro/MECHANICA vo výskumnej činnosti

ABSTRAKT: Programový systém Pro/MECHANICA je špecializovaný produkt určený pre riešenie technických úloh v oblasti strojárenstva. Využitie vo výskumnej činnosti sa hľadalo nielen v klasickom modelovaní a optimalizovaní návrhov strojových súčiastok, ale tiež v oblasti teramechaniky. Uskutočnila sa simulácia zaťažovania pôdy tuhou kruhovou doskou (súčasťou bevametra) a následné uplatnenie MKP (metóda konečných prvkov) pri výpočte deformácií a napätí pod doskou. Riešená úloha ukazuje na možnosti využitia tohto programového produktu s určitým obmedzením aj v oblastiach netypických pre tento produkt.

Kľúčové slová: programový produkt; MKP; Pro/MECHANICA; deformácie a napätia v pôde; modelovanie

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