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FINITE ELEMENT ANALYSIS OF THE CONTACT BETWEEN TOOL AND WORKPIECE IN TRANSVERSAL DIRECTION AT CERAMIC MATERIALS GRINDING

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1. INTRODUCTION

The workability of a material or group of materials, whether ceramic or classic, is expressed by means of all factors that occur during obtaining of a workpiece that is within the geometric, dimensional, qualitative and surface finish limits imposed by the given workpiece. It is determined by a large set of factors such as cutting tool endurance, magnitude of the cutting forces, roughness of work material, grinding temperature, the deformation degree of the processing layer during chip formation, the generation of product configuration, etc., which take part in obtaining a workpiece with accurate geometric shape and dimensional precision.

Processing of ceramic materials is relatively low, due to their reduced workability compared to metallic materials. Almost all ceramic products that are suitable for grinding are workable only with diamond tools whose geometric parameters yet remain to be fully established.

Grindability represents the correlation between the characteristics of the given material, the parameters of the technological regime (v, f, ap, cutting force components, power, etc.), characteristics of the diamond cutting tools (diameter, width, granularity, grain fixing adhesive), dimensional and geometric precision, surface finish, etc.

Grinding is a processing procedure with small or micro chips. In order to develop in proper conditions, it is necessary a strong correlation between the mechanical characteristics (strength, bending resistance) of the ceramic product, tool and specific grinding forces (fig. 1).

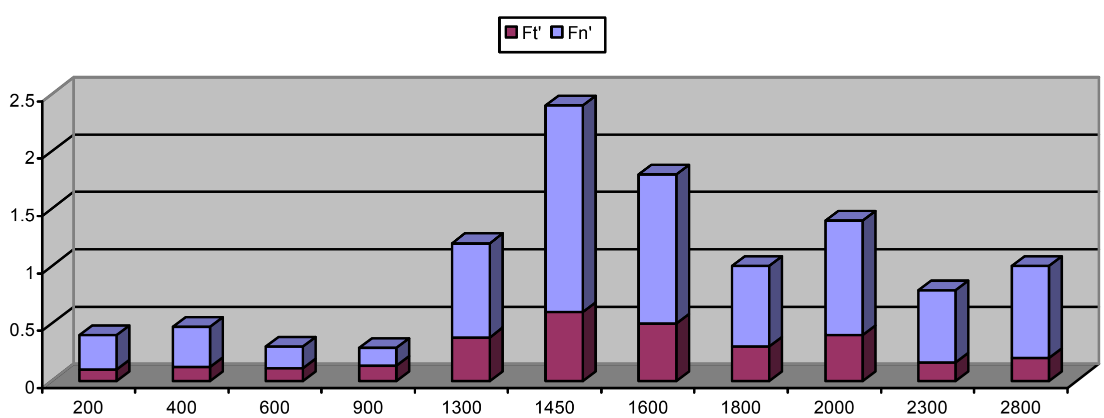


Fig. 1 – Specific normal and tangential forces as function of ceramic material strength

Usually, the grinding forces increase together with the strength and bending resistance of the worked material. There are also exceptions. Thus, in case of processing 99.7% aluminum oxide and silicone nitride, which has lower strength than aluminum oxide, both the normal specific force F_n' and tangential F_t' are larger in case of silicon nitride Si_3N_4. The magnitudes of the normal and tangential force are not primarily determined by the material strength, but by tension intensity critical factor K_{ic}. From fig. 2 it results that the normal specific force F_n' records a larger increase as K_{ic} increases.

Generally the normal and tangential specific forces increase together with the bending resistance, with the exception of boron carbide B_4C and aluminum oxide Al_2O_3 products (fig. 3).

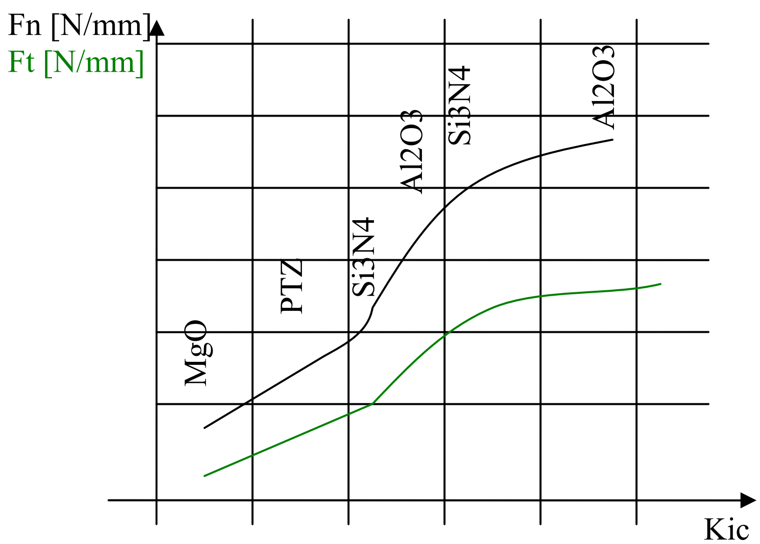


Fig. 2 – Specific normal and tangential forces as function K_{ic}

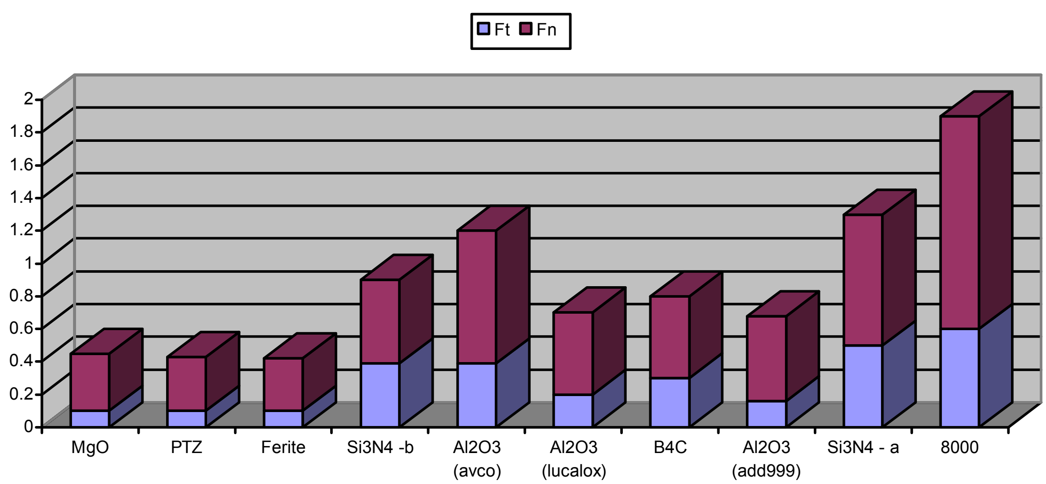


Fig. 3 – Specific normal and tangential forces as of bending resistance

2. FINITE ELEMENT ANALYSIS OF THE CONTACT BETWEEN TOOL AND PIECE IN TRANSVERSAL DIRECTION

2.1. STATIC CASE

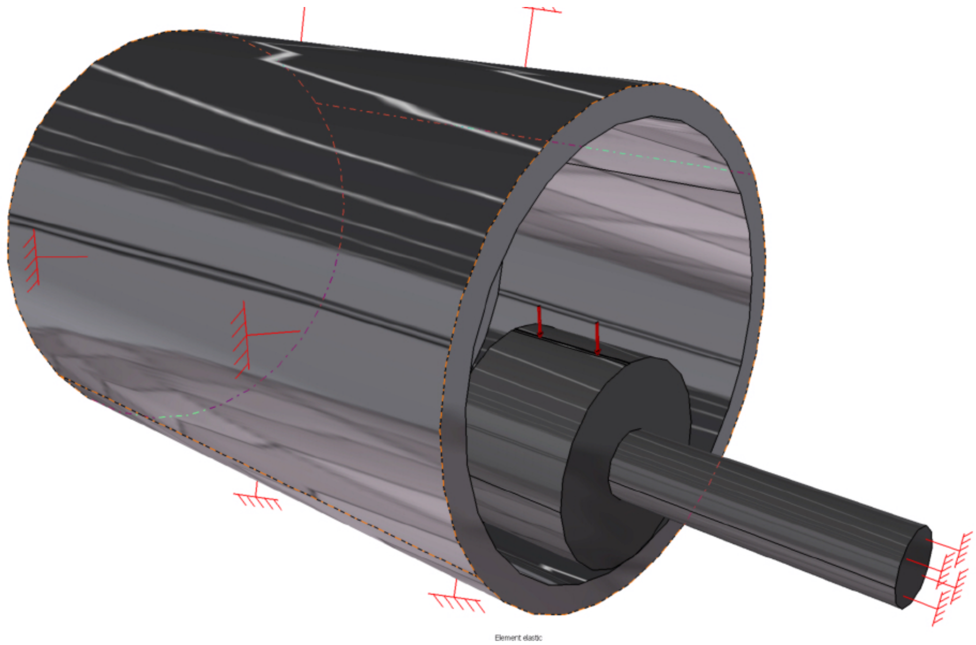
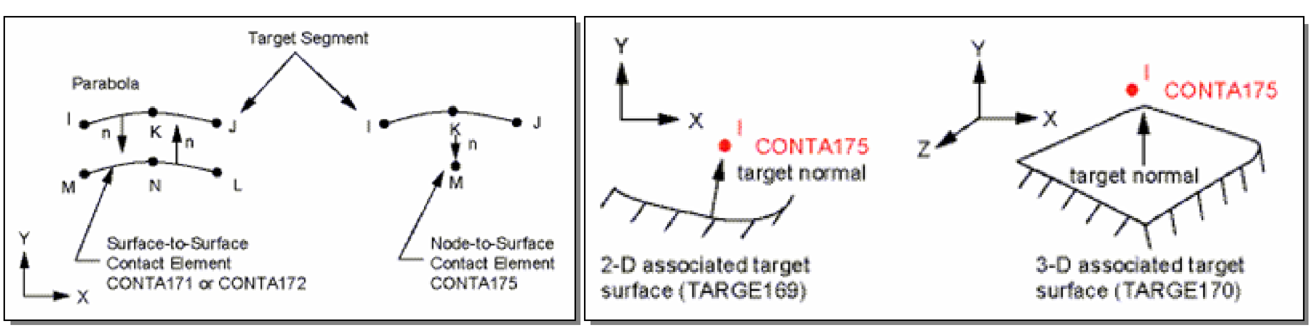


Fig. 4

Corresponding to fig. 4, the analysis is performed in a transversal plane using finite element type "Plane82" with real width constant 20 mm.

At the contact between tool and piece, contact lines are covered with special contact elements "Targe169" and "Conta175" which trough their interaction transmit the load from tool to the workpiece. "Conta175" elements are used for modeling the contact or sliding between two surfaces. Their geometry is presented below:



2.2. STRUCTURE DISCRETIZATION

The discrete plane structure is presented in fig. 5, in which no element exceeds the shape limits of the tool and workpiece.

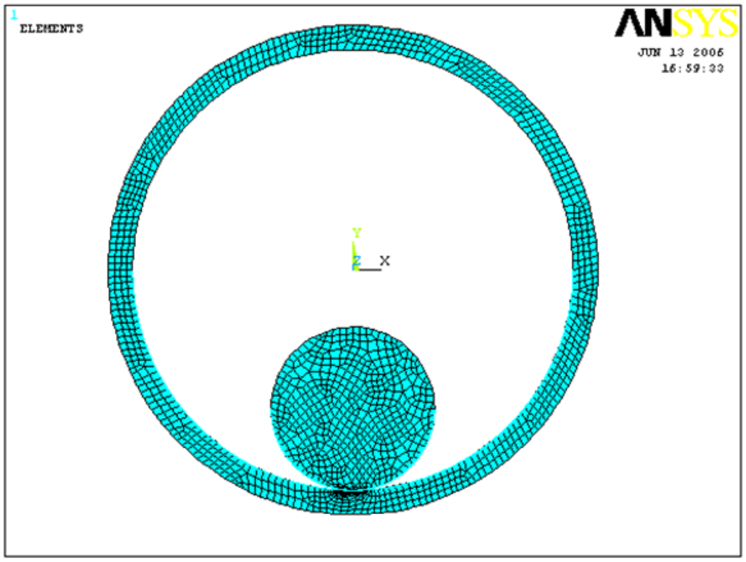


Fig. 5

It should be noted that the nodes in the inferior part of the tool where the concentrated force will be applied are coupled in UY (vertical) nodal direction in order to avoid a singularity in the force application point.

2.3. SOLUTION

In this phase the model is constraint and the load is applied, defining the type of analysis ant the control elements. The analysis type is static, in which large deformations are allowed, and the minimum and maximum numbers of sub-steps that lead to convergence are 1 and 1000, respectively.

The value of the applied force is 300N.

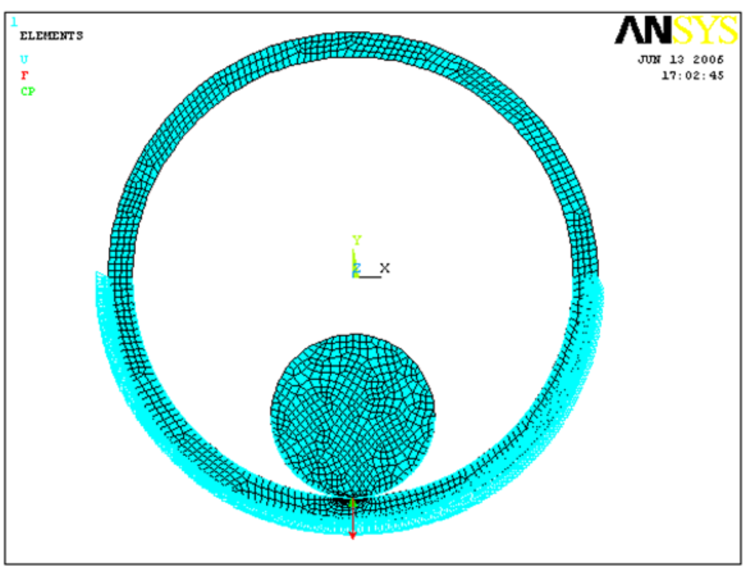


Fig. 6

In the first phase, the piece is considered to be manufactured from silicon nitride with transversal contraction coefficient $\nu = 0.29$ and longitudinal elasticity modulus E = 295 Gpa.

The maximum equivalent tension (von Mises) is 99.285 n/mm^2 and its distribution is presented in fig. 7.

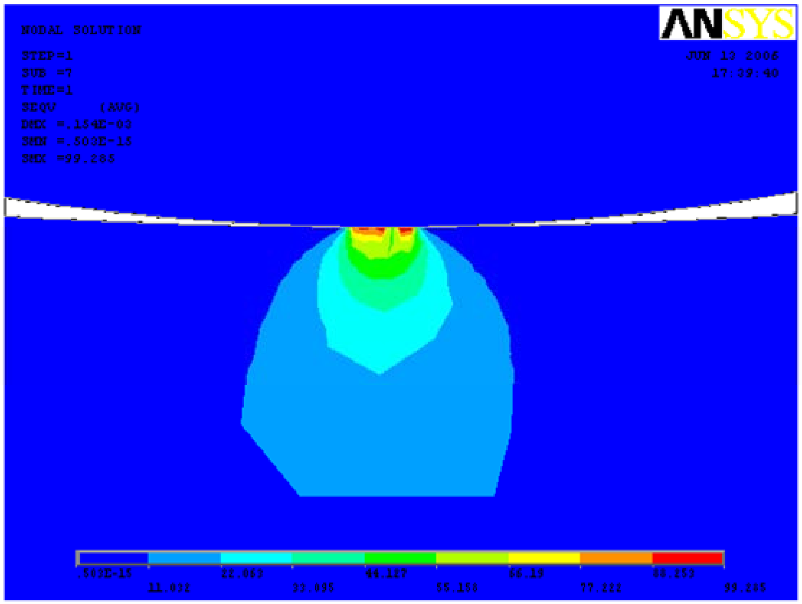


Fig. 7

The equivalent 3D model on which analysis is performed is the one from fig. 8. Its thickness is determined by a real constant taking into account the 20 mm thickness of the plane elements.

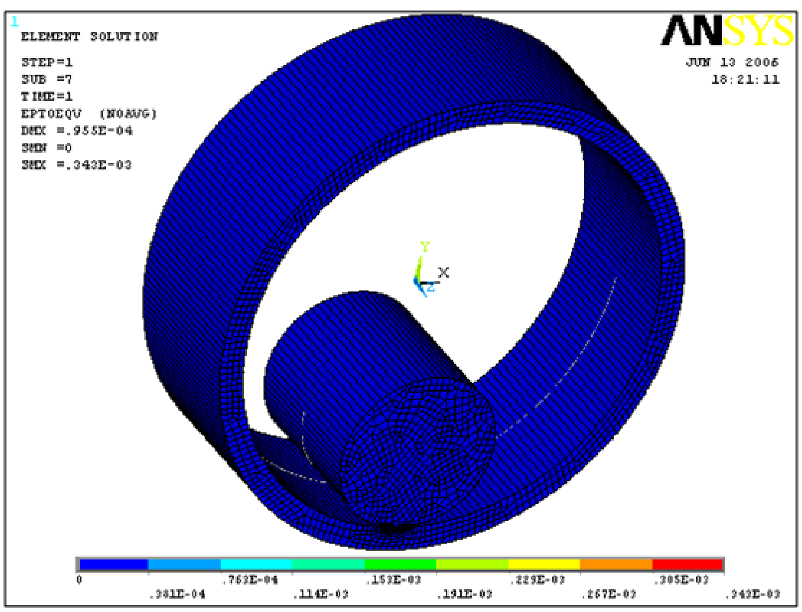


Fig. 8

Next are presented the tension components along the X and Y coordinate axes.

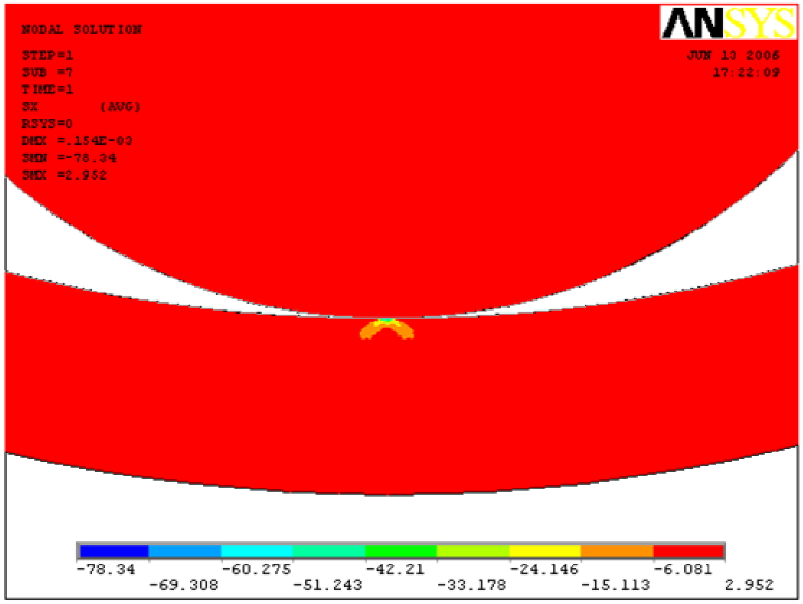


Fig. 9 – Tension component along X axis

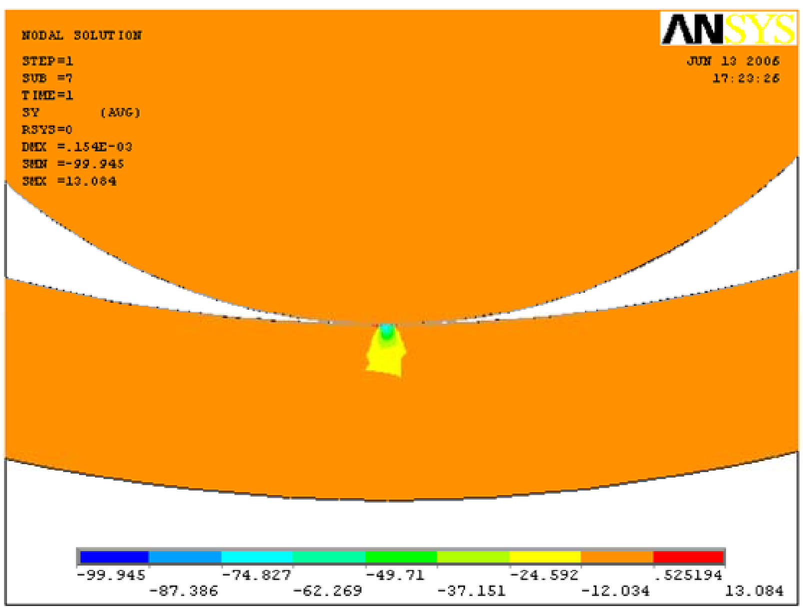


Fig. 10 – Tension component along Y axis

The maximum value of node displacement at 300 N load in case of silicon nitride is $0.154*10^{-3}$ mm, and the maximum value of relative deformations ε is $0.559*10^{-3}$ (fig. 11, 12).

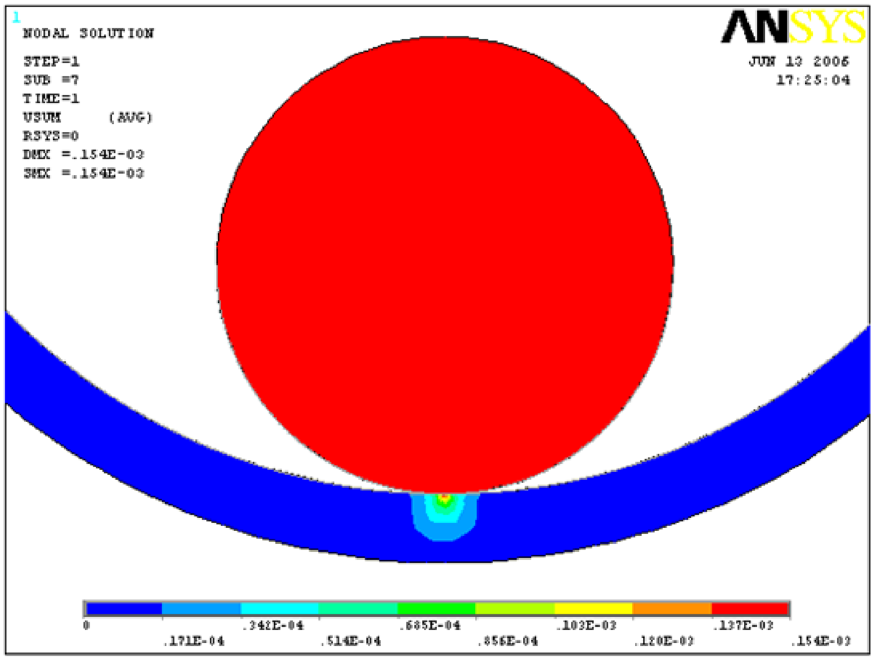


Fig. 11 – Nodal displacements

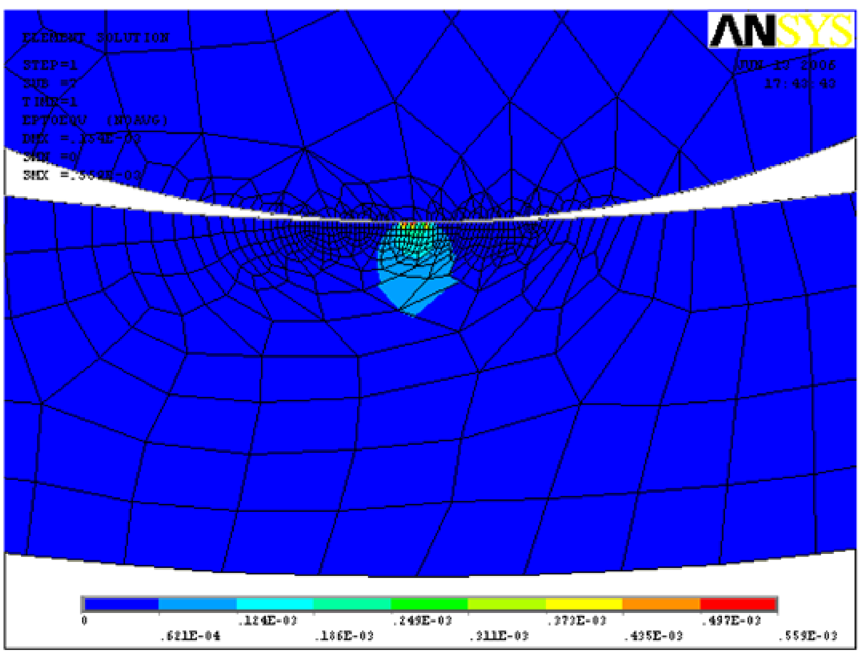


Fig. 12 – Relative deformations

It can be observed that the largest displacements of the tool are due to the fact that its freedom degrees are constraint only by the contact with the workpiece.

It is considered a piece manufactured of Al_2O_3 (AYCO) with longitudinal elasticity modulus E = 360 GPa and transversal contraction coefficient ν = 0.23. In what follows only the relative deformations of workpieces from different ceramic materials will be studied.

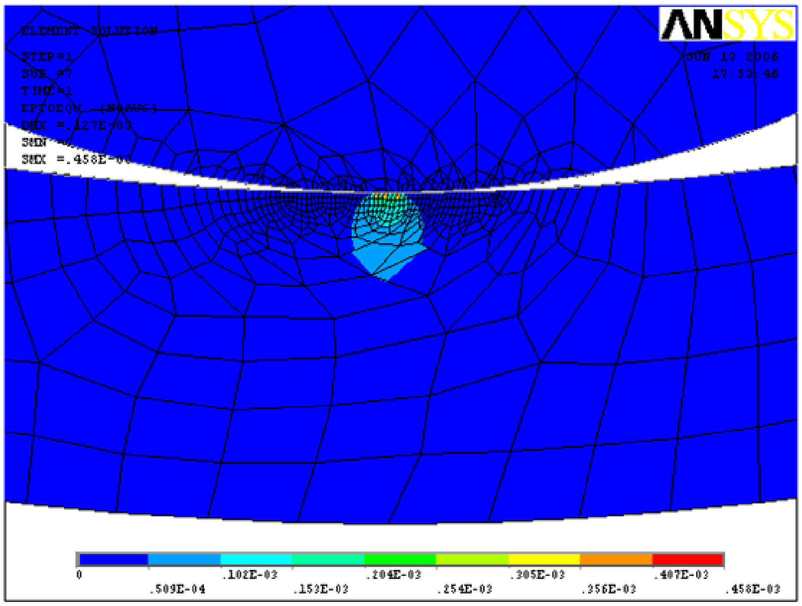


Fig. 13

The maximum deformation value in this case is $0.458*10^{-3}$ mm (fig. 13).

It is considered a piece manufactured from Al_2O_3 (LUCALOX) with longitudinal elasticity modulus E = 410 GPa and transversal contraction coefficient $\nu = 0.23$.

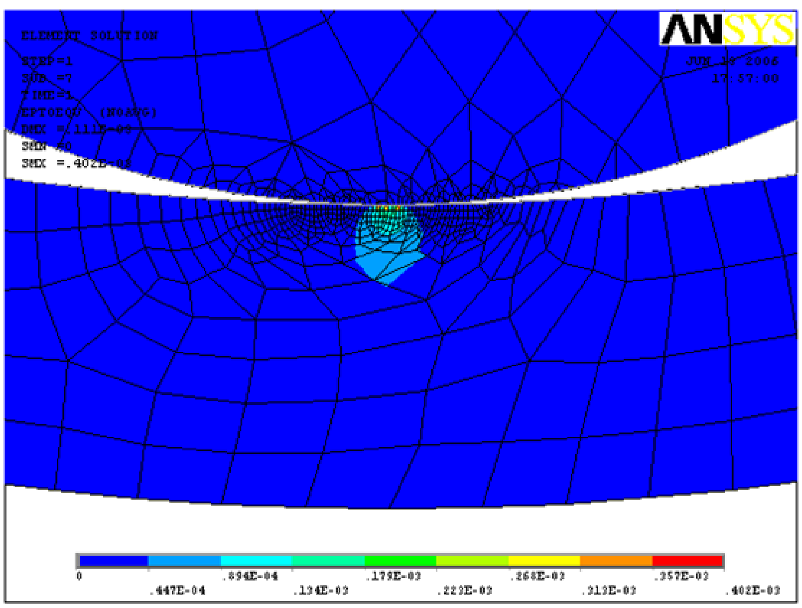


Fig. 14

According to fig. 14 the maximum relative deformation in this case is $0.402*10^{-3}$ mm.

It is considered a piece manufactured from boron carbide with longitudinal elasticity modulus E = 450 GPa and transversal contraction coefficient $\nu = 0.2$.

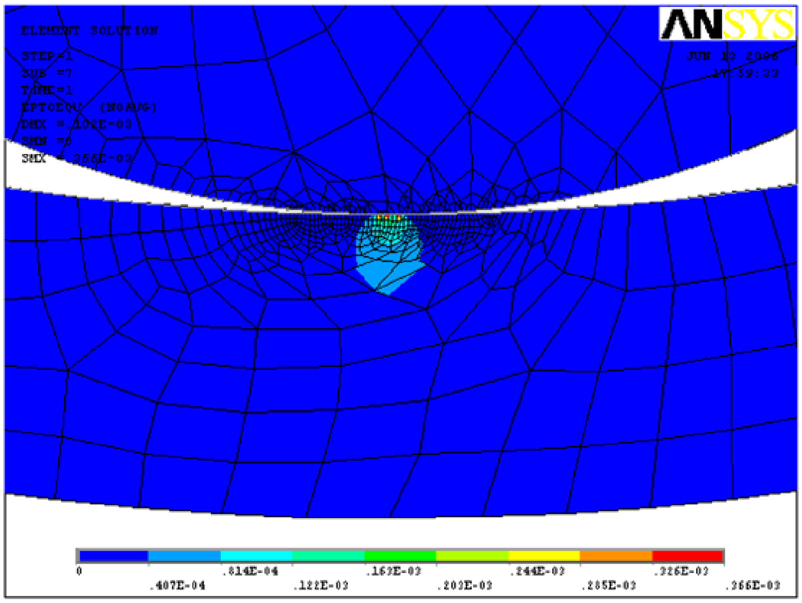


Fig. 15

In this case, the relative deformation is $0.366*10^{-3}$ mm (fig.15).

It is considered a piece manufactured from silicon carbide SiC with longitudinal elasticity modulus E = 480 GPa and transversal contraction coefficient ν = 0.17.

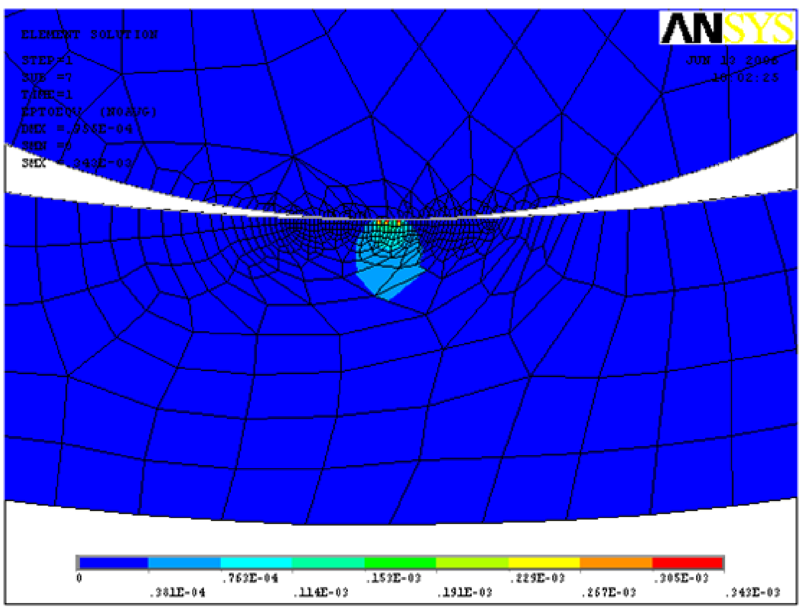


Fig. 16

In this case the maximum relative deformation is $0.343*10^{-3}$ mm (fig.16).

3. CONCLUSIONS

In conclusion, there are presented the variations of the nodal displacements as function of the longitudinal elasticity modulus E and of the transversal contraction coefficient ν for different types of ceramic materials.

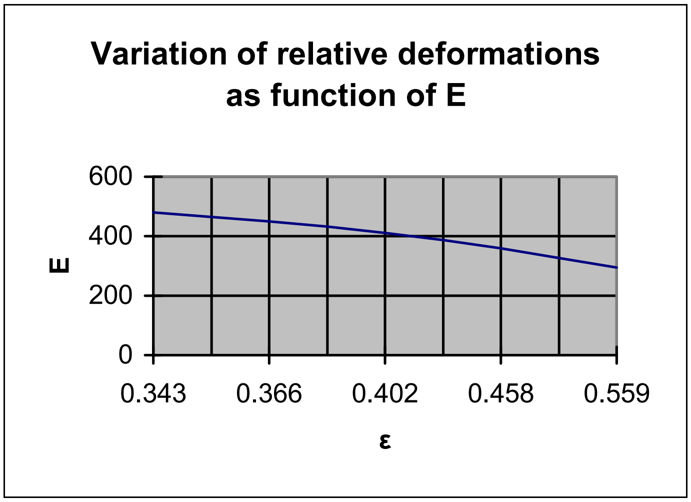


Fig.17

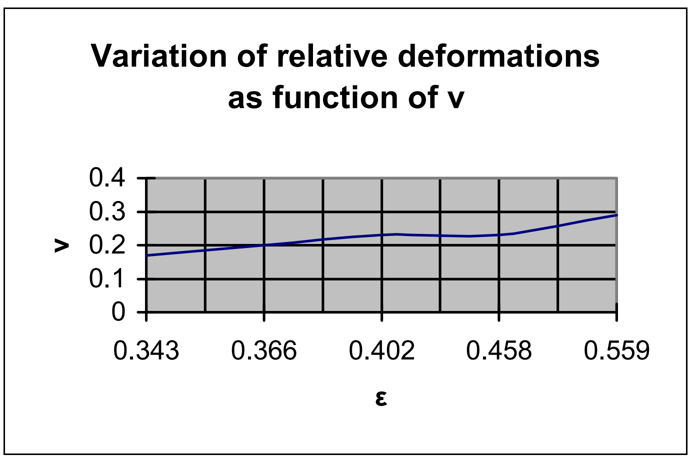


Fig.18

The relative deformations for the same load increase with the decrease of the transversal contraction coefficient, while the increase of the elasticity module cause the decrease of the realtive deformations.

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