Some Technical Possibilities by Computer Modeling and Thermo Vision Diagnostic for Stability of Constructions

Slavgorodskaya A. V., Pogodaev A. V., and Molokov K. A.

Abstract—In the paper the technique of cooling of thin surfaces by perforating for removal of thermal processes by elastic deformation, based on experimental data of thermo vision research of deformation process in constructive elements, having defects is offered. One of the applying of the cooling technique is a method decreasing cavitation on the blades of rowing screws by introducing round holes in heating surface. Some additional positive effects from deduction on an interface of blade boundary liquid flow layer explained in paper.

***Index Terms*—Cooling, cavitation, rowing screw, term vision.**

I. Introduction

In the course of cyclic deformation dependence between tension and deformation for a cycle is represented in the form of a loop of a dynamic hysteresis. As shown in Fig. 1; thus the loop area in a certain scale characterizes energy, is irreversible spent for a cycle of deformation of unit of volume of a material, and width of a loop – not elastic (plastic) deformation for a cycle.

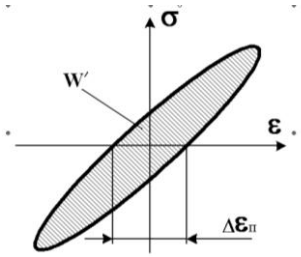

Fig. 1. A loop of a dynamic hysteresis in coordinates "tension - deformation": W' - the loop area (it is irreversible spent for a deformation cycle energy).

Change of density of thermal energy is shown in the form of a material warming up at deformation. Generally as parameter of damageability and criterion of destruction the specific size of internal energy should be accepted.

In other words, it is a question of density of internal energy, i.e. about energy carried to unit of volume. The fact of destruction is caused only by size of critical density of internal energy in a material regardless of a way of its message, and this or that level of a destruction is defined by quantity of the saved-up energy.

All real designs have cracks, scratches, openings and other defects. Engineering practice has examples of many failures, which have occurred and the first look for the unknown reasons as destruction of fragile type occurred at rather low level of tension.

The crack in a deformable body creates the centre of a tension indignations, characteristic strong concentration of tension at its edge. At first sight any small crack thanks to aspiration of tension to unlimited growth with approach to a tip of a crack should generate progressing process of destruction. However such theoretical result follows from model of ideally elastic continuous environment and doesn't correspond to real physical properties of a material. The discrete structure of a real material and nonlinearity of mechanical ratios for it in strong degree change a picture of the physicist - the mechanical condition, following of the linear theory of elasticity. As a result, as shows experiment, in one conditions the crack can steadily exist, without showing somehow itself, and in others — there is explosion a similar growth of the crack leading to sudden destruction of a body.

Temperature - the most universal reflection of a condition of the equipment. At almost all "diseases" of the equipment, change of temperature is the very first symptom, indicating to us on "illness".

Application of term vision diagnostics is based that existence practically all types of defects of the equipment causes change of temperature of defective units and, as a result, change of intensity of infra-red of radiation which can be registered by term vision devices.

Experiment on comparison of data of static test stretching of flat samples of brass, copper and steel were carried out by the universal car of firm to Shimadzu 1000KHi and the Russian measuring term vision device IRTIS 2000 with a conclusion of term graphics to the personal computer, Fig. 2 was used [1].

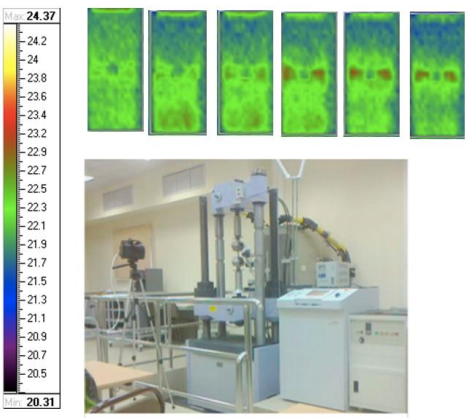

Fig. 2. Tests by the universal equipment of Japanese firm Shimadzu of U1000кHi and the Russian thermovisionary IRTIS 200 (FEFU).

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II. Methodology

For tests flat samples of brass in the sizes 100x40x1,5 мм, copper 100x40x1мм and constructional steel of 60x24x1,9 mm without cuts, with cut ∅ 10 mm and with a cut of 5 mm were used. Charts of stretching of materials fixed tendency to plastic deformation at samples having cuts, however the general work (it was estimated on the chart area) on destruction appeared less in comparison with samples not having concentrators of tension, As shown in Fig. 3, Fig. 4, Fig. 5.

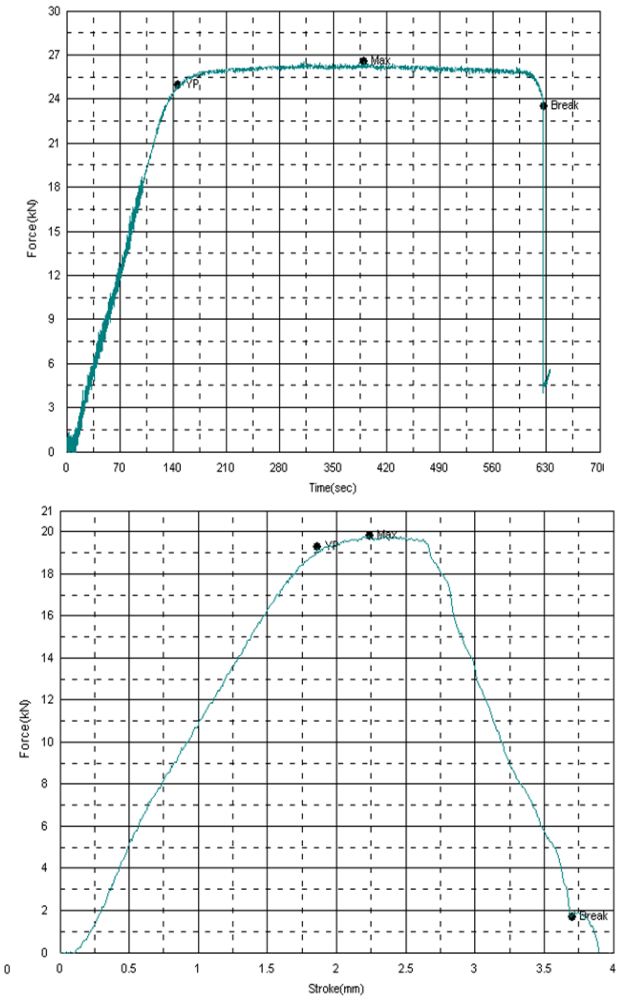

Fig. 3. The charts of stretching of flat samples of brass (on the right with round cut).

Decrease in strength was insignificant and kept within norms of standard factor of concentration of tension for round holes.

Experimental data thanks to possibilities of the used equipment were synchronized and kept in a digital format that considerably simplifies data processing and the comparative analysis.

From experience of stretching of flat thin samples with round openings the following regularity is traced: with increase in quantity of openings at the identical area of the weakened cross-section section strength (tension corresponding to the maximum stretching force) practically doesn't change however the area of the chart of stretching (in coordinate axes force lengthening) decreases at the expense of reduction of plastic deformation. Than naturally fragile destruction more than openings, especially at more high dangerous voltage – effect of temporary hardening of a material (the phenomenon sometimes is called "peening" as a result of preliminary plastic deformation).

Integration of these teplovizionny images in a table Excel format in the program of the engineering analysis of MATHCAD allows not only to visualize results and to carry out complete statistical processing of experiment, but also to enter new criteria of an assessment of parameters intense the deformed condition of a design including stability to fragile destruction or plastic deformation, As shown in Fig. 6. [1].

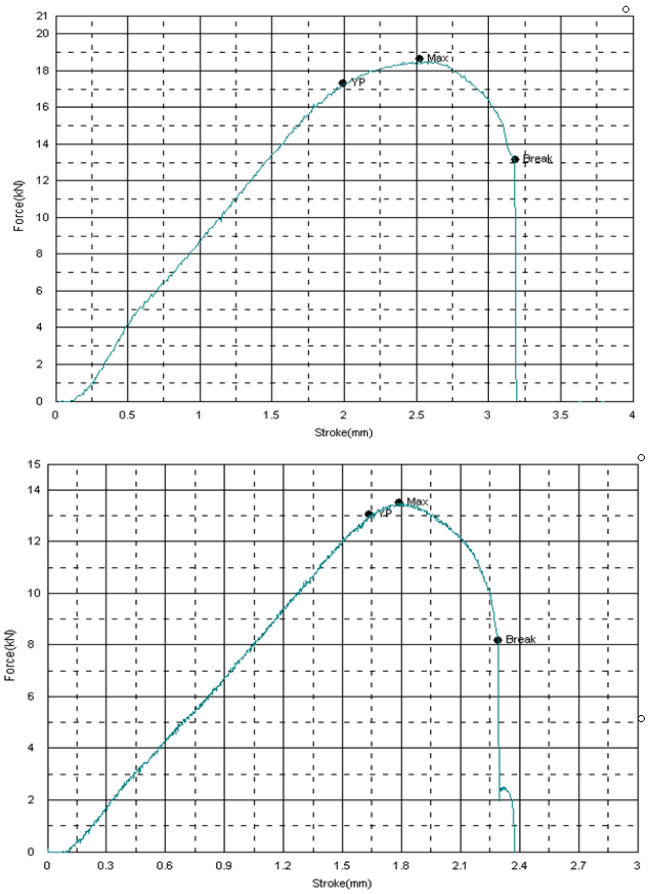

Fig. 4. The Chart of stretching of flat samples of copper (on the right with round cut).

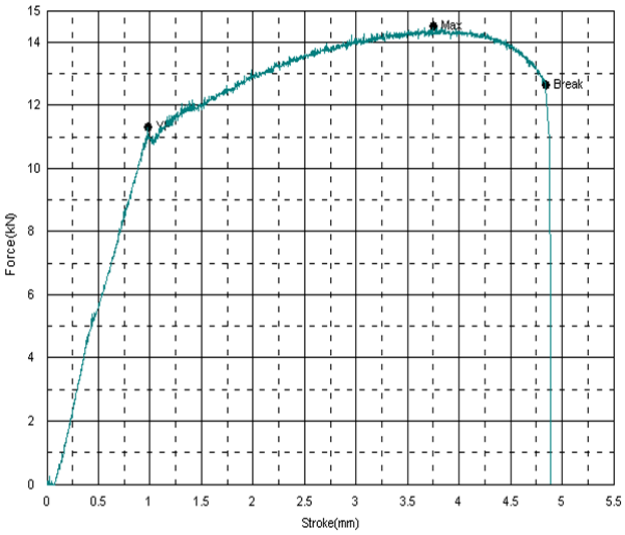

Fig. 5. The chart of stretching of flat steel samples (on the right with round cut).

In an offered technique the temperature field represents

itself a volume surface where marks of heights correspond to temperatures in points. The planes of one level (isoclines) divide a surface into final elements, accuracy of reflection of geometry of model is determined by a display resolution (quantity of points), spline degree (transformation of a matrix to function) and frequency of isoclines by height (a step task for acceleration of speed of calculation).

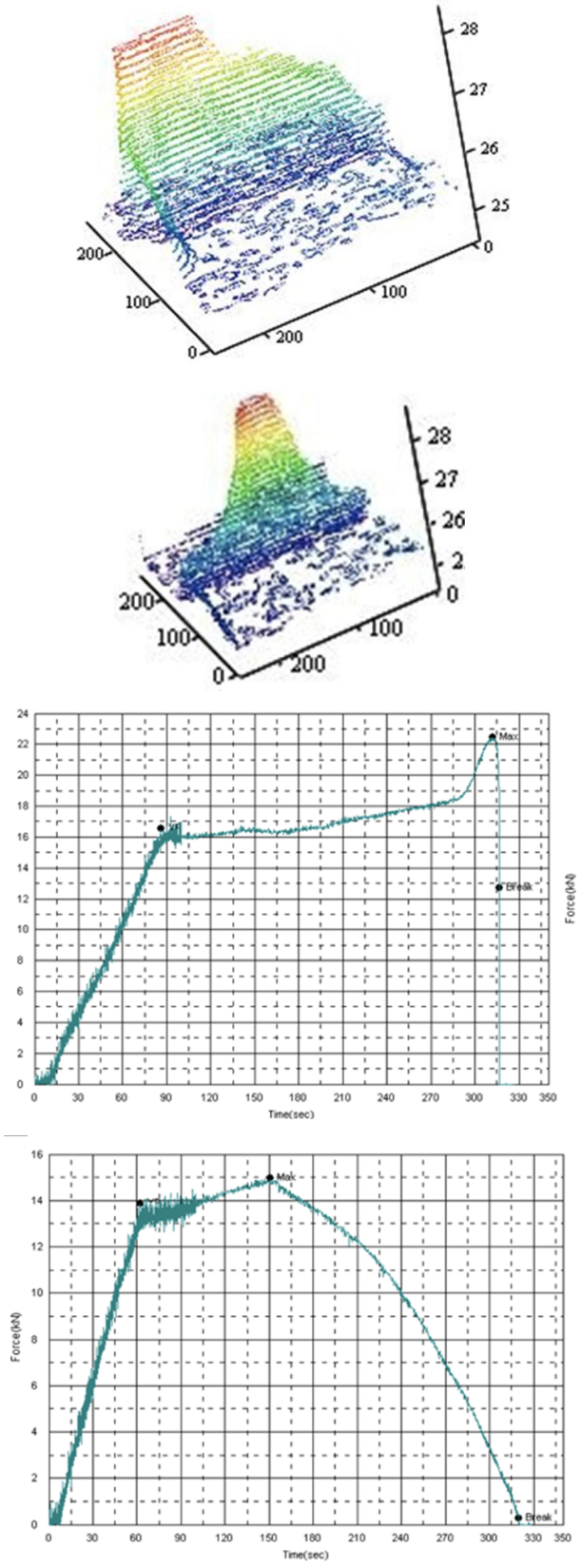

Fig. 6. Isotherms and the corresponding charts of static stretching of flat samples without a cut and with a cut.

Isoclines and interferential strips give evident idea of the sizes of area on which influence of an opening on a tension in a considered body extends and allow to do conclusions about a scope of theoretical decisions (a curve passing through points with the identical directions of the main tension; a curve tangent to which has the direction of the main tension in this point; the interferential strip has in average points identical greatest tangents of tension).

Comparison of theoretical results at strip stretching with a circular opening with the experimental testifies to possibility of carrying out analogy of distribution of a temperature field with theoretical assumptions and other experimental data (methods of more strips, varnish coverings, an elasticity photo), and that the indignant zone in process of removal from openings considerably disappears.

As changing the thermal field in comparison with other methods can be fixed in the form of the thermo graphic film, thermo diagnostics is the most suitable method for an assessment not only durability and endurance, but also for forecasting of stability of a constructive element

One of offered stability conditions of balance: the main sectorial coordinates of rather main axes of inertia should aspire to zero:

$$\alpha_{\text{u}} = \frac{S_{u\omega C}}{J_{u\max}} = \frac{\int\limits_{\text{A}} v\omega_C dA}{\int\limits_{\text{A}} v^2 dA} = \frac{\iint\limits_{A} v^2 u dA}{\int\limits_{\text{A}} v^2 dA};$$

$$\alpha_{\text{v}} = -\frac{S_{v\omega C}}{J_{v\min}} = -\frac{\int\limits_{\text{A}} u\omega_C dA}{\int\limits_{\text{A}} u^2 dA} = \frac{\iint\limits_{A} v u^2 dA}{\int\limits_{\text{A}} u^2 dA}.$$

where α_u, α_v – coordinates of the centre of shift of rather main central axes; J_u, J_v, $S_{u\omega C}$, $S_{v\omega C}$ – axial and sektorialno - the linear moments of inertia, см^4; ω_C – the sectorial area limited by isoclines of rather geometrical centre of gravity C.

Sectorial straight-line geometrical characteristics are used at calculations intense the deformed condition of thin-walled rod designs and steadily entered into practice of settlement design thanks to the S. P. Tymoshenko's Russian scientist, the centre which has brought concept of shift (the elastic centre (the torsion centre) [2].

III. Result and Discussion

In mechanics of deformable objects there are a lot of problems on analogy and similarity without an explanation of the nature of the phenomenon therefore the author allowed to transfer the theory of shift for possibility to the purpose of determination parameter of defect. In work the technique of thermo diagnostics based on experimental data of thermo vision research of deformation process of constructive elements, having defects is offered. As parameter of stability the condition coincidence of the geometrical center of gravity to the shift center is offered.

In an offered technique the temperature field represents itself a volume surface where marks of heights correspond to temperatures in points.

The planes of one level (isoline) divide a surface into final elements, accuracy of reflection of geometry of model is determined by a display resolution (quantity of points), spline degree (transformation of a matrix to function) and frequency of isolines by height (a step task for acceleration of speed of calculation). The offered structurization of volume is comparable with the similar image of a geodetic surface As shown in Fig. 7.

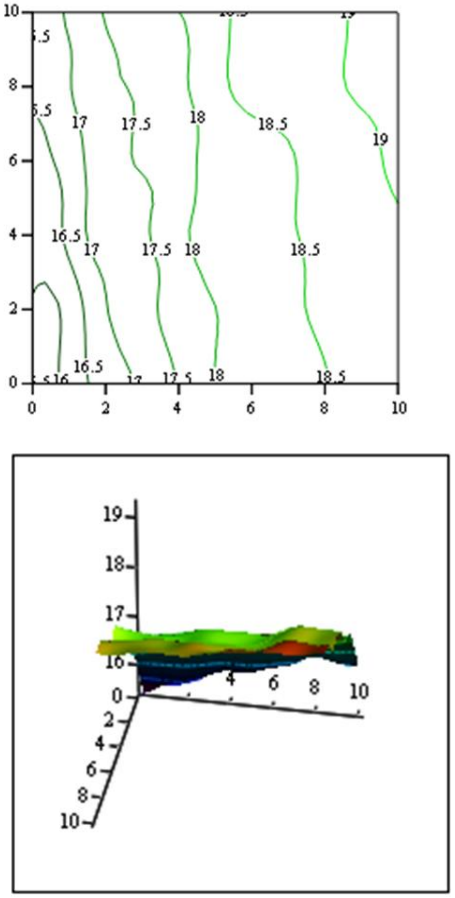

Fig. 7. Thermo graphics in Autocad.

As the received surface under action of external loading changes the form and volume, it is obviously possible to fix speed of change and specific characteristics of a thermal stream.

Representation possibilities of thermo grams in a volume look allow to apply analogy of an assessment of stability of the loose environments, successfully applied not only in mechanics (for example, in resistance of materials the analogy is used for finding of the moments of resistance to torsion of not round shaft) [3], but also in economy for the description of catastrophic collapses of the market.

In both cases for the criterion of stability offered still by the Pendent, the corner of a natural slope of volume of the studied parameter equivalent to critical value which excess causes a collapse or the avalanche movement depending on some factors of a condition of the environment and a trajectory is accepted. The assessment of tendency to plastic deformation or fragile destruction by a critical angle of a slope of prisms of a collapse spatial thermo graphics is supposed possible.

The offered structuration of volume is comparable with the similar image of a geodetic surface (Fig. 2). In work on the basis of experimental thermo graphics it is offered to apply analogy of a surface of a temperature field to a technique of an assessment of stability of the loose environments, successfully applied not only in mechanics, but also in economy to the description of catastrophic collapses of the market.

From experience of stretching of flat thin samples with round openings the following regularity is traced: with increase in quantity of openings at the identical area of the weakened cross-section section strength (tension corresponding to the maximum stretching force) practically doesn't change however the area of the chart of stretching (in coordinate axes force lengthening) decreases at the expense of reduction of plastic deformation. Than naturally fragile destruction more than openings, especially at more high dangerous voltage – effect of temporary hardening of a material (the phenomenon sometimes is called "peening" as a result of preliminary plastic deformation)

The author offers a technique of cooling of elastic surfaces by introduction of openings (punching) for removal of thermal processes by elastic deformation (As shown in Fig. 8) for thin blades of rowing screw.

The effect of decrease in temperature of a surface by elastic deformation can be take place in temperature regulators too.

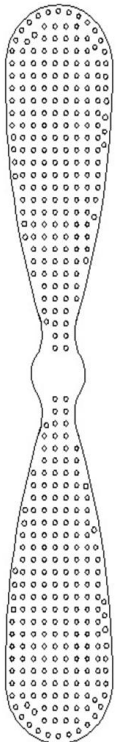

Fig. 8. The punched surface rowing screw's thin blades.

There is a way of decrease in dangerous tension near cracks at the expense of a drilling of the end of a crack a round opening, tension near the crack end in that case changes, i.e. round openings exclude possible tangents shift moving at the expense of increase in a area and by that decrease in dangerous tension.

As growth of a crack occurs at the expense of inflow of external energy, and is accompanied by heating in the direction of its growth, it is possible to offer a way of cooling of a design having the round openings absorbing energy of

external heat at elastic deformation.

One of the reasons of cavitation of blades of rowing screws is surface heating much lowering limit of fluidity (tension corresponding to the beginning appreciable plastic deformations and being accompanied a material warming up). Round openings thermal energy is necessary for development of safe elastic deformation for in advance weakened surface.

The temperature heating is sometimes used for removal of residual tension (plastic) in a material and regulation of crystal structure of a material. Temperature moving is not always creates temperature tensions - in the absence of an obstacle to growth of temperature moving temperature tension doesn't arise.

IV. Conclusion

Round holes are concentrators of tension less dangerous than long cracks, but at deformation the concentrator area increases, and the part of tension decreases, and is redistributed in the direction of cuts. Heat inflow from the outside excludes development of plastic deformations and is spent for temperature moving that promotes safe elastic deformations.

Laser technologies allow to cut out openings of a difficult geometrical form on the thin blade without residual deformations, without fragmentary edges and other defects of an edge - the cutting accuracy makes 0,05 mm, as shown in Fig. 9.

Fig. 9. Laser it is sharp metal in RUSSIA.

Blade punching except decrease in temperature of a surface at the expense of elastic deformation should possess other positive properties:

- Smaller hydrodynamic resistance at the expense of so-called artificial cavities (in our case - round holes), creating effect of deduction of an interface boundary liquid flow layer;
- In advance known direction of deformations will allow set the optimum provision of openings reducing risk of destruction of the blade.

The interferential strips give evident idea of the sizes of area on which influence of an opening on a tension in a considered body extends and allow to do conclusions about a scope of theoretical decisions (a curve passing through points with the identical directions of the main tension; a curve tangent to which has the direction of the main tension in this point; the interferential curve has in average points identical greatest tangents of tension).

V. Acknowledgement

Comparison of theoretical results at strip stretching with a circular opening with the experimental testifies to possibility of carrying out analogy of distribution of a temperature field with theoretical assumptions and other experimental data (methods of moiré strips, varnish coverings, an elasticity photo), and that the indignant zone in process of removal from openings considerably disappears.

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