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DESTRUCTION OF THE BILLET MATERIAL DURING PLANING

Abstract: *The cutting process of the steel billet with the planing cutter was simulated in the article. Nature of material destruction was described for the specified geometric parameters of the cutting tool. The values of the strain coefficients during destruction of the billet material were determined.*
Key words: *the model, the cutter, strain, material, destruction.*
Language: *English*

Introduction

Planing is the process of machining the flat and shaped surfaces on the billet using the special cutting tool. The cutters are used as the cutting tools. The cutting part of the planing cutter is made in the form of the triangle for reducing cutting forces that occur during machining. The tool movement is straight. The planing process was researched in the works [1-10].

So as the cutting tool moves with high velocity during planing (compared to movement of the cutter during turning) then insignificant temperature loads will be distributed only in the deformed volume of the billet material. Destruction of the material layers during planing leads to strain on the resulting surfaces of the billet. Strain intensity of the processed material can be determined by calculating the values of the strain coefficients. Let us consider nature of strain of the metal billet during planing with the cutter with the positive rake angle.

Materials and methods

The cutting process with the planing cutter was simulated in the modules of the Ansys program. The three-dimensional statement of the researched problem is presented in the Fig. 1. The conditions for modeling the planing process of the billet in the Autodyn module are presented in the table 1. The mechanical properties and the destruction parameters were set for material of the billet.
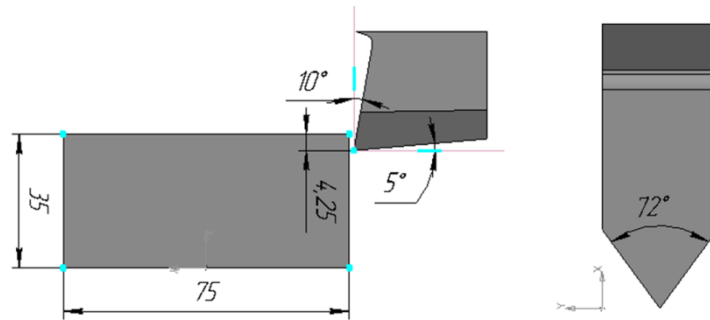

Figure 1 – The problem statement of machining the billet with the blade tool.

Table 1. The conditions for modeling the planing process.

Materials	
Cutter	Rigid
Billet	Structural steel
Reference density	7.85 g/cm^3
EOS	
Model	Linear
Bulk modulus	1.666667×10^8 kPa
Reference temperature	295.149994 K
Specific heat	434 J/kg×K
Strength	
Model	von Mises
Shear modulus	8.1×10^7 kPa
Yield stress	7.5×10^5 kPa
Failure	
Model	Plastic strain
Plastic strain	1.01×10^{20}
Stochastic failure	Yes
Stochastic variance (gamma)	16
Minimum fail fraction	0.1
Distribution type	Fixed seed
Erosion	
Model	Geometric strain
Erosion strain	1.5
Type of geometric strain	Instantaneous
Cutoffs	
Maximum expansion	0.1

Minimum density factor	1.0×10^{-4}
Minimum density factor (SPH)	0.2
Maximum density factor (SPH)	3
Minimum velocity	1.0×10^{-6}
Maximum velocity	1.0×10^{10}
Radius cutoff	0.001
Strain rate cutoff	1×10^{-10}
Solver	
Hex integration	Exact
Hex hourglass control	AD standard
Viscous coefficient	0.1
Tet integration	ANP
Method for Lagrange/ALE density update	Automatic
Method for Euler strain rate calculation	Weighted
Method for Euler pressure calculation	Averaged
Join	
Join tolerance	0.05
Interactions (Lagrange/Lagrange)	
Type	Trajectory
Method	Penalty
Timestep options	
Safety factor	0.9
Method of calculating characteristic zone dimension	Diagonals
Damping options	
Quadratic viscosity	1
Linear viscosity	0.2
Hourglass damping	0.1
Transport	
Material velocity timestep safety factor	1
Euler-FCT	Multidimensional
ALE/Euler energy	Total
Euler	SLIC

The solid models of the cutting tool and the billet were divided into the finite elements. The minimum length of the element edge was 1.5437×10^{-2} m. The total number of the elements was 111362. Refinement that reduced the size of the finite elements in removed allowance was performed on the processed surface of the billet model. The billet model was fixed by the side surfaces and the unprocessed flat surface. The cutter model was moved to the billet model with constant velocity. Splitting the three-dimensional models into the finite elements, setting velocity of the cutter and fixing the billet are presented in the Fig. 2.
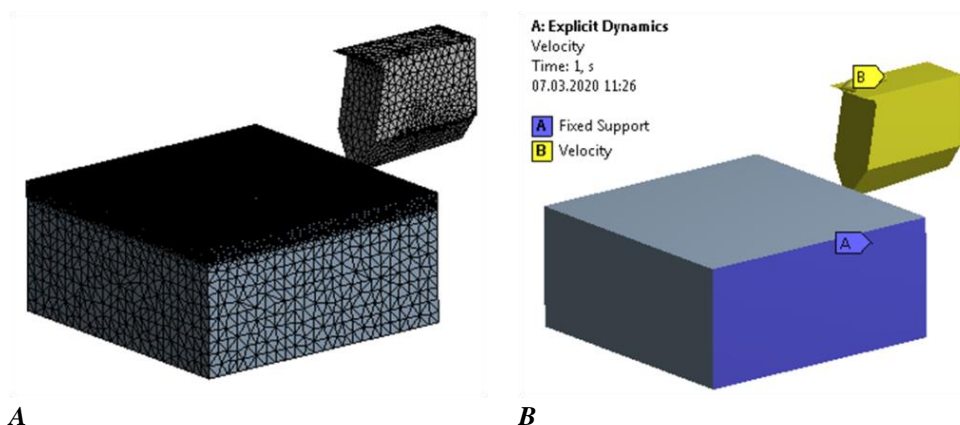

A   *B*

Figure 2 – The conditions for modeling the planing process: *A* – splitting the billet and cutter models into the finite elements, *B* – setting velocity of the cutter and fixing the billet.

Results and discussion

The cutting process with the planing cutter is presented in the Fig. 3. The cutting part of the planing cutter was moved along the processed surface of the billet by 15 mm. Chips are formed on the front surface of the cutter during the chipping layers of the billet material. It is known that material in the cutting zone is subjected to maximum strain. The strain degree of the billet material during cutting can be characterized by the values of the strain coefficients. The simulation results are presented by the strains contours of the billet material during planing (the Figs. 4-5).
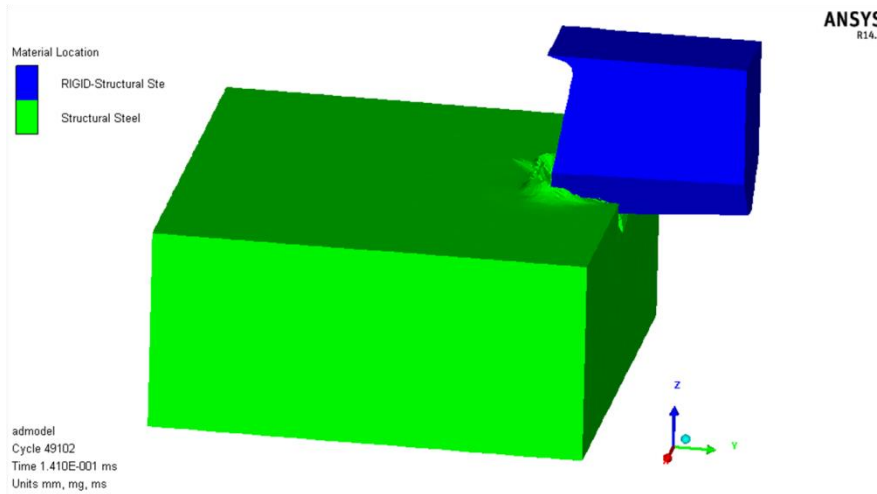

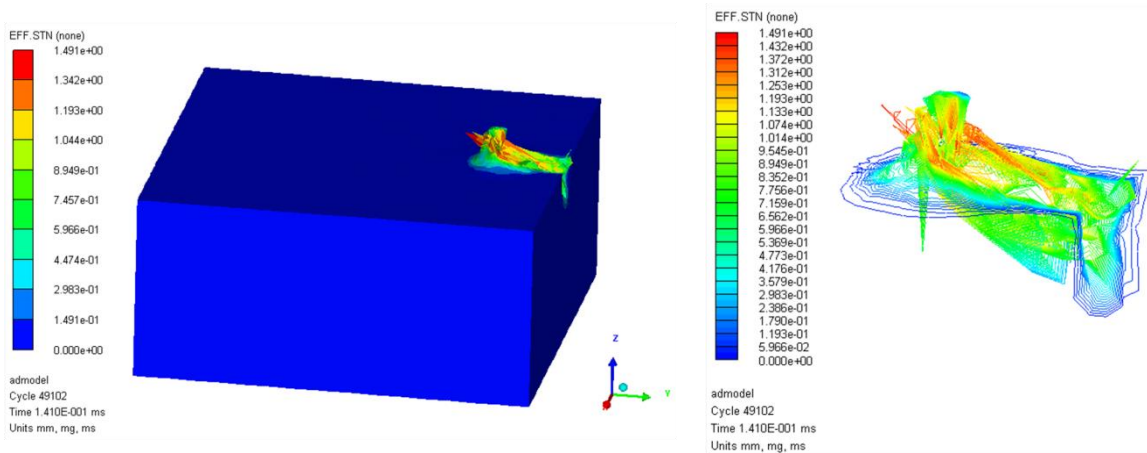**Figure 3 – The cutting process with the planing cutter.**

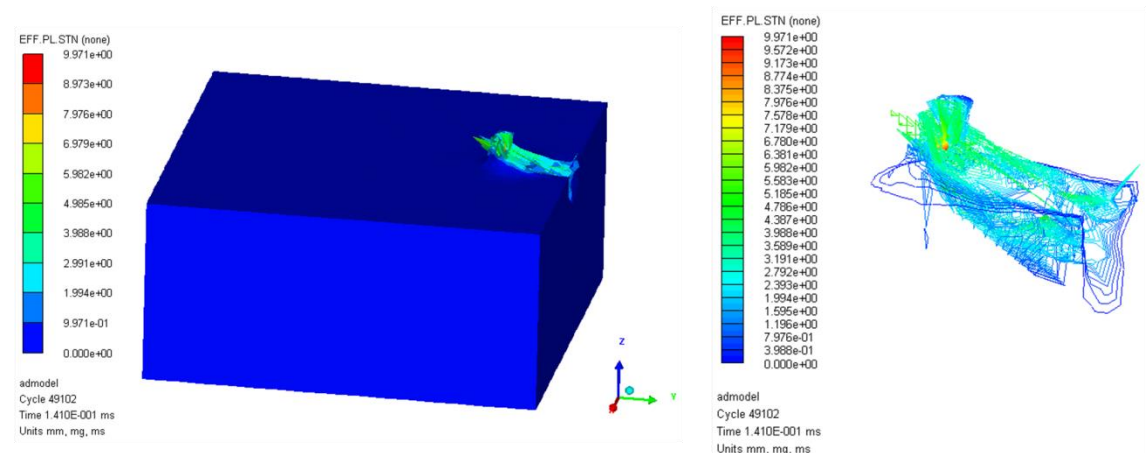**Figure 4 – The contours of effective strain of the billet material during planing.**

Figure 5 – The contours of effective plastic strain of the billet material during planing.

The contours of effective strain give an idea of the volume of deformed (destroyed) material of the billet. Strain accumulates during the entire process. Metal is destroyed in the cutting zone at the coefficient of effective strain of 1.1 (with the small positive rake angle of the cutter). The processed side surfaces of the billet after moving the cutting tool are deformed 1.55 times less than material in the cutting zone. So as the cutting process is carried out during the stationary billet then the main factor of maximum strain will be the largest contact area of the front surface of the planing cutter with material.

The contours color of the coefficient of effective plastic strain indicates uniform destruction of the billet material in all layers of removed allowance. Exception is the volume of material that is deformed at the nose of the cutter. On average, the value of the coefficient of effective plastic strain varies in the range of 1.2...3.5. The coefficient of effective plastic strain of the billet material can reach 10 in the zone of active destruction.

Conclusion

Thus, based on the results of computer modeling, the following conclusions can be drawn:

1. Planing the billet with the proposed positive rake angle of the cutting tool does not lead to active chip formation.

2. Structural steel with the specified mechanical properties is destroyed at the coefficient of effective strain of 1.1. The billet surface in contact with the nose of the cutting tool is deformed at the coefficient of effective strain of 0.89.

3. The coefficient of effective plastic strain during planing varies in the range of 1.2-10. The maximum value of the coefficient is observed in the zone of chip formation.

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