THE ANALYSIS WITH THE HELP OF THE FINITE ELEMENT METHOD OF THE FORCES THAT APPEAR AT THE SPLINTERING PROCESSING WORKER

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Keywords: finite elements, splintering processing, splintering speed, tangent force's, axial force's;

ABSTRACT: In the finite element method it is used as starting point an integral pattern of the studied phenomenon. This method is based on the local approximation on sections and subfields. Due to the use of an integral pattern as starting base and of sets of continuous functions on sections, the finite element method is not conditioned any more by the existence of a rectangular network. With its help, some geometrical bodies can be practically discretized. Due to its increased performances, the finite element method has become an analyzing and projecting standard method in the machines constructing engineering and in other fields.

1. Introduction

In the last decades, as a result of the explosive development of the technical calculation, a calculation method appeared and strengthened, in the engineering applications field – the finite elements method (FEM) – that, through the distinct flexibility that characterizes it, can be extended in any field of the continuous environments' physics.

One of the directions on which the finite elements method was successfully developed is the deformable solid's mechanics in which also splintering processing worker problems are included. Nowadays, there exists the tendency that the phenomena specific to the splintering processing worker be approached, on an even broader scale, through the finite elements method.

The essence of the finite elements method consists in the transformation of the continuous field, in which a certain phenomenon is developed, in a framework of points, named knots, interconnected after rules that reflect the characteristics of the continuous environment. The conditionings of the analyzed field with the exterior are adequately transferred to the knots framework. As for the deformable solid, the functions that describe the displacements' field u(x, y, z, t), v(x, y, z, t) and w(x, y, z, t), position and time continuous functions, are replaced with a nodal functions set u,(t), v,(t) and w,(t) depending only on time.

2. The analysis of the splintering process through F.E.M.

The deformation state in the production area is plane. The reasons that allow this simplification are the following:

- the splinter's breadth (the dimension in the length of the blade) is much bigger compared to the advance;

- the splinter's forming takes place in contact with the base material that opposes to the transversal deformation;

- soon after the splinter's forming, this is almost normally moving on the blade's edge. Concerning the moving way of the splinter on the emitting side, in the literature there are mentioned values of the deviation angle from a normal deviation of until ± 6° when the attack angle is of 60°. Because in the making of the tools, for the deep perforation, the attack angles do not exceed 20°, the deviation of the splinter's movement from normal to the tool's edge can be considered as insignificant. In these conditions, it is admitted that during the viscous-elastic-plastic deformation for the splinter's forming and afterwards, the materials points are strictly moving in the normal plane on the tool's blade.

For the numerical analysis, through the finite elements method of the phenomena that are taking place at splinter's forming and afterwards, provided that the deformation state be admitted as plane, it is enough to be analyzed a layer of material contained between two normal planes on the tool's blade, distanced at a length unit, for example 1 mm. For a more general feature of the analysis through the finite elements method, the concept of advance is defined as the normal component part on the tool's blade of the real advance. The introduction of the normal advance allows the approach of any splintering process as a frontal process in which the tool is normally moving on the blade. For the real situations, the calculations of the splintering forces are made by integrating the forces on unit of length, in the calculation being introduced the normal advance established as a projection of the real advance on the normal at the blade.

In figure 1 it is represented a section from the splintering material and a section from the splintering tool in the initial state.

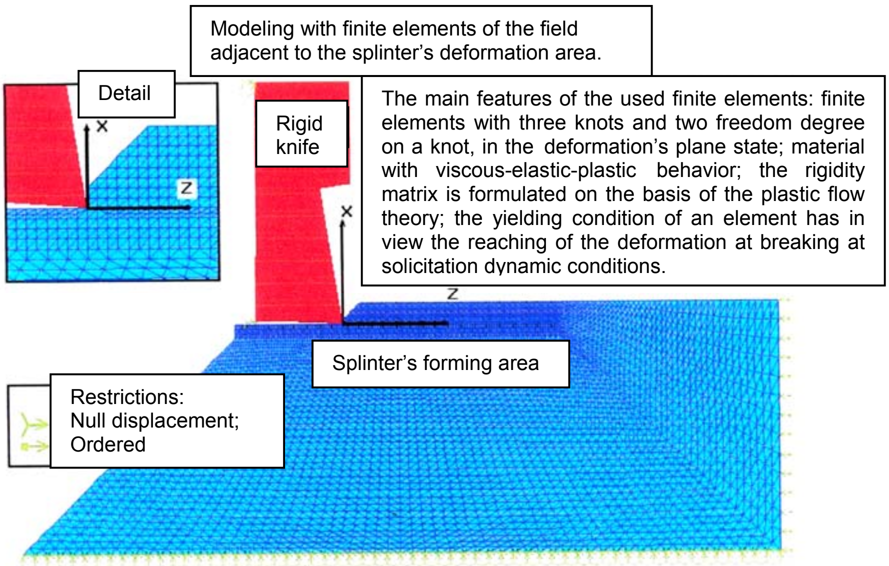

Figure1. Modeling with finite elements of the field adjacent to the splinter's deformation area.

The field employed by the material was discretized with finite elements with variable network density. Discretization is finer in the splinter's deformation area, where there are expected bigger gradients of the functions that describe the deformations and tensions. Knife being considered very rigid, meaning that it cannot be plastically deformed, was modeled with a minimum number of elements.

The developed reactions in the knife's restricted knots give the measure of the forces with which the splintered material works over it.

For the modeling of the material's plane there were used triangular plane elements of three knots and with two freedom degrees on a knot, these being the two displacements from the xOz plane (figure 1).

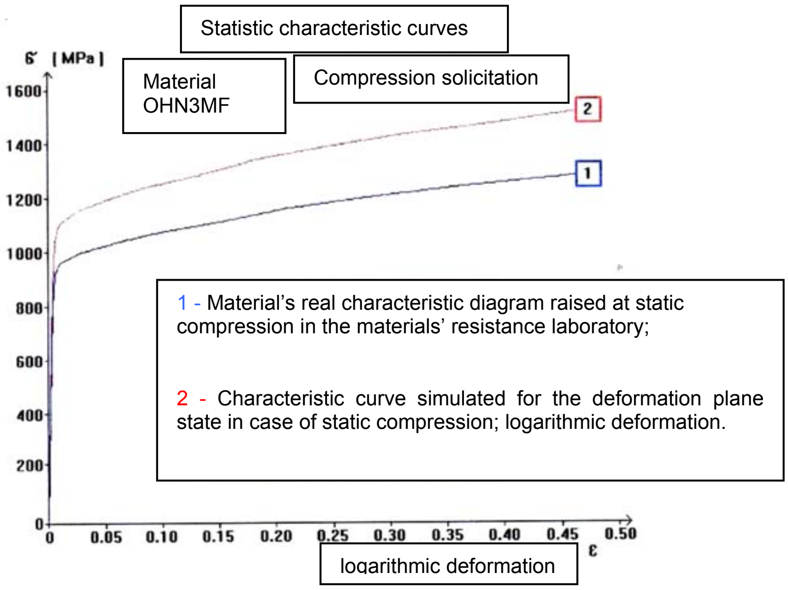

Figure 2. Static characteristic curves

Because the available analysis program, COSMOS/M, has not incorporated an element with viscous-elastic-plastic behavior in the elements library, it was used the superposition in the same area of two elements with different features:

a) an elastic-plastic element with isotropic reinforcement of von Mises type, whose features are introduced through curve 1 of fig.2.;

b) an elastic-plastic element of Maxwell type generalized with features shown in fig.3.

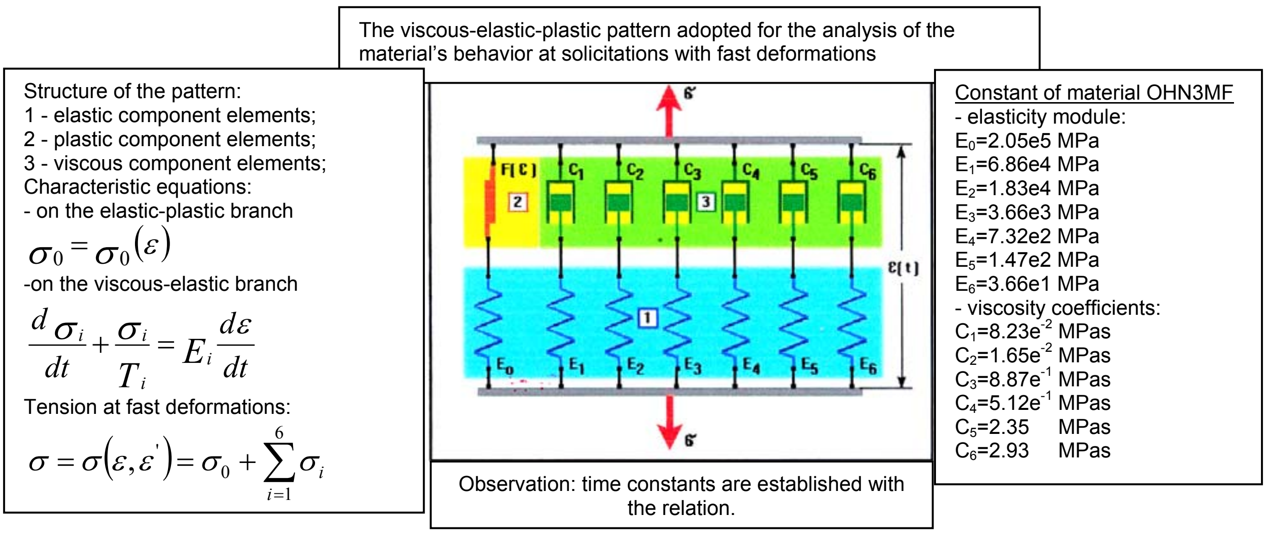

Figure 3. The viscous-elastic-plastic pattern adopted for the analysis of the material's behavior at solicitations with fast deformations

For ensuring a good compatibility between the two types of elements, to the Poisson's coefficient, for the second element, it was attributed a value close to 0,5 thus being ensured the incompressibility condition of the material in plastic deformation state.

On the probable direction of fissure's program, a band of special elements was introduced, that does not exist in the library of the COSMOSM program, elements able to yield through breaking at the reaching of a certain limit of equivalent deformation. After yielding, such an element is eliminated from the system.

In the proposed pattern it was admitted that the splinter remains continuous until this reaches the crushing limit placed at a certain distance from the blade. When the splinter is in contact with the crushing limit, addition tensions occur in its elements, tensions that lead to the breaking in the embedding area of the splinter, thus splinter pieces being formed.

The contact between splinter and the emitting side of the knife was modeled with elements of contact with abrasion, with the abrasion coefficient p=0,05, being considered the use of a an adequate cooling liquid. The same type of elements was used also for the modeling of the contact between the left material and the laying side of the material.

The dimensions of the pattern were big enough taken so that on the separation border deformations be considered negligible.

In fig.1 there are also represented the constraints imposed to the material through null displacements ordered after a rule in accordance with the splintering speed, considered as constant and performed through the displacement of the material in relation with the splintering tool admitted as fixed.

The knife was modeled with quadrilateral elements with four knots, with two freedom degrees on a knot and with a very big rigidity. On the basis of the hypothesis of the plane state of deformation, the issue can be reasonably approached on the existent P.C. computers. In case of yielding at the hypothesis of the plane deformation, the issue's dimension would considerably increase, making practically impossible the solution on this type of computer.

Working variants

In order to cover an even larger range of working possibilities met in practice, the working conditions were established by combining the following variants:

a) values of the emitting angle: 5° and 10°;
b) values of the splintering speed: (0,5; 1; 1,5; 2) m/s
c) values of the advance: (0,075; 0,0100; 0,125; 0,150; 0,175; 0,200) mm/rot.

In all, there were analyzed 48 variants resulted from the combination of the two values of the emitting angle with the four values of the splintering speed and with the six values of the advance.

The values established for the elements of the splintering conditions are in accordance with the practical data established for the deep perforation method of the alloyed steel with raised mechanic features.

3.F.E.M application conditions

The analyzed issue frames in the category of non-linear issues of the deformable solid, the non-linearities being physical, as well as geometrical. For every splintering speed the integrating duration was established so that the splinter reaches the crushing limit, breaks and be eliminated. The analyzing duration is established with the relation:

in which:

- l_0, is a fictitious itinerary, bigger than 1,2 … 2 times as distance from blade to the splinter's crushing limit;

- v_a is the splintering speed.

The time increment between two steps of the analysis were established at the value in which:

- 800 being the number of steps for a complete analysis, as well as for the fictitious displacement on the length $l_0 = 2$ mm.

From 10 to 10 integrating steps, the COSMOS/M program was interrupted for analyzing the state of the element affected by fissure, with the help of a specially conceived program, for eliminating the elements in which the yielding condition was met. When in an element the yielding condition was met, this is considered “dead” and eliminated from the system, after which we can enter again in the COSMOSM program.

In the analysis of the 48 variants of the splintering conditions, the time increment was included between 1,25u.s and 5us. The fineness of the time variable’s discretization ensures the necessary precision of the numerical solutions obtained through the finite elements method.

After the analysis of the solutions obtained in the first calculation variants it was found that, in order to reduce the calculation effort, the analysis concrete duration can be reduced, even until half, because after the transitory condition inherent to the moment of splinter’s breaking, a stationary condition is installed, in which the analyzed parameters frame between two fixed limits. From the first analysis performed on the whole duration, T, there were kept the sequences with which it was performed the animation of the frontal splintering process in bi-dimensional representation.

4. Selection, processing and analysis of solutions

The analysis program through the finite elements method COSMOSM has the capacity to deliver, at output, complete information about the space and time functions that intervene in deformable solid’s mechanics issues.

In the order of their obtaining through calculation, these are:

- displacements, speeds and nodal accelerations;
- deformations on elements;
- nodal tensions and tensions on elements;
- reactions.

These functions are given as tables of the nodal values or on elements and diagrams in fields of colors.

After solving every variant, there were extracted, with the help of a selecting program, the reactions from the knife’s supports, that were transformed then into splintering forces on the span of 1 mm of blade, F_z and F_x.

These forces are represented in time (fig. 4 and fig. 5) and they have fluctuations that can be justified through the dynamic effect, through the existence of the abrasion forces between splinter and knife and especially by the jerky breakings of the elements that yield. In the diagrams of the figure 4 and figure 5 there are also represented the splintering specific forces mediated on the analysis duration.

The influence of the splintering speed over the splintering forces is reflected through the deformation speed, appreciated through the equivalent slide’s speed shown in fig. 6.

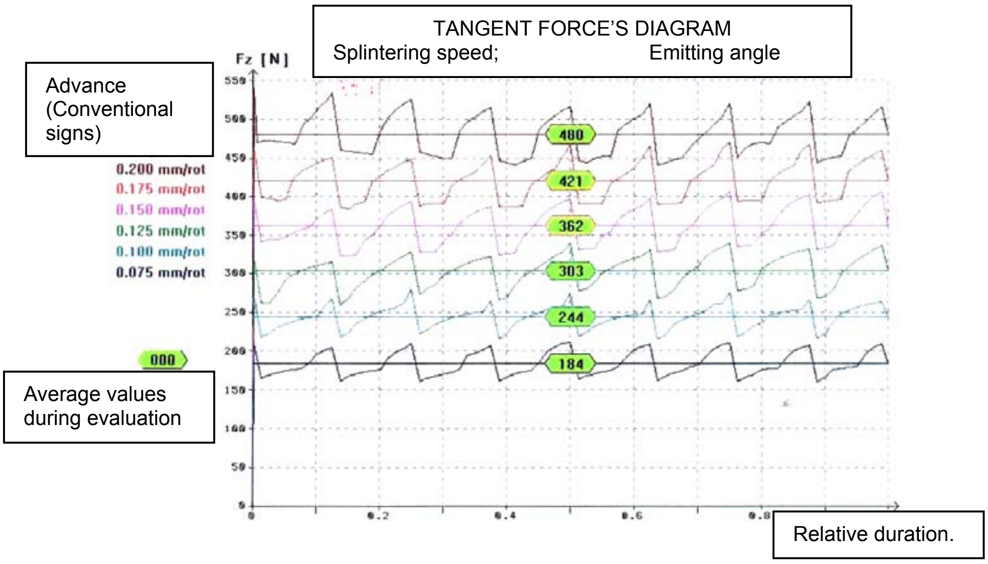

Figure 4. Tangent force's diagram

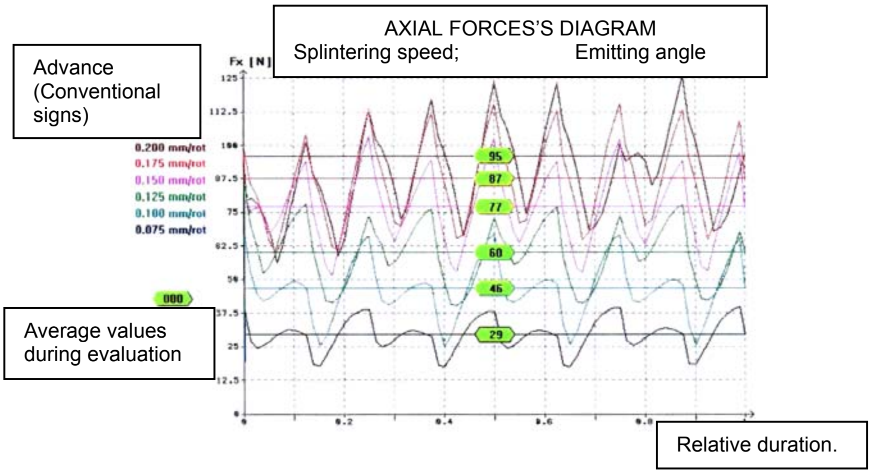

Figure 5. Axial force's diagram

By analyzing the figure 6, it is found that in the splinter's forming area the deformation speed has the biggest values and, by consequence, in these areas the effect of viscosity becomes very important, fact that leads to substantial increases of tensions.

After the numerical analysis, it was found that the deformation speeds in the splinter's forming area reach very big values, coming to values with the order of $10^3 \ldots 10^4\ s^{-1}$.

The magnitude of the deformation speed justifies the presence of a viscous component element in the material's behavior taken into consideration in the pattern from image 3 and through the curves from image 2.

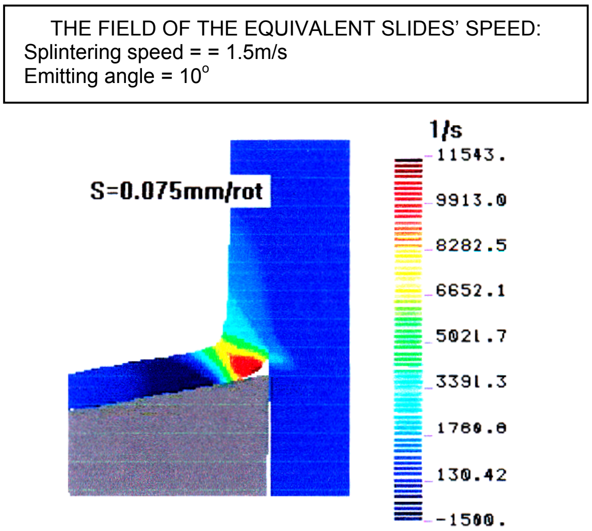

Figure 6. The field of the equivalent slides' speed

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