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GRAPHIC PRESENTATION OF RESULTS OF CALCULATIONS BY CALCULABLE COMPLEX «MIRELA +»

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S u m m a r y . The analysis of visualization in the system of the automated planning of constructions is resulted in the article. The new going is offered near realization of algorithms of visualization of results of calculations within the framework of complex «MIRELA +».
K e y w o r d s : finite element methods, visualization.

INTRODUCTION

In a modern engineer, aircraft building, on the stage of planning of details and elements of constructions, and also for the design of different processes and phenomena the FINITE element method is used. It also is successfully used in mechanics, biomechanics. Engineers use the specialized packages, which allow not only to boundary problems but also build geometrical models, create a calculable grid, and do an analysis of the got calculation data.

A finite element method (FEM) is a widespread numeral method, which is used many researchers and engineers for the calculations of processes and phenomena which take place in a technological process. A numeral design can replace a model experiment often, when last inaccessible as a result of absence of experimental base and facilities for his realization.

Application of FEM is realized in the large number of the programs (CAD/CAM products, computer-aided designs) of home and imported production. It is world-wide complexes of ANSYS, AutoCAD, COMPASS and other, that well showed oneself not only abroad but also on Ukraine. For today FEM is inalienable part of engineering analysis and developments. Important property of these methods is authenticity, possibility of the use in a computer design with the large enough stake of confidence in their reliability.

Experience of application of MCE shows for the decision of engineering and scientific tasks, that the phase of analysis of numeral results of calculation on working hours and duration often substantially excels the first two stages of decision of task - preparation of basic data and calculation of task on computer. All modern programmatic systems of decision of tasks of mechanics of FEM contain the special modules that automation the process of analysis of results. The most effective method of such analysis is graphic presentation of the got numerical values.

PROBLEMS AND RESULTS

An aim of work is an analysis of algorithm of visualization of numeral results of calculation by means of construction of a semitone or variegated images with the use of illumination of three-dimensional objects.

To solve the problem of deforming, damping and dissipative warming of elastic construction the many works is devoted [1-12]

There is plenty enough of different variations of visualization of results of calculation. Among most widespread is a construction of different two-dimensional and three-dimensional charts, lines. However the most effective method of visual presentation and perception of distribution of numerical size after some two-dimensional or three-dimensional calculation area is an image of a semitone or variegated picture, where every tint or color is answered by the well-known range of numerical values.

Visualization of conclusion of numeral decision it is related to two basic problems:

- by the presence of large array of numeral information, that must be prospected on authenticity, exactness and adequacy of maintenance of task;
- by the necessity of synthesis of additional information - standard results of finite element analysis(for example, after the got key moving it is necessary to find the key values of components of tensors of deformation and tension).

In most cases the visible surface of geometrical area that is prospected by the method of eventual elements shows a soba eventual totality of flat non-intersection geometrical figures of simply-shaped (mostly triangles or quadrangles) (fig. 1). To Tom, the image of finite-element object is usually taken to visualization in space the determined amount of flat geometrical figures - verges of eventual element.

In general case the problem of visualization of results of numeral calculations of tasks of mechanics is taken the FEM to the decision of two followings tasks:

- a construction of mathematical vehicle of planning of three-dimensional geometrical area is on the plane;
- Painting out of projection by colors or tints, proper distributing on the initial geometrical area of visualized function.

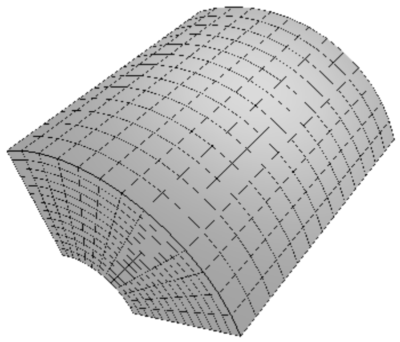


Fig.1. Surface of object as totality of non-intersection quadrangles

The idea of algorithm of visualization of a semitone image consists in the construction of spatial surface of S for tabular the set value of its co-ordinates (x_i, y_i, U_i), where (x_i, y_i) are co-ordinates of key points of area, U_i is point value of researching function, and n is an amount of key points of geometrical area, which form it framework model.

In the case of linear approximation S will show by itself a surface, formed intersecting in space (x, y, U) of m planes, and projection of S on the plane of $z = 0$ will coincide with the probed area [1]. Thus every plane is simply characterized by a corner, formed by it with the plane of $z = 0$ (fig. 2).

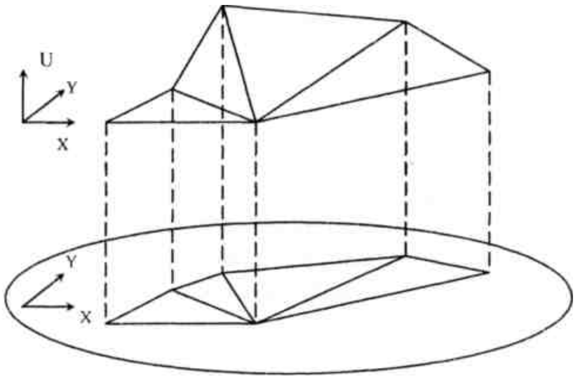


Fig. 2. Chart of construction of surface of results of S

One of the possible going near the visual analysis of function of U there is consideration of auxiliary function $F^{(S)}(e)$, $(e = \overline{1,n})$, that puts in accordance to every formative the surface of S a plane e angle of its slope to the plane of z=0.

If to put every value of function $F^{(S)}(e)$ in accordance any color and to paint out every eventual element this color, got image will allow to judge about distributing of values of function of U on all calculation area. In practice in place of function $F^{(S)}(e)$ examine the following function:

$$\overline{F}^{(S)} = F^{(S)} - \min_e F^{(S)}. \quad (1)$$

This allows to analyses the relative change of size of U on the set area.

Other going near the analysis of surface of S is a construction of real function

$$P^{(S)}(u) = \frac{G \cdot \left(u - \min_S u\right)}{\max_S u - \min_S u}, \quad (2)$$

where: G is some numerical amplification factor.

In general case G is the beforehand set function which acts part «strengthening», that it is needed for adjusting of areas of monotony of function of P on the area of its values. If to put every value of P in accordance any color and to paint out them all areas of the probed area, for which a value of P is identical, the got image also will allow to judge about distributing of analyses parameter on the set area.

An alternative algorithm of construction of a semitone picture of distributing of some function of U is on a three-cornered area. Let the range of visualization of numerical values of function of U be disposed on an interval from $U_{\min}$ to $U_{\max}$ and amount of gradations of colors (half-tones), necessary for visualization of three-cornered area, n is evened. Then the range of values of U, which are painted out on a picture one color, will look like $[U_i;U_{i+1}]$, where

$$U_i = U_{\min} + ih, \quad h = \frac{U_{\max} - U_{\min}}{n-1}.$$

Therefore number of color which answers some value, it is possible to define after a formula:

$$j = \operatorname{int}\frac{U^* - U_{\min}}{h}. \qquad (3)$$

Let it is necessary to build a semitone image for a triangle $P_1P_2P_3$ with key values - $U^{P1}U^{P2}U^{P3}$. And here $U^{P1}$is a maximal key value on a triangle, and U^{P2} – minimum. Obviously, that m_{12} – an amount of gradations of image on a side P_1P_2 will be maximal, here $m_{12} = m_{13} + m_{32}$, where

$$m_{12} = \operatorname{int}\frac{U^{P_1} - U_{\min}}{h} - \operatorname{int}\frac{U^{P_2} - U_{\min}}{h},$$
$$m_{13} = \operatorname{int}\frac{U^{P_1} - U_{\min}}{h} - \operatorname{int}\frac{U^{P_3} - U_{\min}}{h}, \qquad (4)$$
$$m_{32} = \operatorname{int}\frac{U^{P_3} - U_{\min}}{h} - \operatorname{int}\frac{U^{P_2} - U_{\min}}{h}.$$

In this case the image of triangle is taken to the image of aggregate from m_{12} quadrangles and triangles, color each of which answers his number in an image scale.

On fig. 3 the example of such lying out of triangle on image areas ($m_{12} = 4$, $m_{13} = 3$, $m_{32} = 1$) is resulted. Easily to see that the set of image grounds consists of two triangles and two quadrangles (shaded area), here color each such area answers the number of his index.

The example of work of a semitone algorithm is represented on fig. 4.

During visualization of semitone images for the increase of evidentness it is often needed to destroy alongside from object imager scale which gives information about accordance of color or tint of some range of the probed function (fig. 5).

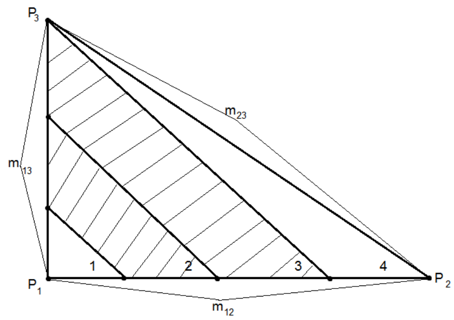


Fig. 3. An example of breaking up of triangle is on image areas

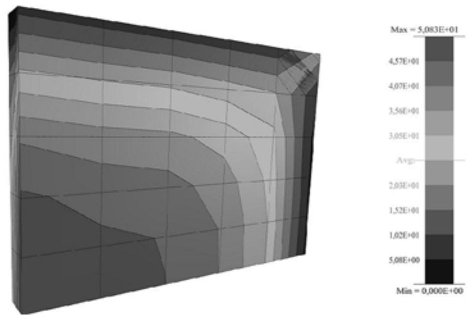
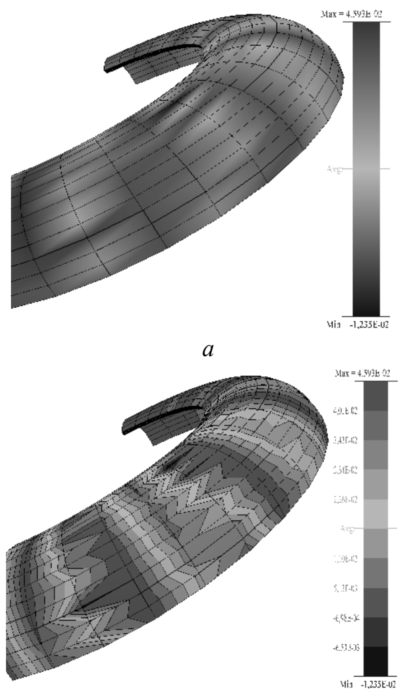


Fig. 4. Distributing of tensions for the areas of surface of flag



a

b

Fig. 5. A distribution of displacements of shall construction (visualization of object with animage scale):a – Semitone image, b – Coloured image

Other going near the construction of gray-scale pictures a construction and visualization of a semitone picture, corresponding distribution of gradient can serve on the prospected surface of object [13-16].

The alternative going near visualization of results of calculation is a change of geometry of area in accordance with distributing of effects of illumination of spatial object. It gives an opportunity to see the features of form of surface of object. That allows getting additional information about distribution of analyzable parameter.

For the image of the lighted up stage in computer graphic arts the models of diffuse and mirror reflection of object of light are more frequent all used from set one or a few point sources of illumination [14, 15].

The diffuse reflection of light of point source from ideal diffuser is determined the law of Lambert, in obedience to which light, that falls, dispersed in all sides with identical intensity. Luminosity of point is proportional its area, to visible from a source in this case, and described next correlation:

$$I_r = I_p P_d \cos\varphi, \quad (5)$$

where: I_r – intensity of the reflected light, I_p – intensity of point source, $P_d \in [0;1]$ – coefficient of diffuse reflection, dependency upon properties of material of beating back object and color of source of illumination, $\varphi \in [0; \pi/2]$ – corner, formed direction of light and normal of surface.

For the increase of reality of perception of picture in computer graphic arts also taken into account the presence of dissipated light which is described by the coefficient of dispersion:

$$I = I_r \cdot P_r + I_p \cdot P_d \cdot \cos\varphi, \quad (6)$$

where: I_r – is intensity of the dissipated light, $P_r \in [0,1]$ – is a coefficient of diffuse reflection of the dissipated light.

The design of fading of light with distance from a source is described the following formula:

$$I = \frac{I_r \cdot P_r + I_p \cdot P_d \cdot \cos\varphi}{d + K}, \quad (7)$$

where: d is distance from the center of projection to object, K is an arbitrary constant which sets the measure of fading of light

At the use of the parallel planning the account of distance is provided by that the nearest to the observer object is illuminated with maximal intensity, and all are located farther - with less. Thus, as distance of d, distance is used to the nearest to the point supervision of object.

It is removed from an ideal mirror light evidently only in case that a corner form directions of supervision and reflection equals a zero. For non-perfect reflected surfaces the model of Fong is used:

$$I_s = I_p \cdot W(\lambda, \varphi) \cdot \cos^n \alpha, \quad (8)$$

where: $W(\lambda, \varphi)$ – is a curve of reflection which dependency upon a wave-length of light of source λ and angle of incidence φ, $a \in [-\pi/2; \pi/2]$ – is a corner between directions of supervision and reflection, is an index of measure that sets the decrease of intensity at the change of corner.

For simplicity in practice usually $W(\lambda, \varphi)$ replace some constant of K_s, neat so that the built picture was subjectively perceived realistically.

The total model of illumination used in computer graphics looks like:

$$I = I_r \cdot P_r + \frac{I_p}{d + K} \cdot \left(P_d \cdot \cos\varphi + W(\lambda, \varphi) \cdot \cos^n \alpha\right) \quad (9)$$

or $$I = I_r \cdot P_r + \frac{I_p}{d + K} \cdot \left(P_d \cdot \cos\varphi + K_s \cdot \cos^n \alpha\right) \quad (10)$$

At the use of the rationed vectors straight falling of L, normals of N, reflections of R and supervision of V, the model of illumination for one source is described thus:

$$I = I_r \cdot P_r + \frac{I_p}{d + K} \cdot \left(P_d \cdot L \cdot N + K_s \cdot (R \cdot V)^n\right) \quad (11)$$

During visualization of flat polygon figure (for example, verges of finite element) if a source of light is on endlessness, then $L \cdot N$ equals a constant, and $R \cdot V$ changes within the limits of this figure. Thus visualization of the lighted up certainly-element object requires the point constructions of character that results in the necessity of the use of original algorithm of Z- of buffer. Possibilities of modern computers with the use of modern graphic standards of OpenGL or DirectX the lighted up objects allow effectively to visualize.

To give form of surface in such libraries it is necessary to determine a normal vector. In this case as components of these vectors it is possible to use the corresponding components of vector of moving, deformations or tension. If to the coordinates of knots to add the properly rationed values of the investigated function and represent the got corrugated surface of object lighted up by the lateral source of light, then the got picture also will allow to judge about distribution of the investigated numerical size for areas.

On fig. 6 the lighted up image over of difficult object is brought [17, 18].

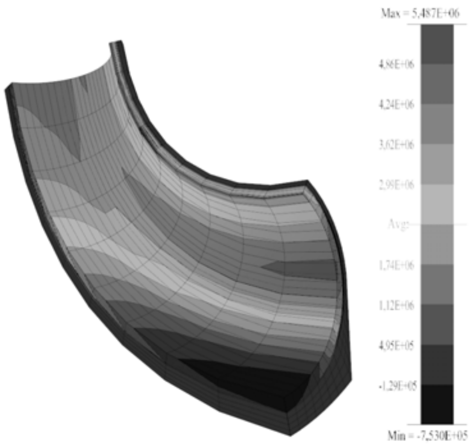


Fig. 6. Colour distribution of σ_{yy}

CONCLUSIONS

On the basis of the considered approach the method of half-tone visualization of results of calculation of the tensely-deformed and thermal state of constructions is offered on the basis of calculable complex "MIRELA+".

The offered method allows presenting transferring, tensions and temperature to the knots and centers of finite elements as moiré stripes, isolines or surfaces on volume or in the set sections.

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ГРАФИЧЕСКОЕ ПРЕДСТАВЛЕНИЕ РЕЗУЛЬТАТОВ РАСЧЕТОВ В ВЫЧИСЛИТЕЛЬНОМ КОМПЛЕКСЕ «МІРЕЛА +»

Юрий Козуб, Галина Козуб

Аннтотация. Рассмотрен анализ процедур визуализации в системах автоматизированного проектирования. Предложен новый поход для реализации алгоритмов графического представления результатов расчета в рамках вычислительного комплекса «МІРЕЛА +».

Ключевые слова: метод конечных элементов, визуализация.