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CASE STUDY ON MECHANICAL INTERACTION BETWEEN THE TWIST DRILL AND THE WORKPIECE

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ABSTRACT: Developing cutting processes is urgent task from the viewpoint of environmentally conscious manufacturing. In this paper the process of drilling is analyzed. Mechanical stress and deformation state of a twist drill and the workpiece are investigated in case of sharp drill. The construction of the CAD and physical model is based on our previous experimental results. The numerical analysis is a finite element analysis carried out by Marc. Results are compared with experimental experiences.
KEYWORDS: environmentally conscious cutting, drilling, contact problem, finite element analysis

❖ INTRODUCTION

Environmentally conscious cutting is a hot topic in production engineering because in terms of annual dollar spent this is the most important of the manufacturing processes. The key point is to decrease the volume of coolants and lubricants, because they mean a substantial source of environmental pollution, in other words a significant cost-increasing factor when neutralizing the chips mixed with coolants [1,2]. However when decreasing coolants an lubricants, tribological circumstances changes what strongly influences all the complex phenomena of cutting: friction, mechanical stresses, heat generation, wear and so on.

In this paper the contact problem of drilling with twist drill is investigated. We study the case when the drill is sharp, and when we are at the beginning instant of drilling. The twist drill is made of hard metal, the workpiece is made of a general steel.

In previous papers we described our experimental work [3,5,6]. In this paper we refer to these results as source of boundary conditions in physical modelling, and we use them for comparison.

❖ GEOMETRY AND PHYSICAL FEATURES OF THE SYSTEM INVESTIGATED

The domain of the finite element analysis is a spatial region which is physically the shape of the tool and the workpiece. We prepared the CAD 3D model of the twist drill we used in our experiments, and the workpiece in a certain state of machining. Special attention was paid to geometric features of the top part of the drill, e.g. chisel edges (Fig. 1). In this work chisel edges are sharp, what is typical in the beginning period of the machining. Later the chisel edge wears, but this case here is not studied.

Geometry was imported to MSC Patran, wich is an effective pre- and postprocessor. Finite element mesh was created in Patran. Linear tetrahedral elements were used for the mesh for allowing the later adaptive mesh refinement. On edges of the drill an original refinement was applied by seeding (Fig 2).

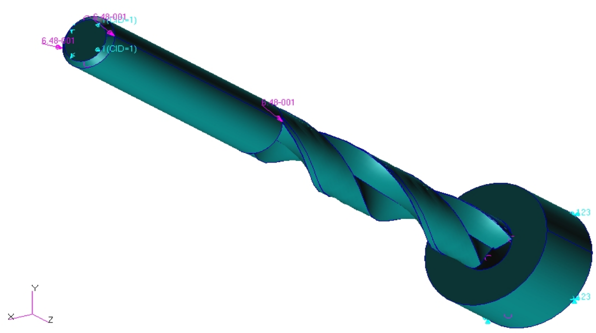

Fig. 1 The CAD model of the system with boundary conditions figured by arrows

❖ PREPARING THE COMPUTATION: PHYSICAL PROPERTIES AND DISCRETE MODEL

In this chapter the set up of computation is summarized. The meshed model was imported into Mentat, a pre- and postprocessor of Marc.

Material of the drill was defined as elastic hard metal. The workpiece was considered to be built up from steel with elastoplastic behaviour. This choice is appropriate for analyzing the stress and deformation state of the system.

Three kind of boundary conditions were applied (Fig. 1). The bottom face of the workpiece was fixed. The radial motion of the drill stem was defined to be zero, simulating the central motion of the chuck. The third boundary condition had two prescribed displacement component, simulating the feed and the rotation motion. This boundary condition had a time dependent ramp up.

The contact phenomenon is a critical part of mechanical finite element analysis. Detecting contact and separation, iterative prevention of penetration require substantial computational cost and strongly influence convergence. Double sided contact detection with optimized contact control was applied. Distance tolerance was left default, bias factor was set to 0.95. The sliding frictional coefficient was 0.2. Initial contact between the drill and the workpiece was set on.

Two kind of local adaptivity criteria was used. First was applied for the drilling tool, and refined when the relative value of the von Mieses stress related to the maximum value reached 0.5 . The second local adaptivity criterion was refining when the von Mieses stress exceeded the yield strength of the workpiece material, this was applied to the workpiece. These together ensured that mesh was refined close to the contact area where it was necessary.

Adaptive time stepping was applied with multi-criteria, and automatic iterative penetration check switched on.

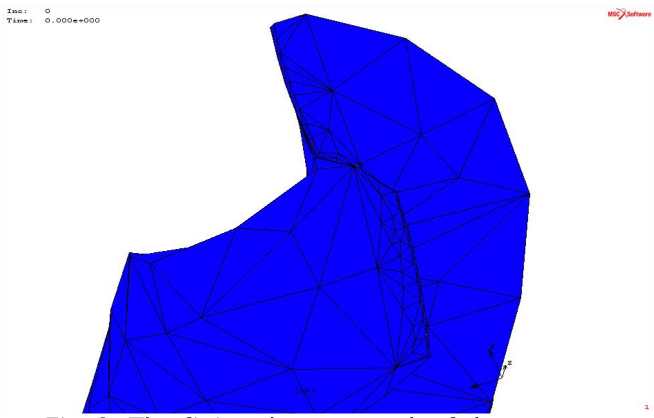

Fig. 2. The finite element mesh of the top part of the drilling tool

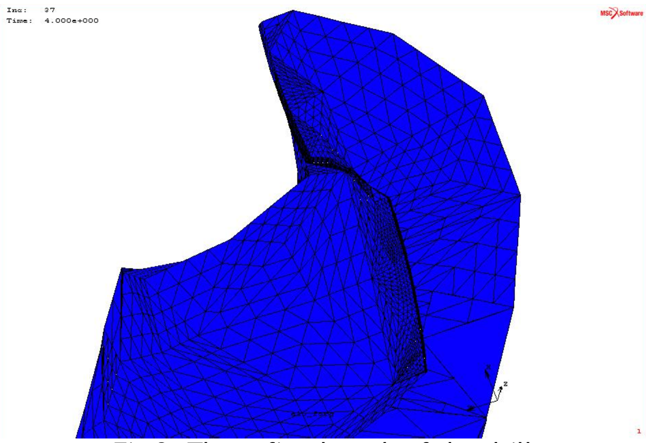

Fig 3. The refined mesh of the drill

❖ RESULTS

A part of a blade server having 2 piece of 2,5 GHz processors and 16 GB RAM was applied for the computation. The finite element application used was Marc, and postprocessing was done by Mentat. The whole nonlinear calculation required 37 increments.

The finite element mesh was significantly refined around the contact area in both bodies, as it was expected (Fig 3).

The stress state of the workpiece is featured by the von Mieses stress distribution (Fig 4). Two important observations must be taken. First, the maximum values arises at chisel edges. This is in agreement with that chisel edges are sharp, not yet worn. The second what we can see on this figure, that it is not symmetric. Really it is quite far from symmetric stress distribution in spite of the original symmetry of the system is high, the workpiece has cylindrical, the drill has twofold rotational symmetry. The original finite element mesh has not the same symmetry. We can think that though the drill is made of a highly hard and strong material, yet it has a (buckling) instability, what we can observe in our static, steady-state calculation. In our previous work the experimental measurement of the asymmetry in wear is described [6]. Of course, when the drill works, it rotates rapidly, so such kind of inhomogenities in the stress distribution are averaged, and can not be seen in the final hole. However this phenomenon may be responsible for important dynamic effects, for example exciting vibrations.

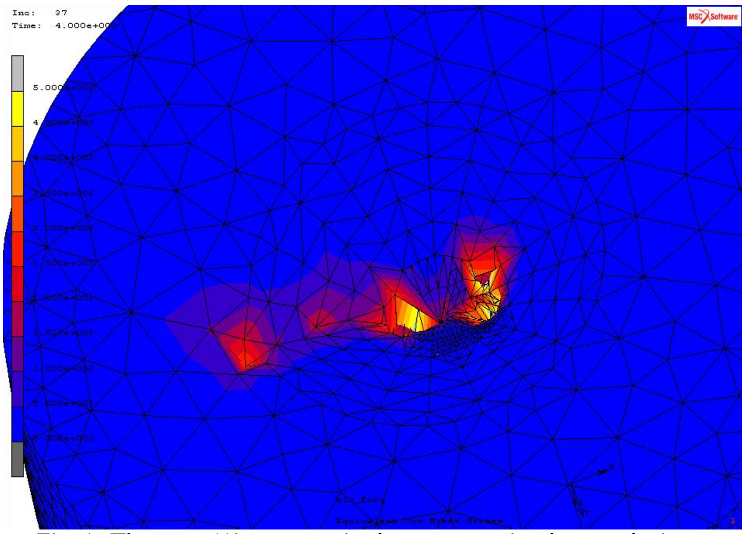

Fig 4. The von Mieses equivalent stress in the workpiece (note, it is not symmetric!)

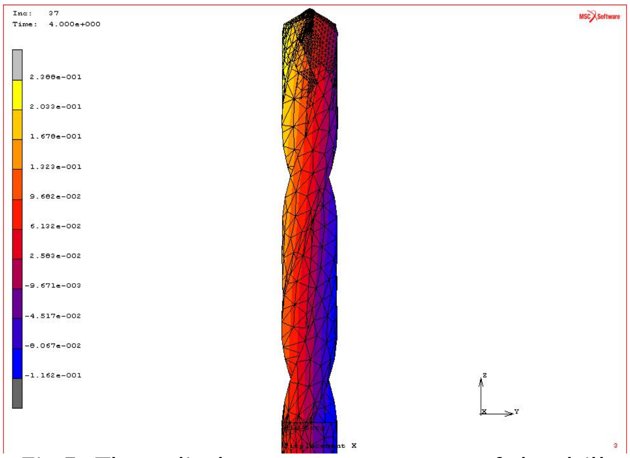

Fig 5. The x displacement component of the drill

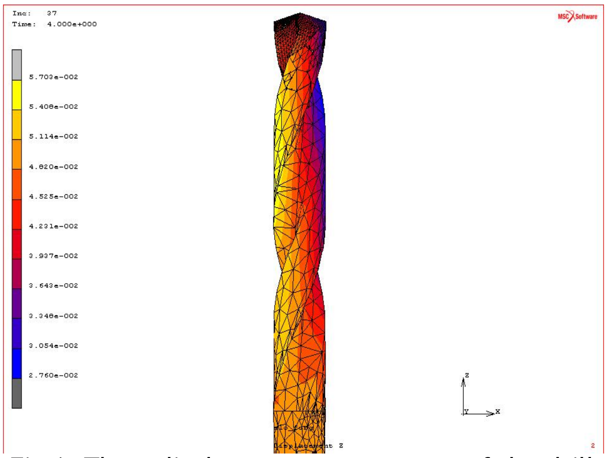

Fig 6. The z displacement component of the drill

Displacement of the drill supports considerations described above (Figs 5 and 6). Nor the z component of the displacement or the x component has not axial symmetry. Consequently we can state that the drill moves not only forward in the z direction and rotates, but it has a small displacement sidelong. It may have bending vibrations when working.

The stress state of the drill top, especially on edges is highly important. On Fig 7 zones of high stresses are demonstrated. Here strong wear can be expected. Besides the asymmetry we can see that such zones are located where we expect them based on the experience: on the corners, on chisel edges, and about at the middle of the edges.

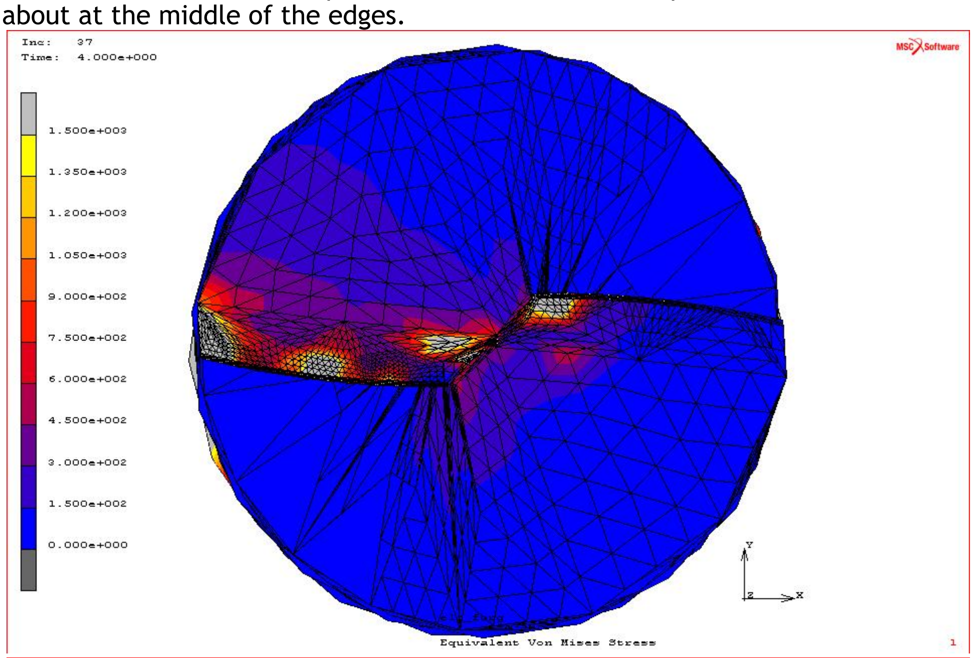

Fig 7. Equivalent von Mieses stress on the top of the drill. White colour indicates zones where the value is beyond 1500 MPa.

❖ CONCLUSIONS

Drilling process with hard metal twist drill was simulated when machining general steel. The starting phase of the drill, when chisel edges are sharp was modelled in a steady-state way.

The drill was studied in contact with the workpiece.

Results are in good agreement with experiences. Asymmetry can be observed both in stress and displacement distribution, what can be responsible for dynamic effects, such as the well known vibration.

In the future thermal effects, wearing, and dynamical phenomena are planned to be studied.

❖ ACKNOWLEDGEMENTS

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