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THE INFLUENCE OF THE CUTTING TOOL GEOMETRY ON THE INTENSITY OF SHEAR STRESS OF THE BLANK MATERIAL

Abstract: The results of computer modeling the cutting process of the metal blank with cutters with different geometry are presented in the article. Cards were formed for the calculation file with the specification of materials properties of the cutting tool and the blank, conditions of the cutting process and other modeling parameters. Recommendations for the choice of the cutter geometry, taking into account calculated minimum shear stress of the blank material were given.
Key words: the blank, the cutter, the model, deformation, the nose radius.
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Introduction

The cutting tool geometry affects the quality and accuracy of the machined blank. The cutting tool must have high strength by reducing the values of the rake and clearance angles during rough machining. However, this leads to an increase in the cutting force and vibrations of the blank and the cutting tool. Cutting edges of the tool must have rounding during finish machining. This geometry of the cutting tool ensures that the requirements for manufacturing the part according to the drawing are met in combination with the low feed speed and the high cutting speed.

On the example of planing, studies were carried out in the works [1-2]. The plastic strain coefficient, the temperature in the cutting zone, internal stresses of material and their effect on the destruction of the steel blank were determined after modeling the process. The material destruction with the generation of significant heat (for example, turning) was described in the works [3-10].

Modeling the dynamics of the cutting process of the metal blank of medium hardness with the planing cutters with the different cutting part geometry will allow you to determine the stress and strain state of deleted material and choose the most optimal option that reduces vibrations of the machine-device-tool-part system.

Materials and methods

The computer experiment was performed in the LS-DYNA special program. The cutting process of the model of the rectangular steel blank with the models of the cutters with the rake angle of 8 degrees and the clearance angle of 10 degrees was simulated. The radius was not performed at the nose of the cutter model in the first test. In the second and third tests, the nose radii of 5 mm and 10 mm, respectively, were performed on the cutters models. The cutting depth decreased with increasing the nose radius. The calculation of the cutting process was carried out in the three-dimensional formulation to visualize the stress and strain state of material in the entire volume of the blank. The statement of modeling the cutting process of the blank with the cutters is presented in the Fig. 1.
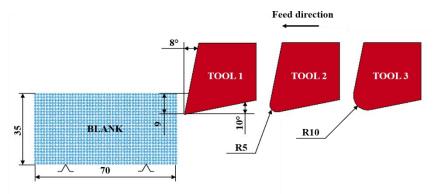

Figure 1 – The statement of the cutting process of the blank.

The calculation was carried out in the conditions as close as possible to the real conditions by setting all the parameters of the cutting process. The accuracy of the obtained results was characterized by the size of the finite element of the models of the blank and the cutter (0.3 mm). The initial conditions for three-dimensional modeling the process of machining the metal blank with the cutters with the different geometry were presented in the special text format, which is demonstrated below.

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*KEYWORD – The keyword, *KEYWORD, flags LS-DYNA that input deck is keyword deck rather than structured format, which has strictly defined format.

*CONTROL_CONTACT – Changing the defaults for computation with contact surfaces.

SLSFAC 0.5 – Scale factor for sliding interface penalties.
RWPNAL 0.0 – Scale factor for rigid wall penalties, which treat nodal points interacting with rigid walls.
ISLCHK 1 – Initial penetration check in contact surfaces with indication of initial penetration in output files. No checking (default).
SHLTHK 0 – Flag for consideration of shell thickness offsets in non-automatic surface-to-surface and non-automatic nodes-to-surface type contacts. Thickness is not considered.
PENOPT 1 – Penalty stiffness value option. Minimum of master segment and slave node (default for most contact types).
THKCHG 0 – Shell thickness changes considered in single surface contact. No consideration (default).

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ORIEN 1 – Optional automatic reorientation of contact interface segments during initialization. Active for automated (part) input only (default).

ENMASS 0 – Flag for treatment of eroded nodes in contact. Eroded node is defined as node that is no longer attached to any element owing to element deletion. Eroded nodes are not considered in contact algorithm.

USRSTR 0 – Storage per contact interface for user supplied interface control subroutine. If zero, no input data is read and no interface storage is permitted in the user subroutine.

USRFRC 0 – Storage per contact interface for user supplied interface friction subroutine. If zero, no input data is read and no interface storage is permitted in the user subroutine.

NSBCS 0 – Number of cycles between contact searching using three-dimensional bucket searches. Using the default value for this field is strongly recommended.

INTERM 0 – Flag for intermittent searching in old surface-to-surface contact using the interval specified (off).

XPENE 4.0 – Contact surface maximum penetration check multiplier. If the small penetration checking option, PENCHK, on the contact surface control card is active, then nodes whose penetration then exceeds the product of XPENE and the element thickness are set free. Set to default which is 4.0.

SSTHK 0 – Flag for determining default contact thickness for shells in single surface contact types. Default contact thickness may be controlled by shell thickness or by shell edge length.

ECDT 0 – Time step size override for eroding contact.

TIEDPRJ 0 – Bypass projection of slave nodes to master surface. Eliminate gaps by projection nodes.

SFRIC 0.0 – Default static coefficient of friction.

DFRIC 0.0 – Default dynamic coefficient of friction.

EDC 0.0 – Default exponential decay coefficient.

VFC 0.0 – Default viscous friction coefficient.

TH 0.0 – Default contact thickness.

TH_SF 0.0 – Default thickness scale factor.

PEN_SF 0.0 – Default local penalty scale factor.

IGNORE 0 – Ignore initial penetrations in the *CONTACT_AUTOMATIC options. The value defined here will be the default. Move nodes to eliminate initial penetrations in the model.

FRCENG 0 – Flag to activate the calculation of frictional sliding energy. Do not calculate.

SKIPRWG 0 – Flag not to display stationary rigid wall by default. Generate 4 extra nodes and 1 shell element to visualize stationary planar rigid wall.

OUTSEG 0 – Flag to determine whether to output each beam spot weld slave node and its master segment for contact type *CONTACT_SPOTWELD into the D3HSP file. Do not write out this information.

SPOTSTP 0 – Flag to determine whether the error termination should occur if the spot weld node or face, which is related to the *MAT_SPOTWELD beam or solid element, respectively, cannot be found on the master surface. No error termination. Silently delete the weld and continue.

SPOTDEL 0 – This option controls the behavior of spot welds when the parent element erodes. Do not delete the spot weld beam or solid element or SPR.

SPOTHIN 0.0 – Optional thickness scale factor. If active, define the factor greater than zero, but less than one. Premature failure of spot welds can occur due to contact of the spot welded parts in the vicinity of the spot weld. This contact creates tensile forces in the spot weld.

ISYM 0 – Symmetry plane option default for automatic segment generation when contact is defined by part IDs.

NSEROD 0 – Flag to invoke old method for ERODING_NODES_TO_SURFACE. Use two-way algorithm (default).

RWGAPS 1 – Flag to add rigid wall gap stiffness. Add gap stiffness.

RWGDTH 0.0 – Death time for gap stiffness. After this time, the gap stiffness is no longer added.

RWKSF 1.0 – Rigid wall penalty scale factor for contact with deformable parts during implicit calculations.

ICOV 0 – Invokes the covariant formulation of Konyukhov and Schweizerhof in the FORMING contact option. Standard formulation (default).

SWRADF 0.0 – Spot weld radius scale factor for neighbor segment thinning. Neighbor segments are not thinned (default).

ITHOFF 0 – Flag for offsetting thermal contact surfaces for thick thermal shells. No offset.

SHLEDG 0 – Flag for assuming edge shape for shells when measuring penetration. Shell edges are assumed round (default).

PSTIFF 0 – Flag to choose the method for calculating the penalty stiffness. Based on material density and segment dimensions (default).

ITHCNT 0 – Thermal contact heat transfer methodology. Set to default which is 1.

TDCNOF 0 – Tied constraint offset contact update option. Update velocities and displacements from accelerations.

FTALL 0 – Option to output contact forces to RCFORC for all 2 surface force transducers when the force transducer surfaces overlap. Output to the first force transducer that matches (default).

SHLTRW 0.0 – Optional shell thickness scale factor for contact with rigid walls. Shell thickness is not considered.

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*CONTROL_ENERGY – Providing the controls for energy dissipation options.

HGEN 2 – Hourglass energy calculation option. This option requires significant additional storage and increases cost by ten percent.

RWEN 2 – Rigid wall energy dissipation option. Energy dissipation is computed and included in the energy balance (default).

SLNTEN 2 – Sliding interface energy dissipation option. This parameter is always set to 2 if contact is active.

RYLEN 2 – Rayleigh energy dissipation option (damping energy dissipation). Energy dissipation is computed and included in the energy balance.

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*CONTROL_SOLUTION – Specifying the analysis solution procedure if thermal only or combined thermal analysis is performed.

SOLN 2 – Analysis solution procedure. Combined structural, multiphysics, and thermal analysis.

NLQ 0 – Define the vector length used in the solution. The default vector length is printed at termination in the message file.

ISNAN 0 – Flag to check for the NaN in the force and moment arrays after the assembly of these arrays is completed. No checking.

LCINT 100 – Number of equally spaced points used in curve rediscretization. The minimum number of 100 is always used, that is, only larger input values are possible.

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*CONTROL_TERMINATION – Stop the job.

ENDTIM 12.0 – Termination time.

ENDCYC 0 – Termination cycle. Cycle number is identical with the time step number.

DTMIN 0.0 – Reduction (or scale) factor to determine minimum time step.

ENDING 0.0 – Percent change in energy ratio for termination of calculation. If undefined, this option is inactive.

ENDMAS 1.000000E8 – Percent change in the total mass for termination of calculation.

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*CONTROL_THERMAL_NONLINEAR – Setting the parameters for the nonlinear thermal or coupled structural/thermal analysis.

REFMAX 100 – Maximum number of matrix reformations per time step.

TOL 0.0 – Convergence tolerance for temperature.

DCP 1.0 – Divergence control parameter. Steady state problems $0.3 \leq DCP \leq 1.0$ default 1.0.

LUMPBC 0 – Lump thermal boundary conditions. Off (default).

THLSTL 0.0 – Line search convergence tolerance. No line search.

NLTHPR 0 – Thermal nonlinear print out level. No print out.

PHCHPN 0.0 – Phase change penalty parameter.

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*CONTROL_THERMAL_SOLVER – Setting the options for the thermal solution in the thermal only or coupled structural-thermal analysis.

ATYPE 1 – Thermal analysis type. Transient analysis.

PTYPE 2 – Thermal problem type. Nonlinear problem with material properties evaluated at element average temperature. Iterative conjugate gradients method, diagonally scalable (default).

CGTOL 1.00000E-6 – Convergence error for type 3 and 4 solvers.

GPT 1 – Number of Gauss points to be used in the solid elements. One point quadrature is used.

EQHEAT 1.0 – Mechanical equivalent of heat. Default value 1.0.

FWORK 1.0 – Fraction of mechanical work converted into heat. Use default value 1.0.

SBC 0.0 – Stefan Boltzmann constant. Value is used with enclosure radiation surfaces.

MSGLVL 0 – Output message level. No output (default).

MAXITR 500 – Maximum number of iterations.

ABSTOL 1.0000E-13 – Absolute convergence tolerance.

RELTOL 1.00000E-4 – Relative convergence tolerance.

OMEGA 1.0 – Relaxation parameter omega for SOLVER 14 and 16. Use default value 1.0 for SOLVER 14.

TSF 1.0 – Thermal speedup factor. This factor multiplies all thermal parameters with units of time in the denominator (e.g., thermal conductivity, convection heat transfer coefficients).

*CONTROL_THERMAL_TIMESTEP – Setting the time step controls for the thermal solution in the thermal only or coupled structural/thermal analysis.

TS 0 – Time step control. Fixed time step.
TIP 0.5 – Time integration parameter. Crank-Nicolson scheme.
ITS 0.001 – Initial thermal time step.
TMIN 1.00000E-7 – Minimum thermal time step.
TMAX 0.0139 – Maximum thermal time step.
DTEMP 100.0 – Maximum temperature change in each time step above which the thermal time step will be decreased.
TSCP 0.5 – Time step control parameter.
LCTS 0 – Load curve ID which defines data pairs (thermal time breakpoint, new time step).

*CONTROL_TIMESTEP – Setting the structural time step size control using different options.

DTINIT 0.0 – Initial time step size.
TSSFAC 0.6 – Scale factor for computed time step.
ISDO 0 – Basis of time size calculation for 4-node shell elements.
TSLIMT 0.0 – Shell element minimum time step assignment.
DT2MS 0.0 – Time step size for mass scaled solutions.
LCTM 0 – Load curve ID that limits the maximum time step size (optional).
ERODE 0 – Erosion flag for elements with small time step. Calculation will terminate if the solution time step drops to TSMIN.
MS1ST 0 – Option for mass scaling that applies when DT2MS < 0.
DT2MSF 0.0 – Reduction (or scale) factor for initial time step size to determine the minimum time step size permitted.
DT2MSLC 0 – Load curve for determining the magnitude of DT2MS as the function of time during the explicit solutions phase.
IMSCL 0 – Flag for selective mass scaling if and only if mass scaling active.
RMSCL 0.0 – Flag for using rotational option in selective mass scaling only translational inertia are selectively mass scaled.

*DATABASE_GLSTAT – Global statistics and energies.

DT 0.0 – Time interval between outputs. If DT is zero, no output is printed.
BINARY 0 – Flag for binary output.
LCUR 0 – Optional curve ID specifying time interval between outputs.
IOOPT 1 – Flag to govern behavior of the output frequency load curve defined by LCUR. This is the default behavior.

*DATABASE_MATSUM – Part energies.

DT 0.0 – Time interval between outputs. If DT is zero, no output is printed.
BINARY 0 – Flag for binary output.
LCUR 0 – Optional curve ID specifying time interval between outputs.
IOOPT 1 – Flag to govern behavior of the output frequency load curve defined by LCUR. This is the default behavior.

*DATABASE_RCFORC – Resultant contact interface forces.

DT 0.0 – Time interval between outputs. If DT is zero, no output is printed.
BINARY 0 – Flag for binary output.
LCUR 0 – Optional curve ID specifying time interval between outputs.
IOOPT 1 – Flag to govern behavior of the output frequency load curve defined by LCUR. This is the default behavior.

*DATABASE_BINARY_D3DUMP – Database for restarts. Defining the output frequency in cycles.

CYCL 100000.0 – For D3DUMP and RUNRSF options this field is the number of time steps between output states.
LCDT 0 – Optional load curve ID specifying time interval between dumps.

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BEAM 0 – Discrete element option flag. Discrete spring and damper elements are added to the D3PLOT database where they are displayed as beam elements.
NPLTC 0 – DT = ENDTIM/NPLTC.
PSETID 0 – Part set ID.

*DATABASE_BINARY_D3PLOT – Database for entire model. Control to some extent the content of binary output databases D3PLOT, D3THDT, and D3PART.

DT 0.0 – This field defines the time interval between output states.
LCDT 0 – Optional load curve ID specifying time interval between dumps.
BEAM 0 – Discrete element option flag. Discrete spring and damper elements are added to the D3PLOT database where they are displayed as beam elements.
NPLTC 100 – DT = ENDTIM/NPLTC.
PSETID 0 – Part set ID.
IOOPT 0 – This variable applies to the D3PLOT option only and governs how the plot state frequency is determined from curve LCDT.

*BOUNDARY_PRESCRIBED_MOTION_RIGID – Defining the imposed nodal motion (velocity, acceleration, or displacement) on the node or the set of nodes.

PID 1 – Prescribed motion set ID to which this node, node set, segment set, or rigid body belongs. This ID does not need to be unique.
DOF 1 – Applicable degrees-of-freedom, x-translational degree-of-freedom.
VAD 0 – Velocity/Acceleration/Displacement flag. Velocity (rigid bodies and nodes).
LCID 1 – Curve ID or function ID to describe motion value as the function of time.
SF 1.0 – Load curve scale factor. Default set to 1.0.
VID 0 – Vector ID for DOF values of 4 or 8.
DEATH 1.00000E28 – Time imposed motion/constraint is removed.
BIRTH 0.0 – Time that the imposed motion/constraint is activated.

*BOUNDARY_SPC_SET – Defining the nodal single point constraints.

NSID 2 – Node ID or nodal set ID.
CID 0 – Coordinate system ID.
DOFX 1 – Insert 1 for translational constraint in local x-direction.
DOFY 1 – Insert 1 for translational constraint in local y-direction.
DOFZ 1 – Insert 1 for translational constraint in local z-direction.
DOFRX 1 – Insert 1 for rotational constraint about local x-axis.
DOFRY 1 – Insert 1 for rotational constraint about local y-axis.
DOFRZ 1 – Insert 1 for rotational constraint about local z-axis.

*SET_NODE_LIST_TITLE & *SET_NODE_LIST – Defining the nodal set with some identical or unique attributes.

SID 1 & 2 – Set identification. All node sets should have the unique set ID.
DA1 0.0 – The first nodal attribute default value.
DA2 0.0 – The second nodal attribute default value.
DA3 0.0 – The third nodal attribute default value.
DA4 0.0 – The fourth nodal attribute default value.
SOLVER MECH – Name of solver using this set.
NID1 – Nodal ID 1.
NID2 – Nodal ID 2.
NID3 – Nodal ID 3.
NID4 – Nodal ID 4.
NID5 – Nodal ID 5.
NID6 – Nodal ID 6.
NID7 – Nodal ID 7.
NID8 – Nodal ID 8.

*CONTACT_AUTOMATIC_NODES_TO_SURFACE_THERMAL_ID – Defining the contact interface in the 3D model.

CID 1 – Contact interface ID.
SSID 1 – Slave segment set ID, node set ID, part set ID, part ID, or shell element set ID.

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MSID 1 – Master segment set ID, node set ID, part set ID, part ID, or shell element set ID.

SSTYP 4 – ID type of SSID. Node set ID for nodes-to-surface contact.

MSTYP 3 – ID type of MSID. Part ID.

SBOXID 0 – Include in contact definition only those slave nodes/segments within box SBOXID. SBOXID is not available for ERODING contact options.

MBOXID 0 – Include in contact definition only those master segments within box MBOXID. MBOXID is not available for ERODING contact options.

SPR 0 – Include the slave side in the *DATABASE_NCFORC and the *DATABASE_BINARY_INTFOR interface force files, and optionally in the DYNA in file for wear.

MPR 0 – Include the master side in the *DATABASE_NCFORC and the *DATABASE_BINARY_INTFOR interface force files, and optionally in the DYNA in file for wear.

FS 0.2 – Static coefficient of friction.

FD 0.0 – Dynamic coefficient of friction.

DC 0.0 – Exponential decay coefficient.

VC 0.0 – Coefficient for viscous friction.

VDC 20.0 – Viscous damping coefficient in percent of critical or the coefficient of restitution expressed as percentage.

PENCHK 0 – Small penetration in contact search option.

BT 0.0 – Birth time (contact surface becomes active at this time).

DT 1.00000E20 – Death time (contact surface is deactivated at this time).

SFS 1.0 – Scale factor on default slave penalty stiffness.

SFM 1.0 – Scale factor on default master penalty stiffness.

SST 0.0 – Optional contact thickness for slave surface (overrides default contact thickness).

MST 0.0 – Optional contact thickness for master surface (overrides default contact thickness).

SFST 1.0 – Scale factor applied to contact thickness of slave surface.

SFMT 1.0 – Scale factor applied to contact thickness of master surface.

FSF 1.0 – Coulomb friction scale factor.

VSF 1.0 – Viscous friction scale factor.

CF 0.0 – Thermal conductivity of fluid between the contact surfaces.

FRAD 0.0 – Radiation factor between the contact surfaces.

HTC 4.70000E-5 – Heat transfer conductance for closed gaps.

LMIN 2.0 – Minimum gap.

LMAX 10000.0 – No thermal contact if the gap is greater than this value.

FTOSLV 1.0 – Fraction of sliding friction energy partitioned to the slave surface.

BC_FLG 0 – Thermal boundary condition flag. Thermal boundary conditions are on when parts are in contact.

ALGO 0 – Contact algorithm type. Two-way contact, both surfaces change temperature due to contact.

*PART – Defining the parts, that is, combine material information, section properties, hourglass type, thermal properties, and the flag for part adaptivity.

Solid1 & SphNode

PID 1 & 2 – Part identification.

SECID 1 & 2 – Section identification defined in the *SECTION keyword.

MID 1 & 2 – Material identification defined in the *MAT section.

EOSID 0 & 1 – Equation of state identification defined in the *EOS section. Nonzero only for solid elements using the equation of state to compute pressure.

HGID 0 – Hourglass/bulk viscosity identification defined in the *HOURGLASS section. Default values are used.

GRAV 0 – Flag to turn on gravity initialization according to *LOAD_DENSITY_DEPTH.

ADPOPT 0 – Indicate if this part is adapted or not.

TMID 1 – Thermal material property identification defined in the *MAT_THERMAL section.

*SECTION_SOLID – Defining the section properties for solid continuum and fluid elements.

SECID 1 – Section ID.

ELFORM 1 – Element formulation options. Constant stress solid element.

AET 0 – Ambient element type. Non-ambient.

*MAT_RIGID_TITLE – This is material 20. Parts made from this material are considered to belong to the rigid body (for each part ID).

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Tool
MID 2 – Material identification.
RO 7.85000E-6 – Mass density.
E 200.0 – Young's modulus.
PR 0.3 – Poisson's ratio.
N 0.0 – MADYMO3D 5.4 coupling flag, *n*.
COUPLE 0.0 – Coupling option if applicable. The finite element mesh is input.
M 0.0 – MADYMO3D 5.4 coupling flag, *m*.
ALIAS – VDA surface alias name.
CMO 1.0 – Center of mass constraint option. Constraints applied in global directions.
CON1 5 – Global translational constraint. Constrained *y* and *z* displacements.
CON2 7 – Global rotational constraint. Constrained *x*, *y*, and *z* rotations.
A1, A2, A3, V1, V2, V3 0.0 – Alternative method for specifying local system. Define two vectors **a** and **v**, fixed to the rigid body, which are used for output and the user defined airbag sensor subroutines.

*SECTION_SPH_TITLE – Defining the section properties for SPH particles.

SPH
SECID 2 – Section ID.
CSLH 1.2 – Constant used to calculate the initial smoothing length of the particles. The default value works for most problems.
HMIN 0.2 – Scale factor for the minimum smoothing length.
HMAX 2.0 – Scale factor for the maximum smoothing length.
SPHINI 0.0 – Optional initial smoothing length (overrides true smoothing length).
DEATH 1.00000E20 – Time imposed SPH approximation is stopped.
START 0.0 – Time imposed SPH approximation is activated.

*MAT_JOHNSON_COOK_TITLE – This is material type 15. The Johnson/Cook strain and temperature sensitive plasticity is sometimes used for problems where the strain rates vary over the large range and adiabatic temperature increases due to plastic heating cause material softening.

Blank
MID 1 – Material identification.
RO 7.81000E-6 – Mass density.
G 78.5 – Shear modulus.
E 204.0 – Young's modulus.
PR 0.3 – Poisson's ratio.
DTF 1.80000E-7 – Minimum time step size for automatic element deletion.
VP 0.0 – Formulation for rate effects. Scale yield stress (default).
RATEOP 0.0 – Form of strain-rate term. Log-linear Johnson-Cook (default).
A 0.553 – Input constant.
B 0.601 – Input constant.
N 0.234 – Input constant.
C 0.0134 – Input constant.
M 1.0 – Input constant.
TM 1480.0 – Melt temperature.
TR 20.0 – Room temperature.
EPSO 0.001 – Quasi-static threshold strain rate.
CP 642.0 – Specific heat.
PC 0.0 – Tensile failure stress or tensile pressure cutoff.
SPALL 2.0 – Spall type. Shell elements are deleted.
IT 0.0 – Plastic strain iteration option. No iterations (default).
D1 1.2 – Failure parameter.
D2 0.0 – Failure parameter.
D3 0.0 – Failure parameter.
D4 0.0 – Failure parameter.
D5 0.0 – Failure parameter.
C2/P 0.0 – Optional strain-rate parameter.
EROD 0 – Erosion flag. Element erosion allowed (default).
EFMIN 1.00000E-6 – The lower bound for calculated strain at fracture.

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*EOS_LINEAR_POLYNOMIAL – Defining the coefficients for the linear polynomial EOS, and initialization of the thermodynamic state of material by defining E0 and V0 below.

EOSID 1 – Equation of state ID.
C0 0.0 – The 0th polynomial equation coefficient.
C1 170.0 – The 1st polynomial equation coefficient.
C2 0.0 – The 2nd polynomial equation coefficient.
C3 0.0 – The 3rd polynomial equation coefficient.
C4 0.0 – The 4th polynomial equation coefficient.
C5 0.0 – The 5th polynomial equation coefficient.
C6 0.0 – The 6th polynomial equation coefficient.
E0 0.0 – Initial internal energy per unit reference volume.
V0 1.0 – Initial internal energy per unit reference volume.

*MAT_THERMAL_ISOTROPIC – This is thermal material type 1. With this material, isotropic thermal properties can be defined.

TMID 1 – Thermal material identification.
TRO 0.0 – Thermal density. Default to structural density.
TGRLC 0.0 – Thermal generation rate. Load curve ID defining the thermal generation rate as the function of time.
TGMULT 0.0 – Thermal generation rate multiplier. No heat generation.
TLAT 0.0 – Phase change temperature.
HLAT 0.0 – Latent heat.
HC 642.0 – Specific heat.
TC 4.70000E-5 – Thermal conductivity.

*INITIAL_TEMPERATURE_SET – Defining the initial nodal point temperatures using nodal set IDs or node numbers.

NSID 0 – Nodal set ID or nodal point ID.
TEMP 20.0 – Temperature at node or node set.
LOC 0 – Middle surface of thermal shell element.

*DEFINE_CURVE – Defining the curve (for example, load as the function of time, often loosely referred to as the load curve).

LCID 1 – Load curve identification.
SIDR 0 – Flag controlling use of curve during dynamic relaxation.
SFA 1.0 – Scale factor for abscissa value. This is useful for simple modifications.
SFO 1.0 – Scale factor for ordinate value (function). This is useful for simple modifications.
OFFA 0.0 – Offset for abscissa values.
OFFO 0.0 – Offset for ordinate values (function).
DATTYP 0 – Data type. This affects how offsets are applied.
A1 0.0, 0.02, 5.0 – Abscissa values.
O1 0.0, -5.0, -5.0 – Ordinate (function) values.

*ELEMENT_SOLID – Defining the three-dimensional solid elements.

EID – Element ID.
PID – Part ID.
N1 – Nodal point 1.
N2 – Nodal point 2.
N3 – Nodal point 3.
N4 – Nodal point 4.
N5 – Nodal point 5.
N6 – Nodal point 6.
N7 – Nodal point 7.
N8 – Nodal point 8.

*ELEMENT_SPH – Defining the lumped mass element assigned to the nodal point.

NID – Node ID and Element ID are the same for the SPH option.
PID – Part ID to which this node (element) belongs.
MASS – Mass/volume.

*NODE – Defining the node and its coordinates in the global coordinate system.

NID – Node number.
X – *x* coordinate.
Y – *y* coordinate.
Z – *z* coordinate.
TC – Translational constraint.
RC – Rotational constraint.

*CHANGE_CURVE_DEFINITION – Changing the solution options. The new load curve must contain the same number of points as the curve it replaces.

LCID 1 – Load curve ID.

Results and discussion

The contours of maximum shear stress were selected after the calculation in the program. The red color of the contours on the blank model characterizes the maximum value of shear stress, the blue color characterizes the minimum value of shear stress. The contours of maximum shear stress of the blank material during cutting with the cutters with the different geometry are presented in the Fig. 2.

Machining with the cutter without the nose radius leads to significant compression deformations of the blank from the side of the rake face of the tool and tensile deformations from the side of the flank face. The volume of maximum stress is formed on the chipping plane of material from the blank in the cutting zone. It undergoes significant deformation, as evidenced by the change in the geometric shape of the rectangle during machining.
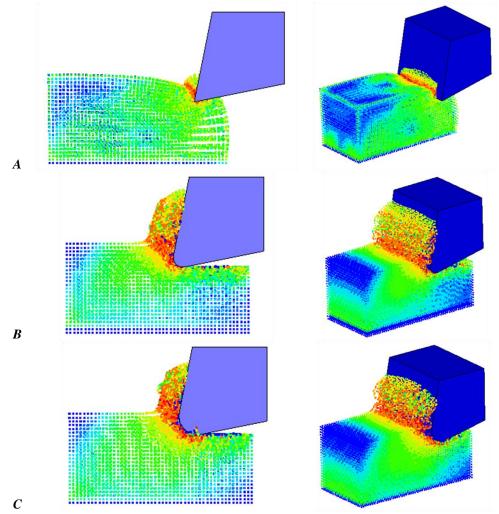

A

B

C

Figure 2 – The contours of maximum shear stress of the blank material during cutting: *A* **– the cutter without the nose radius;** *B* **– the cutter with the nose radius of 5 mm;** *C* **– the cutter with the nose radius of 10 mm.**

Machining with the cutters with the nose radii of 5 mm and 10 mm is accompanied by the permanent formation of maximum shear stresses in the blank volumes, as close as possible to the cutting edge. The intensity distribution of shear stress during cutting with the cutter with the nose radius of 10 mm occurs on the larger volume of the blank than during cutting with the cutter with the nose radius of 5 mm. The average value of shear stress of the blank material during machining with the cutters with the different nose radii is almost the same. Thus, the most preferred option is the cutter with the nose radius of 5 mm, since with less deformation of the blank, you can perform machining with the greater productivity by increasing the cutting depth.

Conclusion

The cutter without the nose radius is not recommended for roughing due to lower strength of the tool and significant deformations of the blank. The nose radius of the cutter facilitates the cutting process of the metal blanks. At the same time, increasing the nose radius in the studied range does not lead to an increase in the cutting forces. The deformation intensity of the inner layers of the blank material will be higher in the conditions of planing with the cutter with the large nose radius.

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