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| | ISI (Dubai, UAE) = 0.829 | РИНЦ (Russia) = 0.179 | |
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**SECTION 7. Mechanics and machine construction.**

# COMPARATIVE ANALYSIS OF STRESS-STRAIN STATE OF WORKPIECES MADE OF ALUMINIUM ALLOY DURING OF THE EQUAL CHANNEL ANGULAR PRESSING PROCESS ACCORDING TO DIFFERENT SCHEMES

***Abstract***: *This article presents a comparative analysis of the results of computer simulation in software LS-DYNA of the process of equal channel angular pressing process of the workpieces made of aluminium alloy in terms of intersection the channel matrix at angles: 90°, 90° with a bending radius axis R30, 120°.*

***Key words***: *equal channel angular pressing, stress, workpiece, normal force, bending moment.*

***Language***: *English*

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***Soi***: http://s-o-i.org/1.1/TAS-07-27-10 ***Doi***: crossref http://dx.doi.org/10.15863/TAS.2015.07.27.10

The classic variant of the equal channel angular pressing (ECAP) process of metallic alloys is a forcing through workpiece of round or square cross-section through intersecting channels of the matrix at an angle of 90°. There are other variants ECAP is based on changing the configuration or angle of intersection of the channels of the matrix. Modernization of configuration is the smoothing of the abrupt transition at the intersection of the channels of the matrix. The angle of intersection of the receiving and output channels of the matrix it is recommended to choose in the range from 90° to 150°.

To implement the process of ECAP process deformable non-ferrous alloys it is necessary to consider the physico-mechanical properties of materials and dimensions of the workpiece, the pressing speed (displacement of the punch in the receiving channel matrix), accuracy, strength and rigidity of the matrix and punch.

ECAP process is performed on all metal deformable plastic alloys: magnesium, nickel, aluminium, titanium, copper, steel, etc. In the works [1, 2, 3, 4, 5, 6] presents an assessment of stress-strain state of pressed under different conditions (without backpressure, with backpressure, pressing in cold and hot condition of the workpiece) metal alloys: Ti-6Al-4V, M1, ASME SA-738 CrA, AZ31, 1340. The workpieces was pressed at an angle of 90°. For titanium alloy plastic strain amounted more than 0.8, the shear stress of more than 150 MPa, the principal stress of more than 300 MPa, the surface stress of more than -500 MPa (at action of negative values of the normal force and bending moment). Taking into account the action of backpressure, hydrostatic pressure in the deformation zone of copper workpiece amounted to more than 700 MPa at a true strain of about 1.0 after one cycle of pressing. The plastic deformation of low-alloy steel (is heated to 500 °C) leads to an increase of the strength characteristics 2.5 times compared with the initial state. ECAP process of magnesium alloy increases the yield strength and tensile strength deformed workpiece at 2.7 and 1.3 times, respectively. 1st principal stress reached a value of 350 MPa, 2nd principal stress of 248 MPa, 3rd principal stress – -237 MPa in the result of ECAP process the aluminium alloy at an angle of 90°.

Aluminium alloys are used in aircraft industry, construction and mechanical engineering. Aluminium alloys are not inferior in strength titanium alloys at lower density The technique of pressing of aluminium alloys relative to other metals is at the highest level [7].

Analysis of stress-strain state of the material of the workpiece is pressed according to different

schemes will identify the most efficient method by comparing the results of computer simulation of the ECAP process in three-dimensional setting.

The implementation of the simulation of the ECAP process was carried out in several stages. In a computer program KOMPAS-3D were constructed three-dimensional solid model matrices with receiving and output channels, intersecting at the following angles: 90°, 90° with a bending radius axis R30, 120°. The model of the pressed workpiece is located in the receiving channel of the matrix. The dimensions of the models matrices and the workpiece presents in Fig. 1.

The models were loaded in the module Explicit Dynamics software Ansys Workbench. For the accuracy of the calculation, on all models were constructed grid defines the number of elements (nodes). The selected matrix materials (steel alloy) and workpieces (aluminium alloy), given appropriate physico-mechanical properties. The matrix is not deformed, was a rigid body. Applied a constant load on the end surface of the workpiece. Formed contact conditions of ECAP process. All information for modeling of ECAP process the workpiece at an angle of 90° presents below in text format.

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4, 20.1802, 1.41678, 43.7637
5, 25.1802, 1.41678, 43.7636
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4, 1, 14, 47, 36, 25, 15, 48, 37, 26
5, 1, 15, 48, 37, 26, 16, 49, 38, 27
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8EPS8
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7ADPORT 8TMID
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$ HEADING
Part 2
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7ADPORT 8TMID
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7DATTYP
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7DATTYP
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7DATTYP
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10000, 0
100000, 0
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7DATTYP
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$ 1A 2O
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8VSF
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8VSF
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5SBOPT 6DEPTH 7BSORT 8FRCFRQ
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5ENDMAS
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5XPENE 6SSTHK 7ECDT 8TIEDPRJ
$ 1SFRIC 2DFRIC 3EDC 4VFC 5TH 6TH_SF
7PEN_SF
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*DATABASE_BINARY_RUNRSF
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277, 278, 279, 280, 281, 282, 283, 284
285, 286, 287, 288, 289, 290, 291, 292
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4837, 4838
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259, 260
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1925, 1925, 1900, 1937
1888, 1909, 1928, 1928
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Modeling of ECAP process was carried out in the program LS-DYNA. The results of the calculations are presented in the form of color contours on the model defining the stress-strain state of the workpiece (Fig. 2 – 4). The contours were obtained at the time of movement of the workpiece from the receiving to the output channels of the matrix.

The plastic strain of the material – irreversible deformation, caused by the change in stresses. The degree of plastic strain is determined by the deformation coefficient, i.e. the ratio of the sizes of the solid body after the deformation to the appropriate sizes before deformation [8].

The deviatoric stress – part of the stress tensor, obtained by subtracting from it the ball portion of this tensor. The deviatoric stress describes the change in shape of the deformed solid body without changing its volume [9].

**1. The receiving and output channels intersect at an angle of 90°.**

In accordance with the colors of the contours on the model, significant plastic deformation of the material (1.1) is observed on the contact surface of the workpiece at the transition of the receiving channel in the output matrix (Fig. 2, b). The plastic strain of the workpiece in the receiving channel is minimal.

In Fig. 2, c – e values of the maximum (1st) principal deviatoric stress of the material is positive (tension), the 2nd principal deviatoric stress – positive and negative (tension and compression), the minimum (3rd) principal deviatoric stress is negative (compression). Defined maximum value: the 1st principal deviatoric stress of the material in the bend of the workpiece, the 2nd and 3rd principal deviatoric stresses around the end surface of the workpiece in the receiving channel.

**2. The receiving and output channels intersect at an angle of 90° with a bending radius axis R30.**

The maximum plastic strain occurs on the end surface of the workpiece, facing to the punch (Fig. 3, b). The value of strain of the material amounted to 0.394. At the output channel, plastic strain of the material is reduced to 0.13.

The maximum value of the 1st principal deviatoric stress of the material (Fig. 3, c) is defined on the end surface, which receives the applied load, and the 3rd principal deviatoric stress – from the opposite end surface of the workpiece (Fig. 3, e). Significant 2nd principal deviatoric stress of the material concentrated is on the maximal bending radius of the workpiece in the channel matrix (Fig. 3, d).

**3. The receiving and output channels intersect at an angle of 120°.**

With increasing angle of intersection of the channels of the matrix, plastic strain of the material in the bend of the workpiece amounted to 0.61. Significant plastic strain occurs in the layers of material in contact with the lower part of the outlet channel (Fig. 4, b).

Significant principal deviatoric stresses distributed by the volume of the workpiece: 1st – in material, located in the output channel of the matrix (Fig. 4, c); 2nd – in the material, located in the receiving channel matrix (Fig. 4, d); 3rd – in local areas of the material located in the output channel of the matrix (Fig. 4, e).

The dependences of the normal force and bending moment from time pressing of the ECAP process presents in Fig. 5 – 7.

The values of the normal force is negative, because there is a compression of the material of the workpiece from the load. With the exception of the alternating change of the normal force in the case of the ECAP process the workpiece in the matrix at the intersection of the channels at an angle of 90° in the plane of the section Y and in the case of the ECAP process the workpiece in the matrix at the intersection of the channels at an angle of 120° in the plane of the section X.

The maximum normal force, acting on the plane of the section X, amounted to $-0.16\times10^9$ mN according to scheme No. 1 (Fig. 5, a).

The maximum normal force, acting on the plane of the section Y, amounted to $-95\times10^6$ mN according to scheme No. 3 (Fig. 7, b).

The maximum normal force, acting on the plane of the section Z, amounted to $-0.425\times10^9$ mN according to scheme No. 1 (Fig. 5, c).

The bending moment occurs as a result of changing the shape of the workpiece. The values of bending moment, for all schemes ECAP process, is positive, i.e., the moment acts in one direction.

The maximum bending moment, acting on the plane of the section X, amounted to $0.23\times10^9$ mN×mm according to scheme No. 3 (Fig. 7, a).

The maximum bending moment, acting on the plane of the section Y, amounted to $0.14\times10^9$ mN×mm according to scheme No. 3 (Fig. 7, b).

The maximum bending moment, acting on the plane of the section Z, amounted to $1.79\times10^9$ mN×mm according to scheme No. 1 (Fig. 5, c).

Thus, the analysis of the results of computer simulation of ECAP process at different angles workpiece of aluminium alloy allows to make the following conclusions:

1. ECAP process the workpieces at the intersection of receiving and output channels of the matrix at an angle of 90° with a bending radius axis R30 is the most rational way of pressing. This is evidenced the small plastic strain and stresses in the workpiece material, compared with other schemes ECAP process. The plastic strain of the workpiece material during ECAP process according to scheme No. 2 in 3 times less, than during ECAP process according to scheme No. 1. ECAP process according to scheme No. 1 is less efficient, requires significant pressure on the punch, which can entail to tool breakage.

2. The maximum normal forces and bending moments act in the plane of the section Z (along the axis of the workpiece).

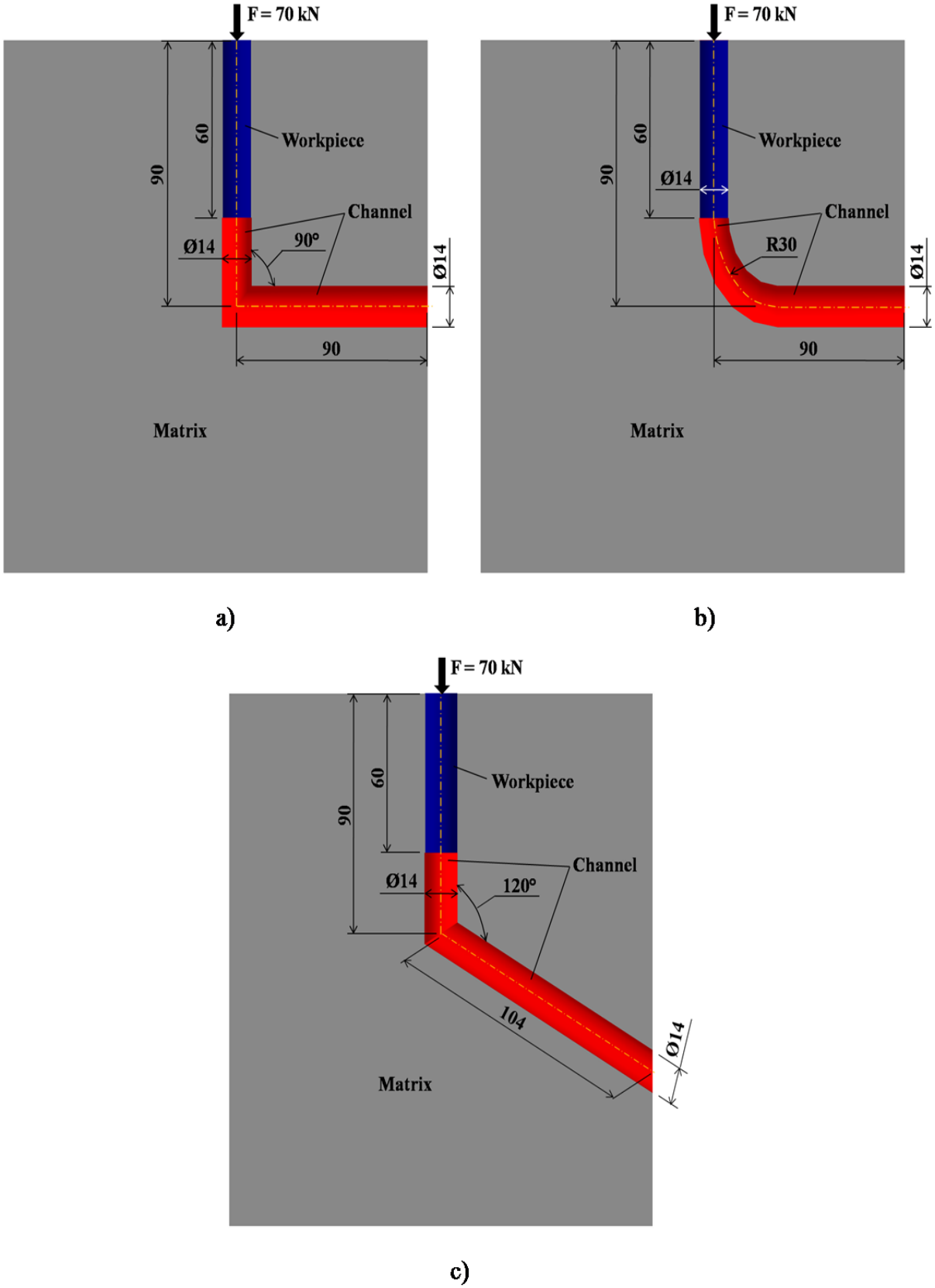



**Figure 1 – Schemes equal channel angular pressing process of the workpieces: a – the receiving and output channels intersect at an angle of 90° (scheme No. 1); b – the receiving and output channels intersect at an angle of 90° with a bending radius axis R30 (scheme No. 2); c – the receiving and output channels intersect at an angle of 120° (scheme No. 3).**

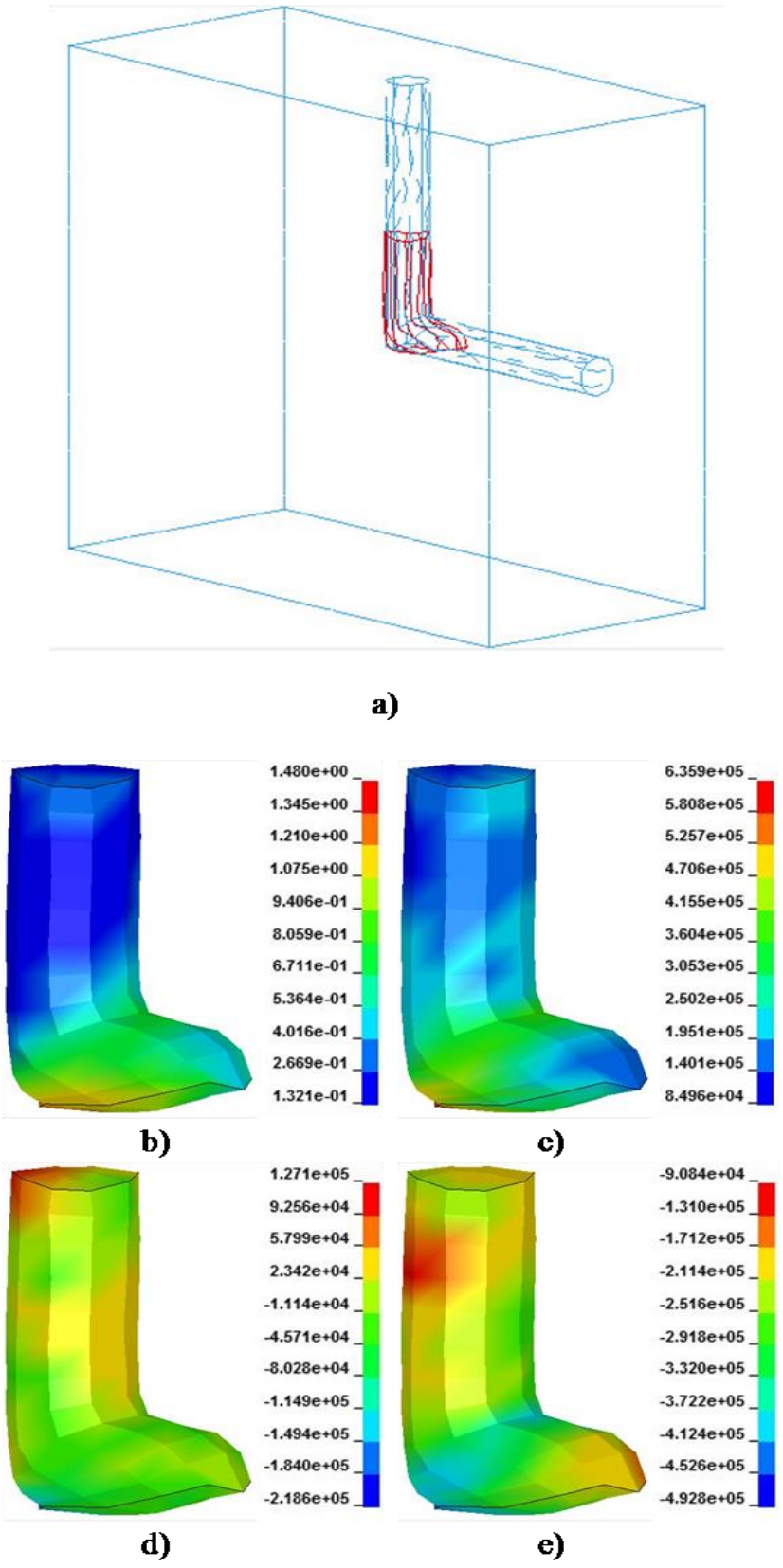



**Figure 2 – The results of simulation of the equal channel angular pressing process of the workpiece in the matrix with intersection of the channels at an angle of 90° (scheme No. 1): a – the location of the deformed workpiece in the channels; b – contours of effective plastic strain; c – contours of maximum principal deviatoric stress; d – contours of 2nd principal deviatoric stress; e – contours of minimum principal deviatoric stress. Units: mm, mg, ms, mN, K.**

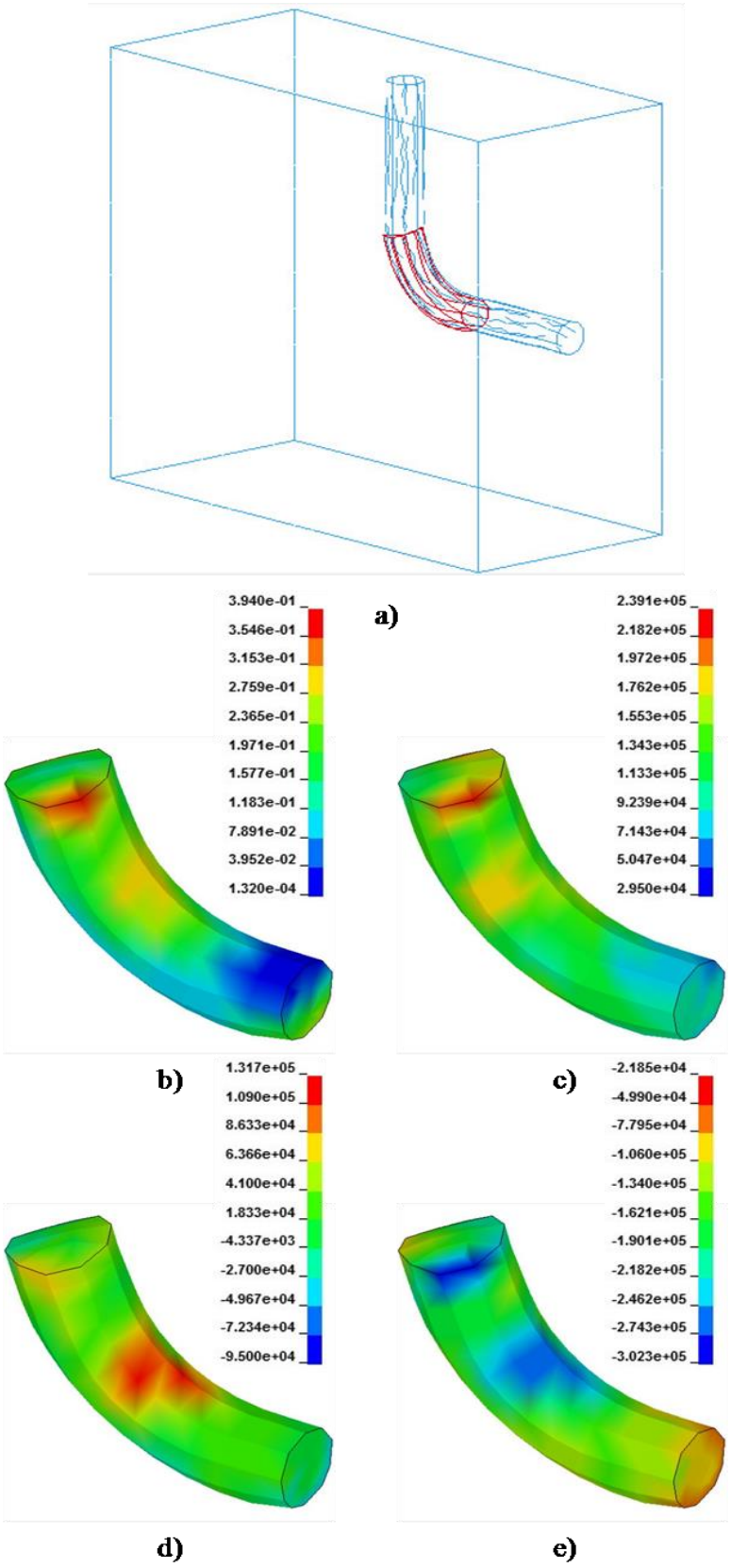
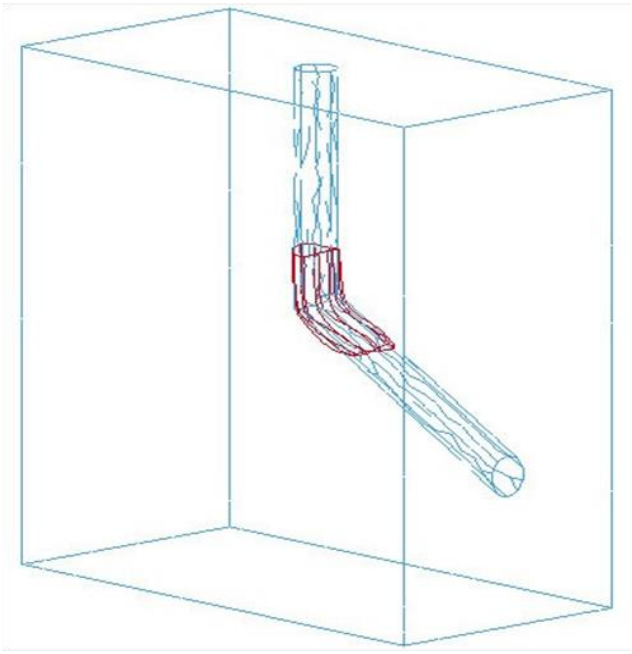
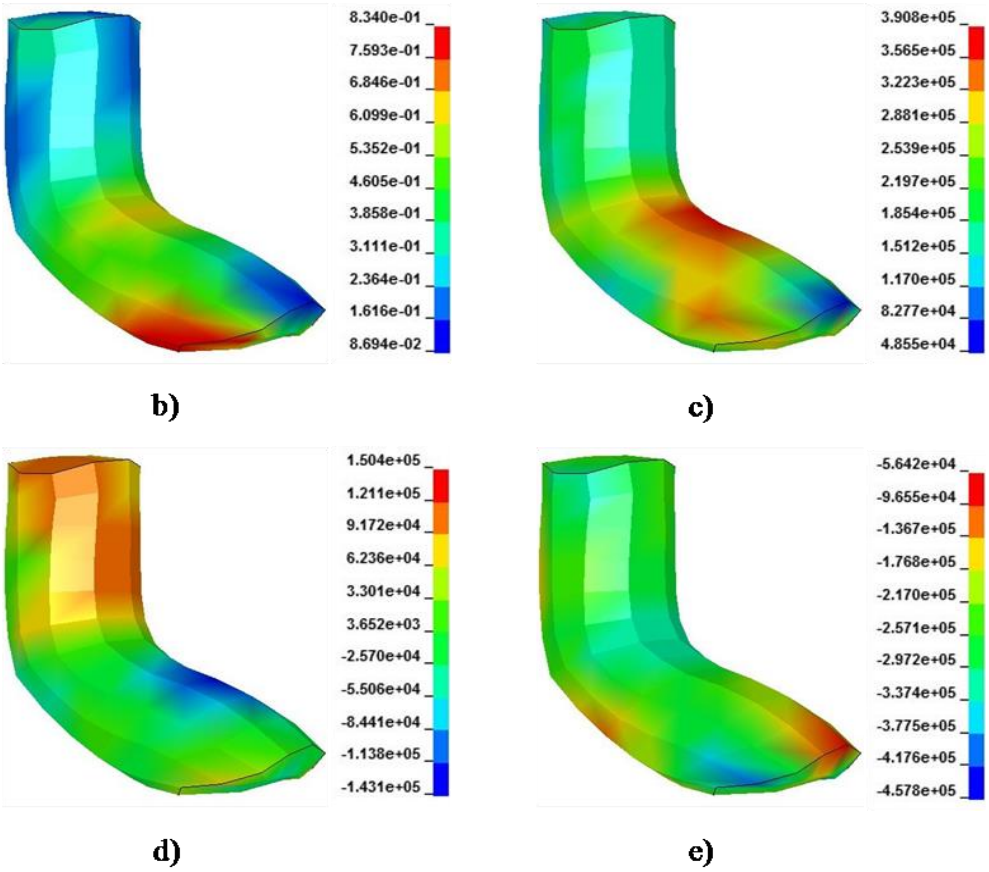



**Figure 3 – The results of simulation of the equal channel angular pressing process of the workpiece in the matrix with intersection of the channels at an angle of 90° with a bending radius axis R30 (scheme No. 2): a – the location of the deformed workpiece in the channels; b – contours of effective plastic strain; c – contours of maximum principal deviatoric stress; d – contours of 2nd principal deviatoric stress; e – contours of minimum principal deviatoric stress. Units: mm, mg, ms, mN, K.**



a)




b) c)

d) e)

**Figure 4 – The results of simulation of the equal channel angular pressing process of the workpiece in the matrix with intersection of the channels at an angle of 120° (scheme No. 3): a – the location of the deformed workpiece in the channels; b – contours of effective plastic strain; c – contours of maximum principal deviatoric stress; d – contours of 2nd principal deviatoric stress; e – contours of minimum principal deviatoric stress. Units: mm, mg, ms, mN, K.**

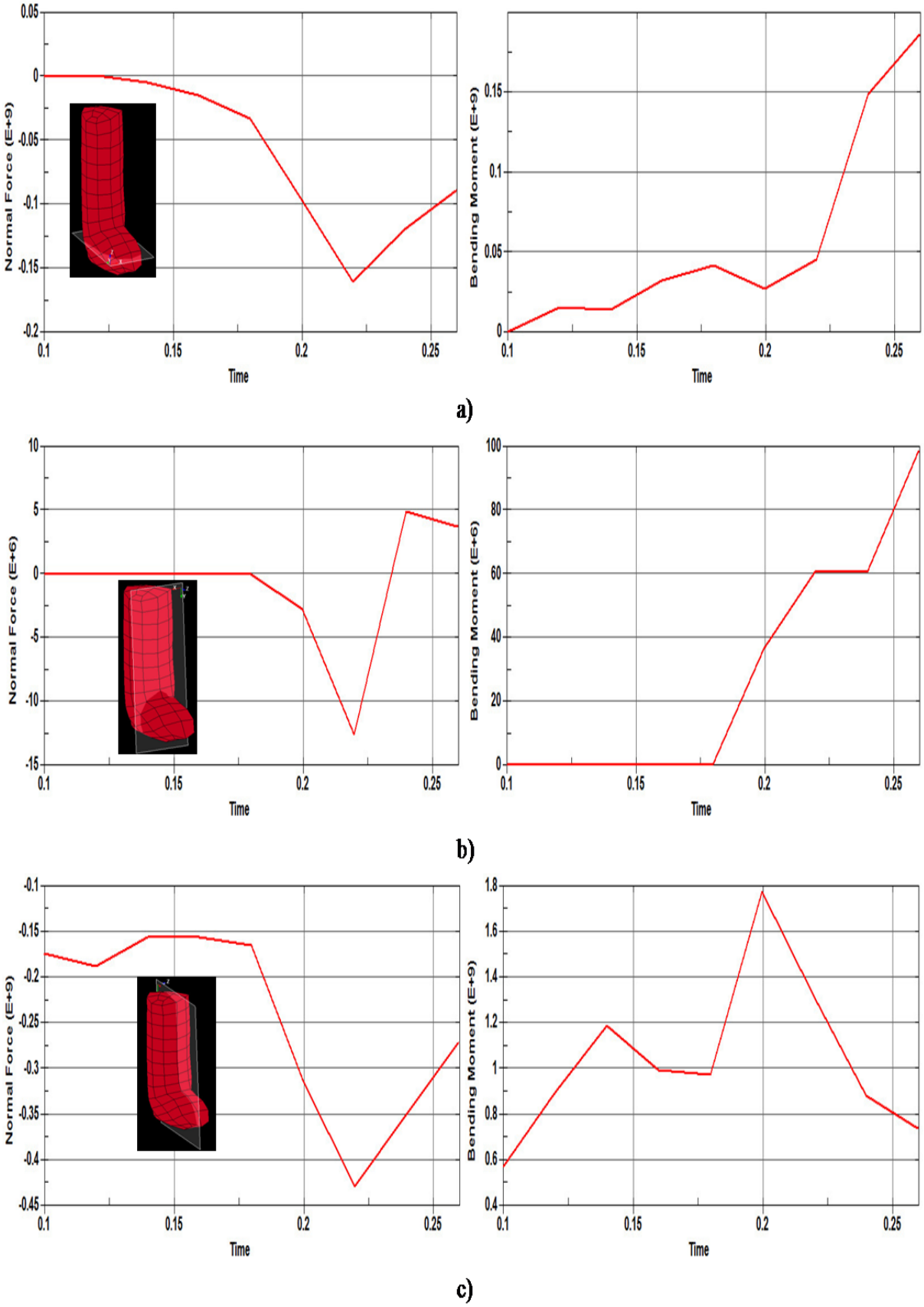



**Figure 5 – The dependences of the normal force and bending moment from the time of the equal channel angular pressing process of the workpiece according to scheme No. 1: a – the plane of the section X; b – the plane of the section Y; c – the plane of the section Z. Units: mm, mg, ms, mN, K.**

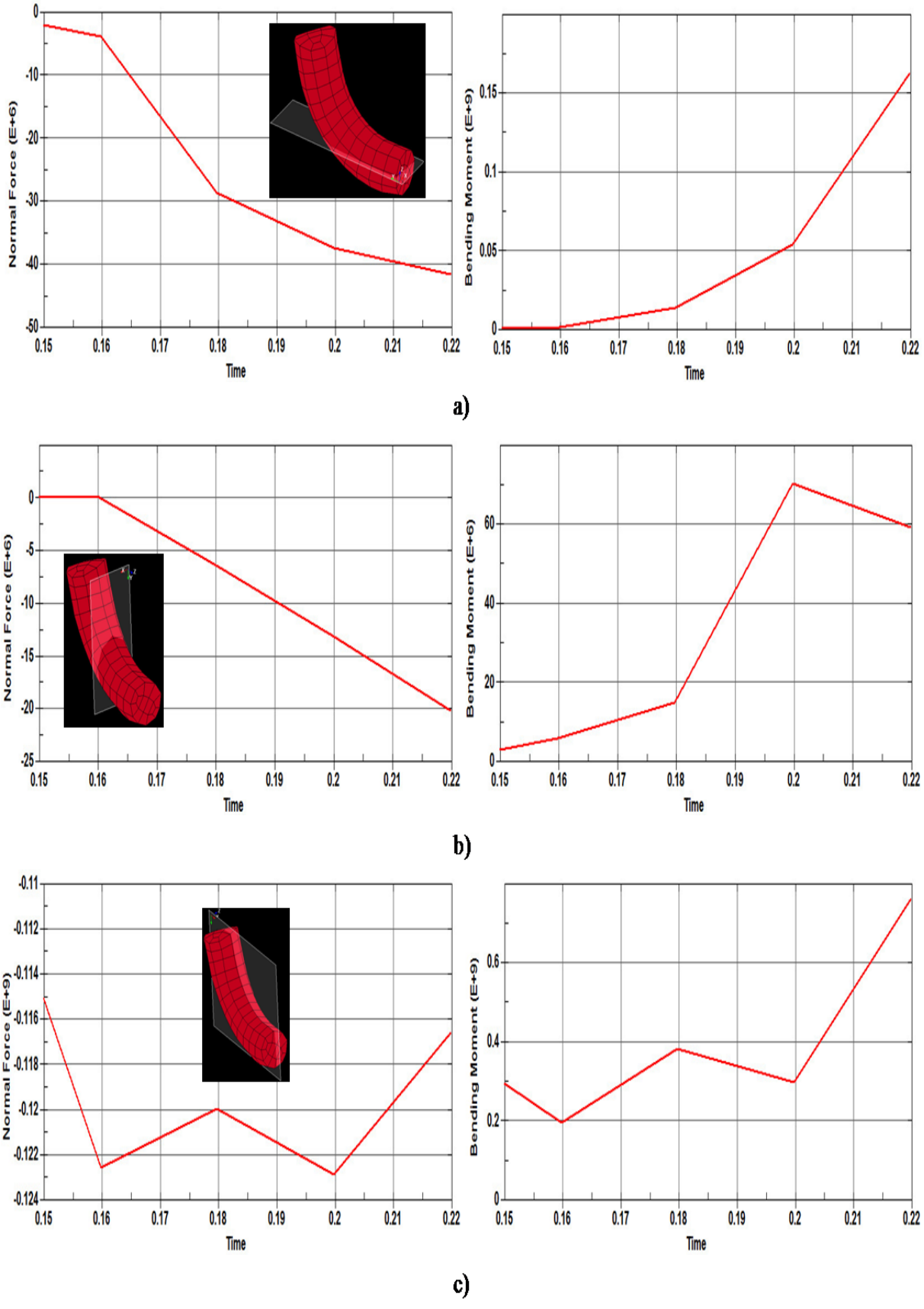



**Figure 6 – The dependences of the normal force and bending moment from the time of the equal channel angular pressing process of the workpiece according to scheme No. 2: a – the plane of the section X; b – the plane of the section Y; c – the plane of the section Z. Units: mm, mg, ms, mN, K.**

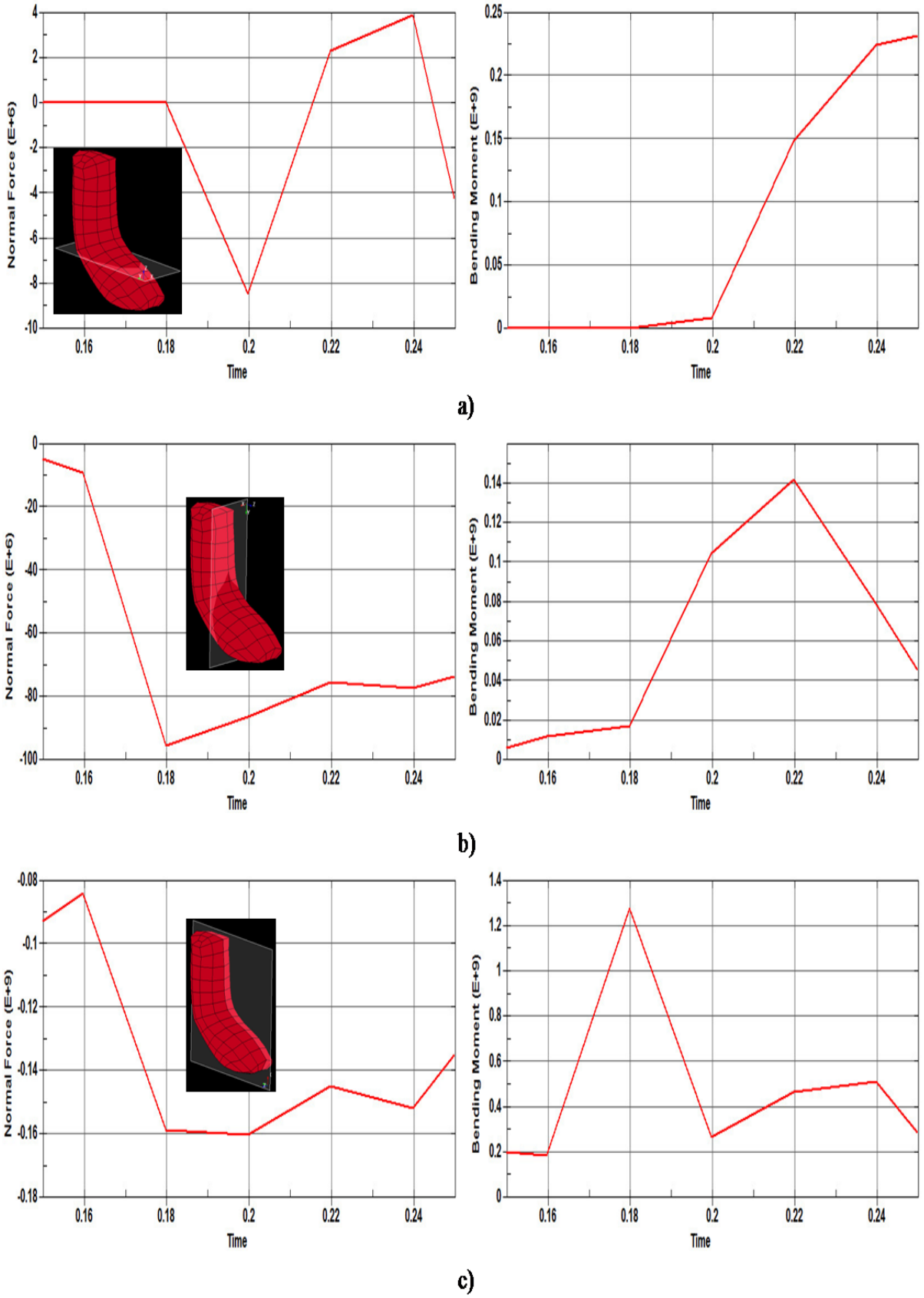



**Figure 7 – The dependences of the normal force and bending moment from the time of the equal channel angular pressing process of the workpiece according to scheme No. 3: a – the plane of the section X; b – the plane of the section Y; c – the plane of the section Z. Units: mm, mg, ms, mN, K.**

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