

AN ADDITION TO MS EXCEL AIMED AT SOLVING OF PROBLEMS IN THE FIELD OF MECHANICS

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ABSTRACT. MS Excel is one of most popular products used for saving, processing and graphic representation of information in the form of tables. MS Excel offers opportunities for easy solving of engineering problems by its set of about 500 built-in functions and great number of additions in the form of add-ins. But in spite of its rich functionality MS Excel doesn't offer built-in instruments for direct application in the field of mechanics and more precisely - statics. The present report represents add-ins *Mechanics* for MS Excel, developed by the authors, which could be used for modeling of some mechanical constructions.

Keywords: MS Excel, lattice girder, stiffness matrix, mechanical constructions, modeling, add-ins.

ЕДНО ДОПЪЛНЕНИЕ КЪМ MS EXCEL ЗА РЕШАВАНЕ НА ЗАДАЧИ ОТ ОБЛАСТТА НА МЕХАНИКАТА

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РЕЗЮМЕ. MS Excel е един от най-популярните продукти за съхраняване, обработка и графично представяне на информация в табличен вид. Със своя набор от около 500 вградени функции и множество надстройки под форма на add-ins, MS Excel предоставя възможности за лесно решаване на разнообразни инженерни задачи. Независимо от богатата функционалност на продукта, обектният модел на MS Excel не предоставя вградени инструменти за директно приложение в областта на механиката и по-конкретно статиката. Настоящият доклад представя разработки от авторите add-ins *Mechanics* за MS Excel, който би могъл да се използва за моделиране на някои видове механични конструкции.

Ключови думи: MS Excel, ферма, матрици на коравина, механични конструкции, моделиране, add-ins.

Introduction

MS Excel is one of most popular products used for saving, processing and graphic representation of information in the form of tables. MS Excel offers opportunities for easy solving of engineering problems by its set of about 500 built-in functions and great number of additions in the form of add-ins. But, so far, the product has not incorporated an officially developed module for strength calculations based on the Finite Element Method. Usually, such kind of problems are solved using specialized software like ANSYS, COSMOS and others. Taking into consideration the wide use of MS Excel including in the education field, the authors of the report have developed add-ins *Mechanics* that can be applied for modeling of some kinds of mechanical constructions. This module have been created on the base of Visual Basic for Application language and can be applied to the solving of some problems in mechanics education. It encompasses 3 classes with more than 20 methods. Loading methods and dialogue are analogical to other add-ins in MS Excel.

The add-ins *Mechanics* encompasses two sub modules: strength calculation for rod structures and lattice girders.

Mathematical basics of the problem

Rod structures

A rod as a finite element has two nodes. When we study the problem within the local system of coordinates of the rod each of its nodes has just one degree of freedom - displacement alongside the rod axis. A force directed alongside rod axis corresponds to this degree of freedom. The approximation of the displacement between the two nodes is linear. In the case of two-dimensional constructions the relation between nodes' displacement and the forces applied to the nodes within the local system of coordinates is as follows:

$$\begin{Bmatrix} \bar{u}_1 \\ \bar{u}_2 \end{Bmatrix} = \frac{AE}{L} \begin{Bmatrix} 1 & -1 \\ -1 & 1 \end{Bmatrix} \begin{Bmatrix} \bar{F}_1 \\ \bar{F}_2 \end{Bmatrix} \quad (1)$$

The expression

$$[k] = \frac{AE}{L} \begin{Bmatrix} 1 & -1 \\ -1 & 1 \end{Bmatrix} \quad (2)$$

represents rod stiffness matrix where

L – rod's length (it's calculated automatically using nodes coordinates);
 A – rod cross section's area;
 E – module of elasticity.

If we treat the rod in a global system of coordinates Oxy, then the degrees of freedom will be the displacements alongside x and y in each node and the rod stiffness matrix will be as follows:

$$K = \frac{AE}{L} \begin{Bmatrix} \cos^2 \alpha & \cos \alpha \sin \alpha & -\cos^2 \alpha & -\cos \alpha \sin \alpha \\ & \sin^2 \alpha & \cos \alpha \sin \alpha & -\sin^2 \alpha \\ & & \cos^2 \alpha & \cos \alpha \sin \alpha \\ & & & \sin^2 \alpha \end{Bmatrix}$$

where α is the angle between the rod and the positive direction of abscissa (Fig. 1). The stiffness matrix is symmetric, that's why its upper triangular part is shown here only.

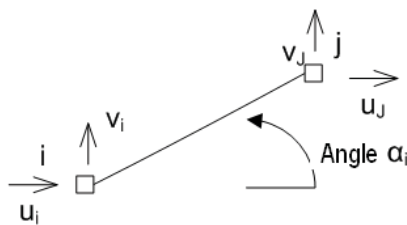


Fig. 1.

The results of Finite Element Method application are displacements against global system of coordinates as well as internal forces and stresses in the elements.

2D lattice girders

If a sample node "i" of a construction is the junction point of elements "K", "L" and "M" (Fig. 2), the balance conditions in this node are as follows:

$$\begin{aligned} \sum N_j \cos \alpha_j &= 0 \\ \sum N_j \sin \alpha_j &= 0 \end{aligned} \quad (3)$$

where α_j is the angle between the corresponding rod and the positive direction of abscissa.

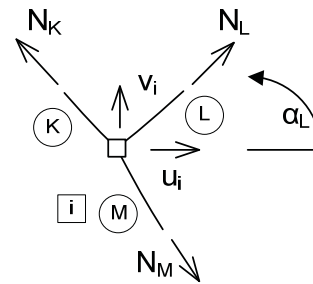


Fig.2

The following data are given in text files:

- coordinates of the nodes (representative points of the construction);
- construction sampling (description of rods);
- material characteristics of construction, fixing and loads.

The program generates a matrix of coefficients in front of the unknown quantities of the system of linear equations of construction on the basis of the balance conditions. MS Excel functions MINVERSE and MMULT are called automatically for calculation of this system.

Numerical example

The girder shown on Fig. 3 is to be examined. It encompasses 6 nodes, i.e. the number of balance equations is 12. Rods' number is 9.

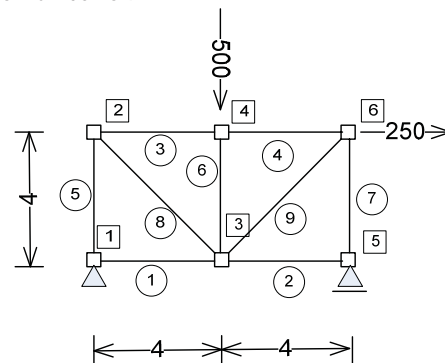


Fig. 3

The result is the following system of 12 equations and 12 unknown quantities. The first 9 of them represent rods' forces:

1.0000	0	0	0	0	0.0000	0	0	0	0	0	1.0000	0.0000	0	Z1	0
0.0000	0	0	0	0	1.0000	0	0	0	0	0	0.0000	1.0000	0	Z2	0
0	0	1.0000	0	0	0.0000	0	0	0.7071	0	0	0	0	0	Z3	0
0	0	0.0000	0	0	-1.0000	0	0	-0.7071	0	0	0	0	0	Z4	0
-1.0000	1.0000	0	0	0	0	0.0000	0	-0.7071	0.7071	0	0	0	0	Z5	0
0.0000	0.0000	0	0	0	0	1.0000	0	0.7071	0.7071	0	0	0	0	Z6	0
0	0	0	-1.0000	1.0000	0	0.0000	0	0	0	0	0	0	0	Z7	0
0	0	0.0000	0.0000	0	0	-1.0000	0	0	0	0	0	0	0	Z8	500
0	-1.0000	0	0	0	0	0	0.0000	0	0	0	0	0	0.0000	Z9	0
0	0.0000	0	0	0	0	0	1.0000	0	0	0	0	1.0000	0	Z10	0
0	0	0	0	-1.0000	0	0	0.0000	0	-0.7071	0	0	0	0	Z11	-250
0	0	0	0.0000	0	0	0	-1.0000	0	-0.7071	0	0	0	0	Z12	0

This system is created automatically in a new sheet. According to the customer's will intermediate steps can be shown in order to visualize the calculation course.

The result of calculation of the system shown above is as follows:

250.00, 0.00, -125.00, -125.00, -125.00, -500.00, -375.00, 176.78, 530.33, -250.00, 125.00, 375.00

The same problem has been calculated using SAP. Maximal deviation has been 0.0023% at rod No 8.

Conclusion

An addition to MS Excel allowing strength analysis of rod constructions has been developed. The product can be used in mechanics education.

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