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INFLUENCE OF BILLET GEOMETRY ON THE PROCESS PARAMETERS IN COLD INDENTING

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ABSTRACT

Cold indenting as a non-cutting technology has been successfully applied in the manufacturing of tools in different industrial brunches. By using this technology both – dies cavities and punches can be produced, but there are certain limitations mainly related to the material formability, form of the tool (dept, area…) and load capacity of the indenting punch. Investigations have shown that great number of parameters influenced to the successful application of this technology.
The purpose of this paper is to present the theoretical and experimental investigation of cold indenting process in manufacturing of cone like punch, where special attention has been paid to the influence of workpiece geometry on the metal flow and other process parameters. Simulations of analyzed models have been performed by FEM, using CAMPform 2D program. FE modeling made possible to obtain different process data such as: deformed shape of the component, metal flow lines, strain and stress distribution and load-stroke diagram.
Experimental investigations were carried out on 6300kN hydraulic press by using specially designed and made tolling. In addition, two geometrically different billets were used.

***Key words**: Cold indenting, Cone punch, Billet geometry, FEM.*

1. INTRODUCTION

Indenting is generally known as a operation in which a hardened and polished punch (hob) is slowly pressed into a bulk material, producing that way a corresponding hollow shape. Compared with other cutting and non-cutting technologies (casting, machining, sparkerosion etc), cold indenting offers many advantages such as:

- Cost saving due to a considerable reduction of process times, that is particularly significant when several dies have to be produced
- All die cavities produced with the same punch are identical
- High level of accuracy and excellent surface finish of produced cavity
- Enhanced mechanical properties due to fiber structure of the produced shape
- Complex hollow geometries can be produced in simple way
- Longer life of the dies, etc.

The main limitations are: material formability, form of the cavity (dept, area…) and loadability of the punch.

Recognizing the advantages of the process, cold indenting is successfully applied to the production of dies in different industries such as: forging dies, die casting tools, plastic injection and glass moulds, coining dies, tableting dies etc. Additionally, punches with different cross section areas can be manufactured by this procedure. In such a case, the indenting punch has a cavity, which represents "negative" of the external profile of the future punch (Fig 1). Due to a higher contact friction and less convenient stress-strain state comparing to "classical" indenting (cavity generating), the problem of material flow and tool loadability is more emphatic, so in this way only small size punches can be produced. In spite of this, punch manufacturing by cold indenting is applied successfully in many areas, especially in production of punches for screw industry and punches for fastener production.

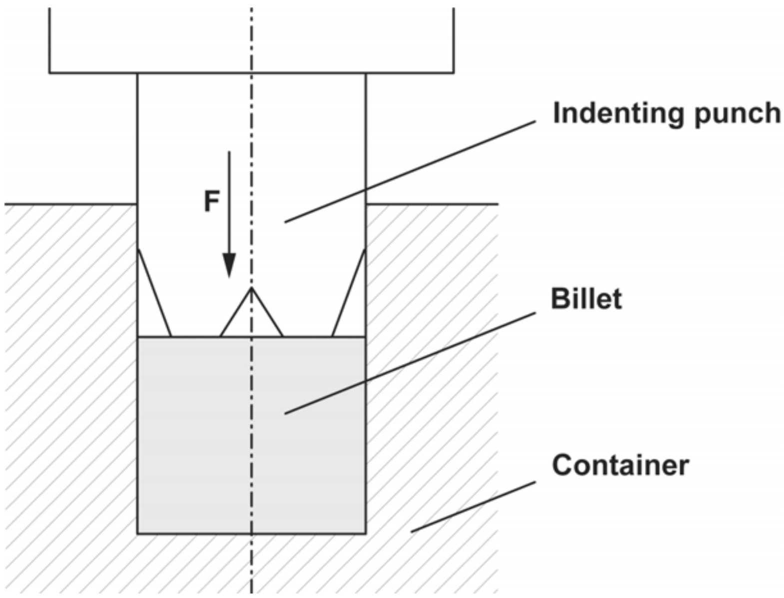


Fig. 1 - Scheme of cold indenting process of punch manufacturing

As it is mentioned above, cold indenting has wide practical implementation, but there is a certain lack of information in the literature regarding relevant parameters of indenting process and die and process design is often performed by "rule of thumb". Having this in mind, the aim of this paper is to yield further insight into the indenting process, where special attention has been paid to the influence of workpiece geometry to material flow and other process parameters. Theoretical and experimental investigation was performed on the model of indenting where cone-like punches were obtained and two geometrically different billets used. Simulation of indenting process has been carried out by FEM, while for experimental part of investigation special tooling was made. Due to its simplicity, this model is very convenient for wide analysis of punch manufacturing indenting process and obtained results can be very easily implemented in the cases with more complex punch geometries.

2. FEM ANALYSIS

Numerical FEM analysis of investigated model was conducted by using CAMPform 2D software, developed at the KAIST institute [9]. The CAMPform 2D program is intended for the 2D simulation of cold and hot forging processes by the finite elements method in PC environment. The program consists of solver and graphic user interface, which provides very easy entry of data on forming in pre-processing, and provides graphic information of simulation results in post-processing.

The solver for CAMPform is based on the thermo-rigidviscoplasticity approach for metal forming, and quadrilateral elements were employed. When elements become severely distorted during simulation, the remeshing process is necessary. CAMPform uses remeshing criteria of either the distortion level of elements or checking the interference with dies, depending on the problem. For automatic mesh generation, paving and looping algorithms are used.

The post-processor provide numerous graphic display functions including color shaped plot, contour plot, vector plot and tensor plot. In terms of simulation results, the deformed shapes of workpiece, material flownet lines, distribution of strain rate, strain, stress components and temperature in the workpiece, and forming load - stroke curve are provided.

Yield stress in CAMPform is set as a function of strain size and velocity of deformation, as elastic deformations are omitted. Friction model is defined by low of constant friction that is mainly applied in bulk metal forming processes, where large strains and contact's pressure are reached.

In this work, the analysis of cold indenting process by using FE simulation was conducted on the model described in previous chapter and shown in Fig.1. Tool and billets geometry including starting FE net, were set in the CAMPform , which are depicted in Fig. 2 and Fig 3. Billet with flat forehead was composed of 510 quads elements as the billet with beveled forehead (angle 10°) was composed of 406 quads elements and both were automaticaly generated by AMG module. Material of the workpieces was Yugoslav steel C1220 (corresponding UK steel is En2E) whose analytical form of the stress-strain curve is $\sigma = 798.5765\,\varphi^{0.111}$ [MPa]. Friction conditions were given by factor of friction m=0.173 (μ=0.1), as punch velocity was 0.1mm/s.

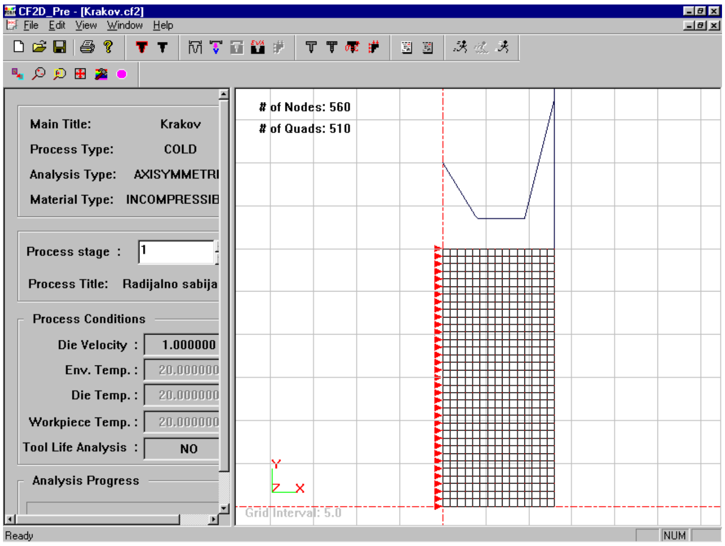


Fig. 2 - Punch and starting FE net of the flat billet shown by CAMPform editor

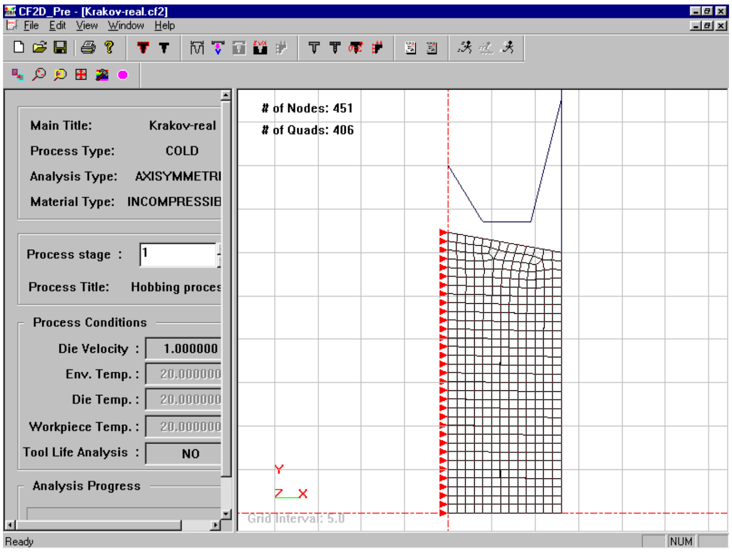


Fig. 3 - Punch and starting FE net of the billet with beveled forehead shown by CAMPform editor

Visualization of the indenting process, i.e. phrasal deformations of the billets with the corresponding punch strokes are shown in Fig 5 and 6. In highly deformed zones of workpieces remeshing of primordial elements had to be applied

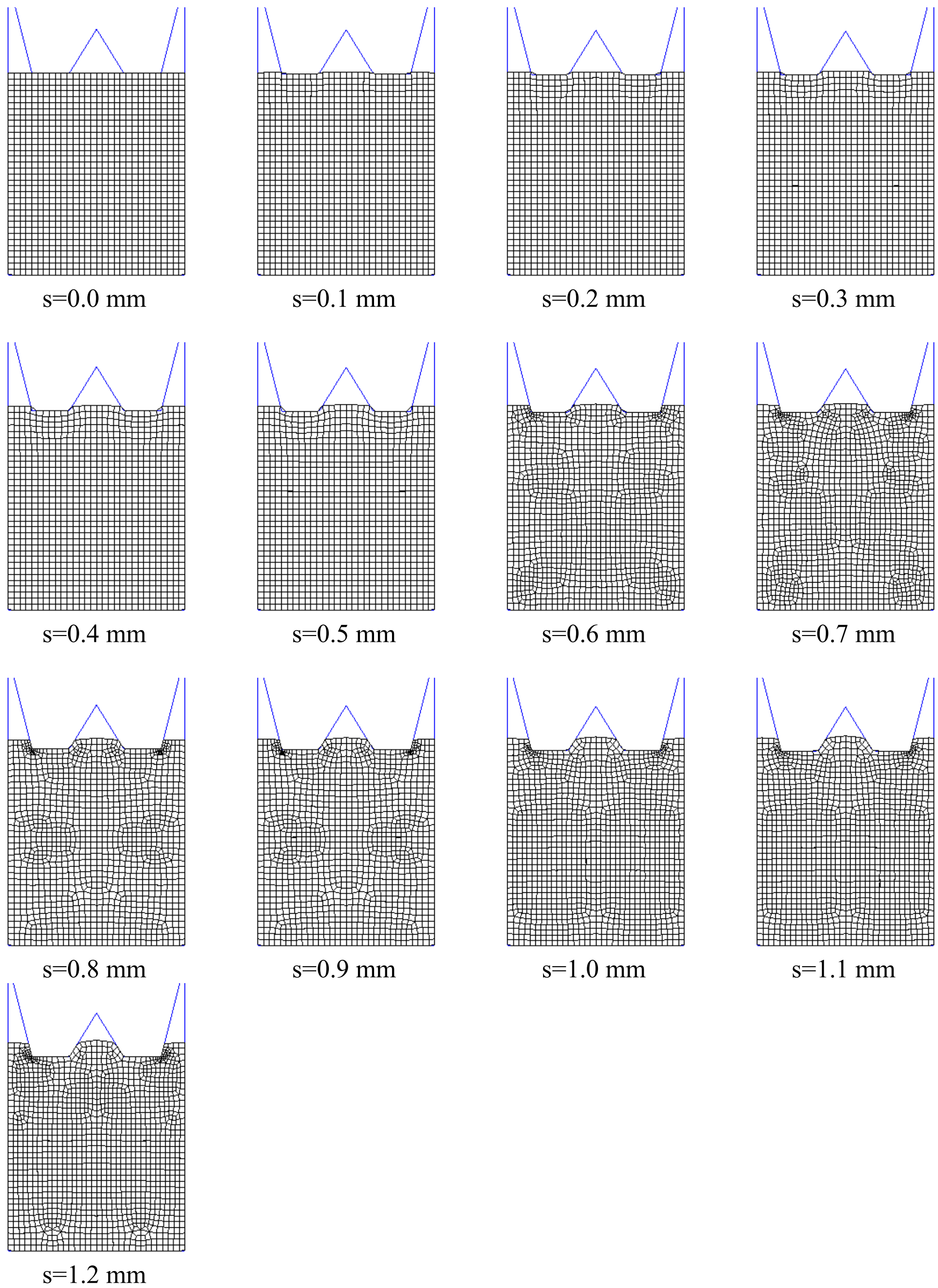


Fig. 4 - Simulation of indenting process for the billet with flat forehead

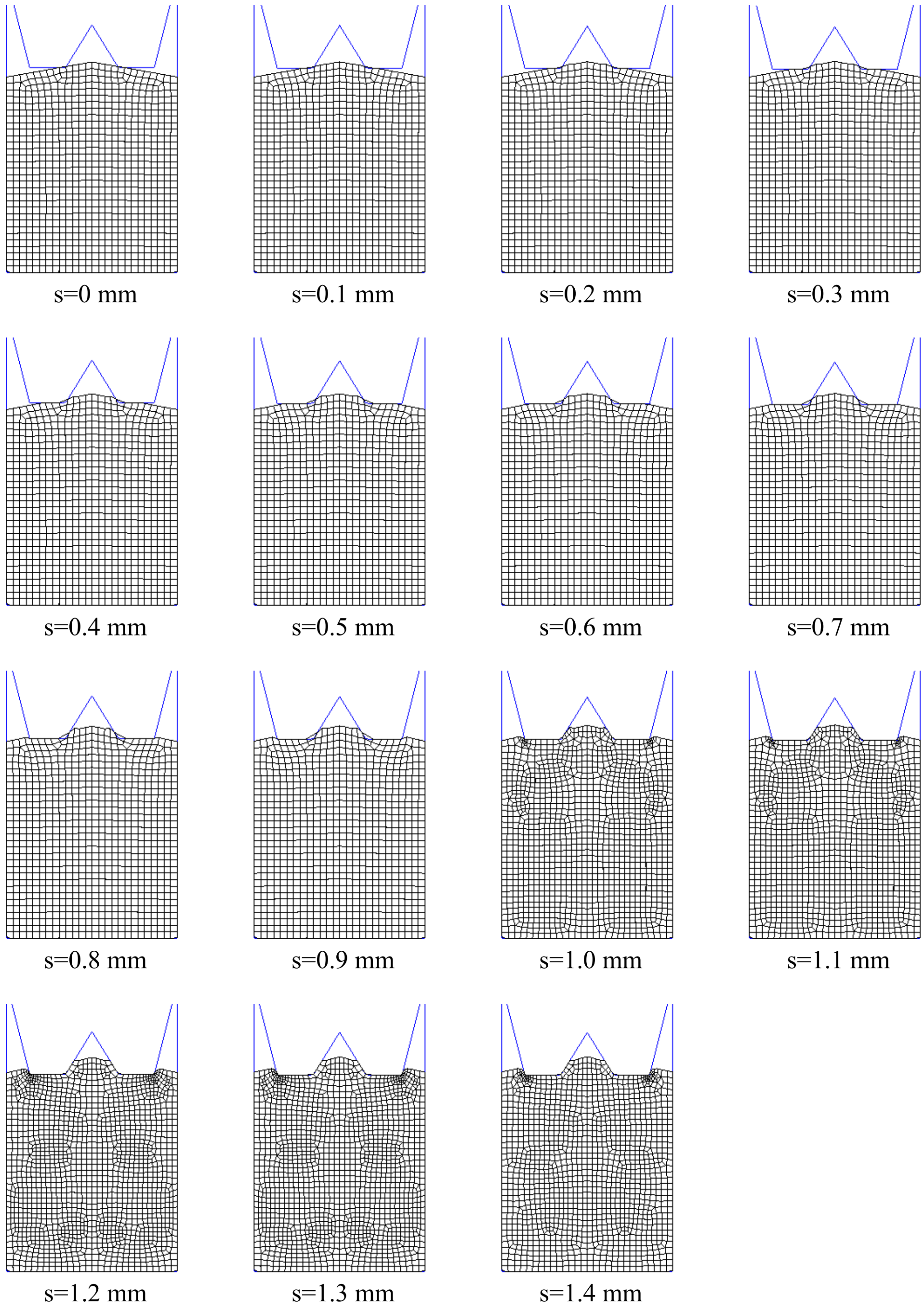


Fig.5 - Simulation of indenting process for the billet with beveled forehead

4. EXPERIMENT

In order to evaluate and verify the results obtained by the FE simulations experimental investigation has been carried out. Fig. 6 shows special tooling that has been designed and made for the experiment, as in Fig. 7 detailed geometry of indenting punch is given.

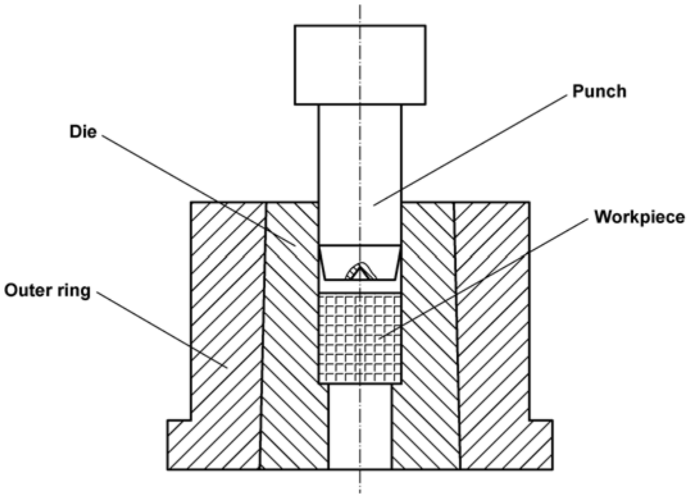


Fig. 6 - Scheme of the indenting tooling

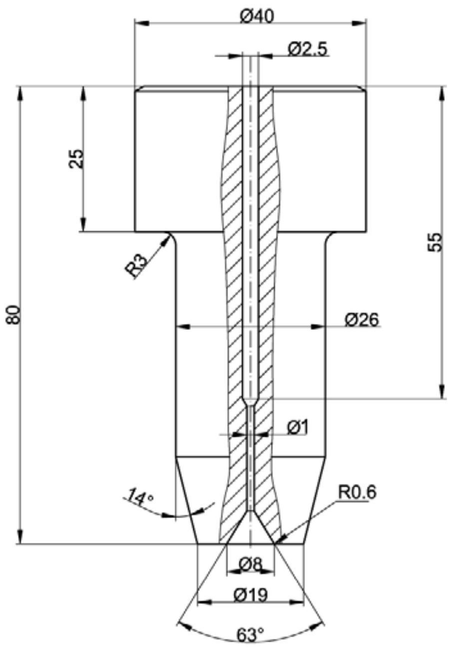


Fig. 7 - Geometry of the punch

Billets which geometry is shown in Fig. 8, were made from the steel C.1220 (JUS C.B9.020) – corresponding UK steel is En2E. The analytical form of the stress-strain curve obtained by Rastegaev test was $K = 299.35 + 504.45 \cdot \varphi^{0.204}$. Other relevant details of experimental were:

- Material of the punch: C.7680 (corresponding UK steel: BM2)
- Material of the die: C.4150 (corresponding UK steel: BD3)
- Punch velocity: 0.05mm/s
- Coeficient of friction μ=0.1
- Lubrication: MoS_2

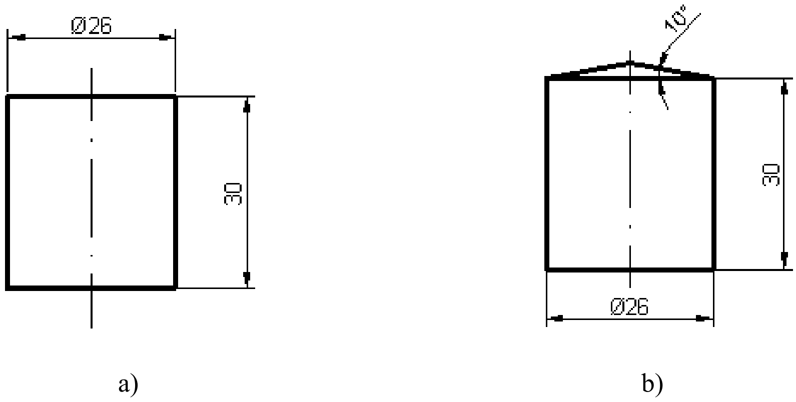


Fig. 8 - Geometry of the billets with a) flat and b) beveled forehead

Experimental investigations have been performed on the hydraulic press Sack Kiselbach (6.4 MN) connected to RIKADENKI BW-133 recorder by which load-stroke diagram was automatically plotted (Fig 9).

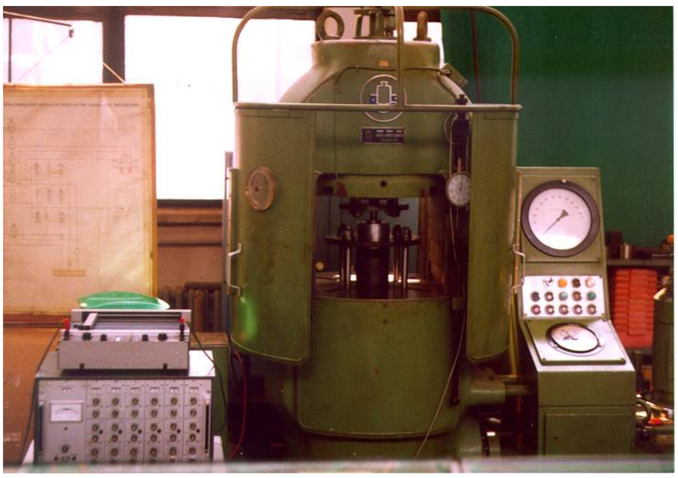


Fig.9 - Indenting tooling mounted in the press

5. ANALYSIS OF THE RESULTS WITH CONCLUDING REMARKS

Simulation presented in Fig 3 (billet with flat forehead), shows that for given process conditions and chosen tool geometry, extruded material fills both punch cavities rather steady and there is little difference in the height of central and peripherial part of workpiece. In case of the billet with beveled forehead (Fig. 4), material flows predominately to the central cavity of the workpiece, especially in the beginning of the process.

In the processes with divided flow, it is very interesting to follow the position of the neutral radius during the indenting process. Velocity vectors which illustrate material flow are shown in Fig. 10 and Fig.11

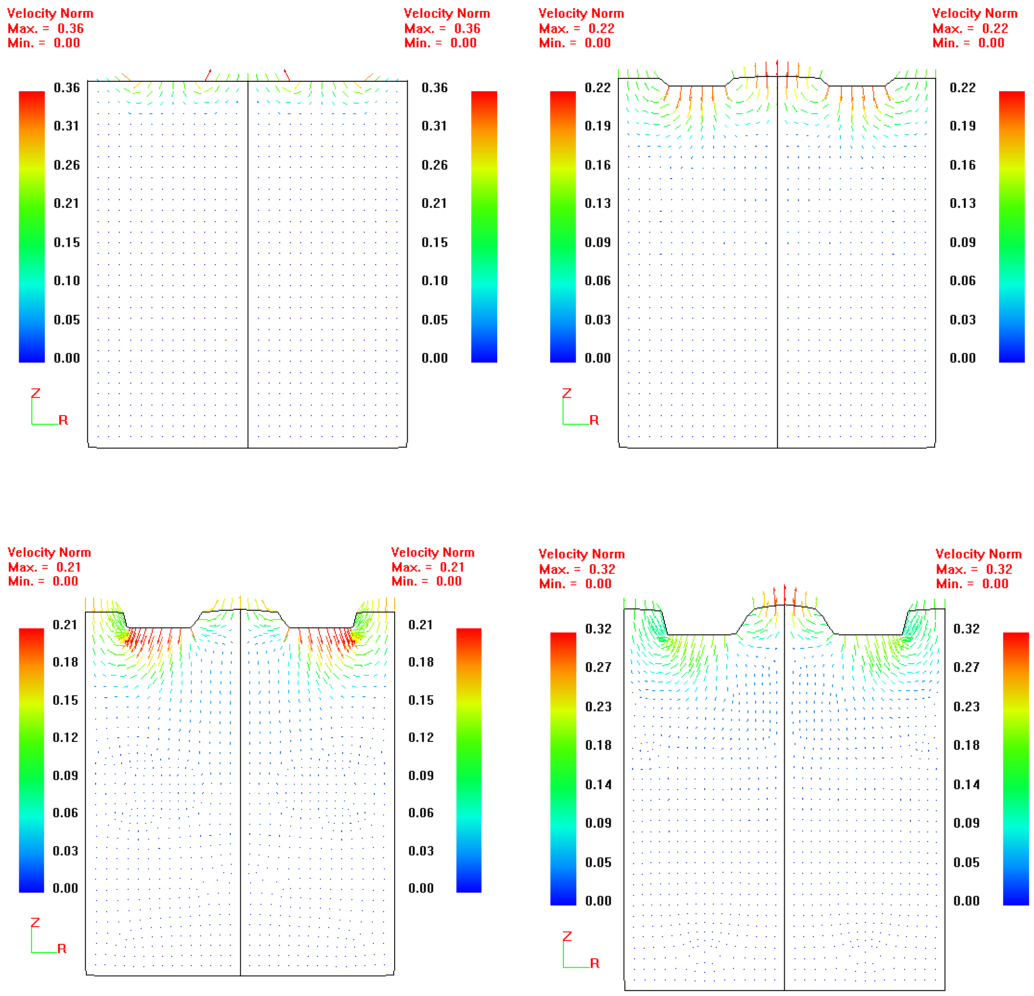


Fig.10 – Velocity vectors during the process of indenting for flat billet

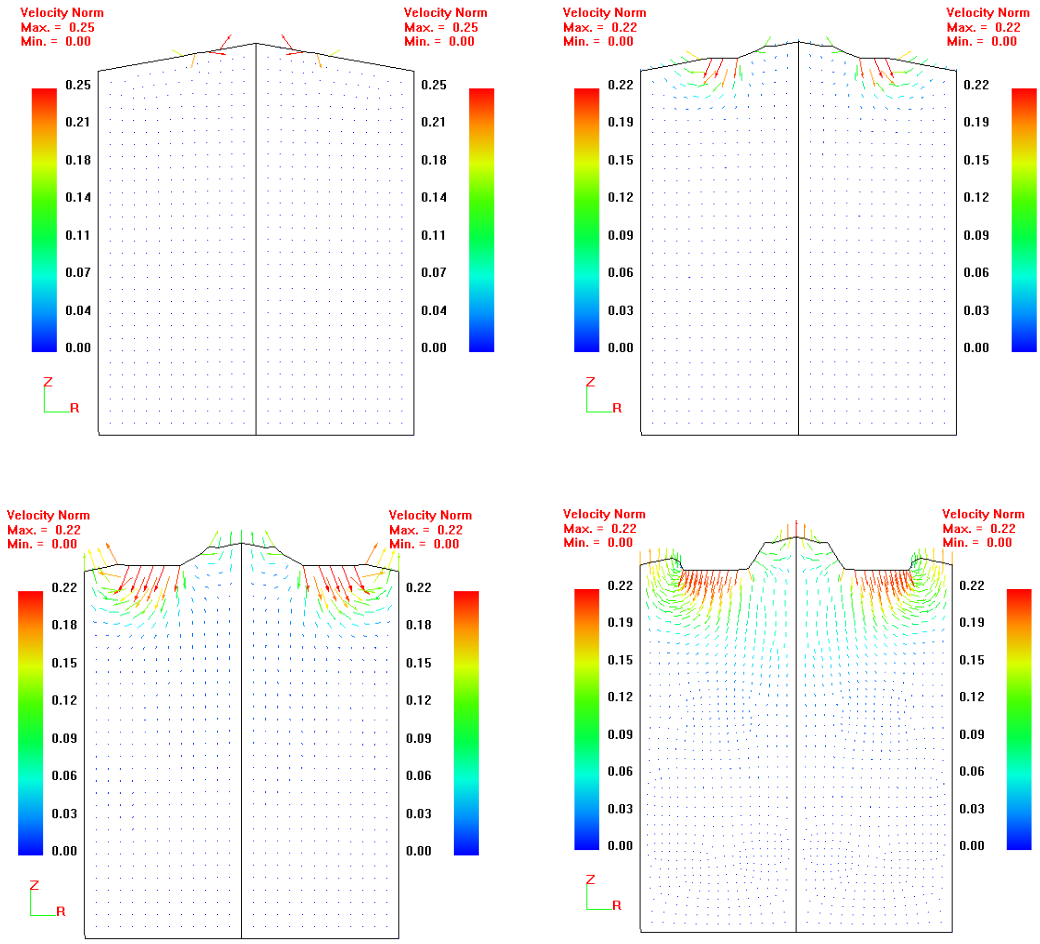
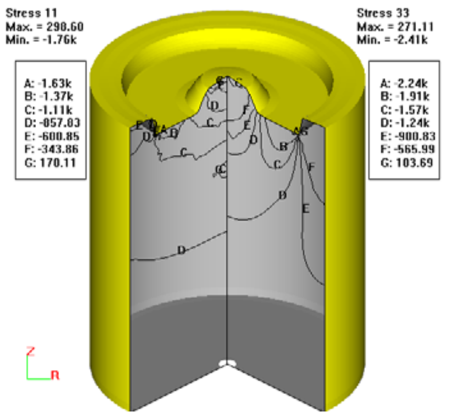


Fig.11 – Velocity vectors during the process of indenting for billet with beveled forehead

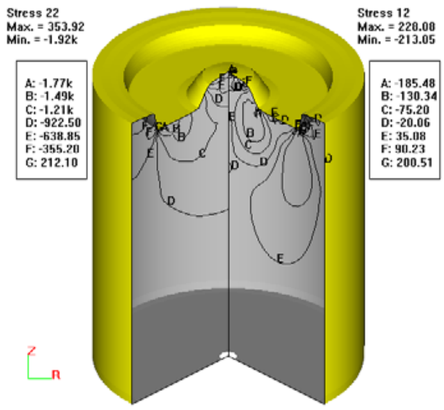
Those vectors clearly indicate the existence of the neutral radius and, as it can be seen from Fig.10 and Fig.11, the position of neutral radius is changeable during the process in both investigated cases.

Stress-strain components and **velocity field** within the workpiece volume obtained by FE are shown in Fig. 12 and Fig. 13. It is significant that stress-strain state is very heterogeneous. While material in the bottom half of workpiece is almost not included in deformation process, at upper zone, especially at the narow zone directly under the forehead of the punch, the changes of stresses and strains are much more emphasized. The maximum values of effective stress and strain appear at the zones around the cavity edges. If results between two investigated model are compared, it can be seen that in case of the indenting of the billet with beveled forehead stresses and strains are about 10% less in regard to the flat one.

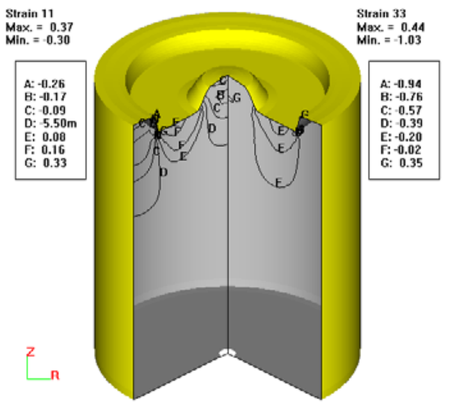
Similar to the effective stress and strain distribution, velocity fields are very heterogeneous within the billets therewith material flows faster in axial than in radial direction.



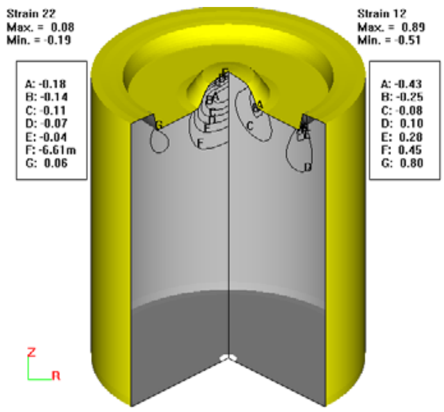
a) Radial (left) and axial (right) stress



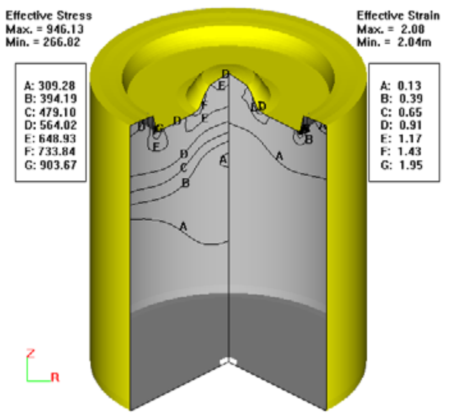
b) Circular (left) and tangential (right) stress



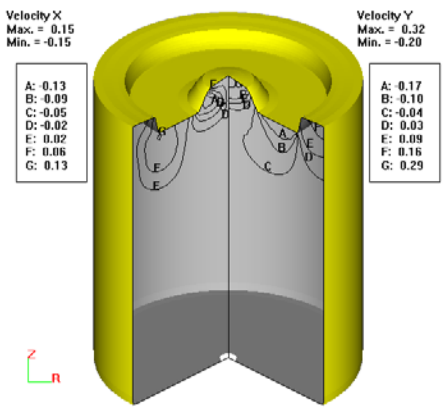
c) Radial (left) and axial (right) strain



d) Circular (left) and tangential (right) strain

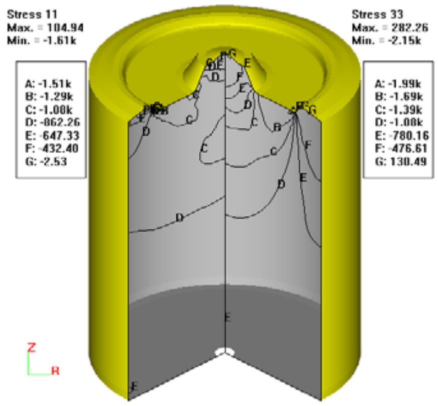


e) Effective stress (left) and effective strain (right)

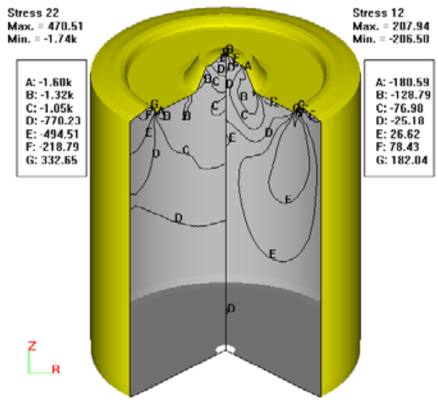


f) Radial (left) and axial (right) velocity

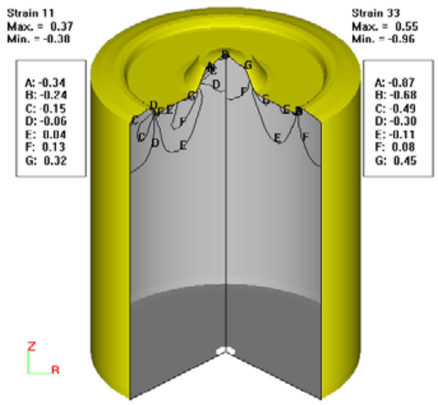
Fig.12 - Stress, strain and velocity fields within the workpiece volume for the flat billet



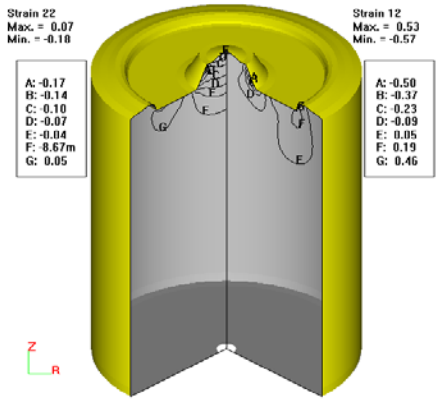
a) Radial (left) and axial (right) stress



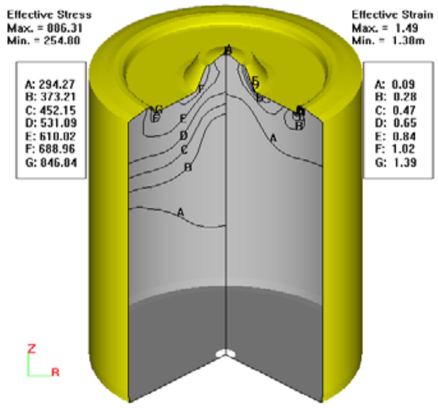
b) Circular (left) and tangential (right) stress



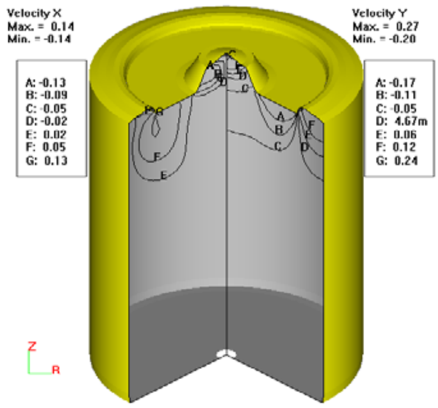
c) Radial (left) and axial (right) strain



d) Circular (left) and tangential (right) strain



e) Effective stress (left) and effective strain (right)



f) Radial (left) and axial (right) velocity

Fig.13 - Stress, strain and velocity fields within the workpiece volume for the beveled billet

Load-stroke diagrams predicted by FE and obtained by experiment are shown in Fig.14 for the billet with flat forehead and in Fig.15 for the billet with beveled forehead. As it can be seen curves on those diagrams show a high degree of coincidence. In both cases there are initially quick load increase up to 0.1mm punch stroke approximately, that is especially evident in Fig 14 (flat billet), while the rest of the process is followed by continual load increase at the constant rate. Large force jumps at the very beginning of indenting process is not considered as problematic, since after the realization of a full contact between billets and container, diagrams perform good and physically explainable behaviour. If we analyze FE and experimentally obtained curves, it can be seen that experiment gives higher values of the deformation load compared to the one predicted by FE. Initially those differences are very small, while they become higher toward the end of the indenting process. In case of billet with flat forehead and for the punch stroke of 1.2mm, load value predicted by FE is approximately 10 % higher than this measured in experiment, while in case of the billet with beveled forehead the difference is smaller and for stroke of 1.4 mm has amount of about 6%. Certain discrepancy between the load obtained by FE simulation and by experiment can be attributed to various reasons, but most significant is that related to the nature of FE i.e. fact that in FE simulation we are dealing with discretized continuum. By increasing the number of the finite elements this fault can be overcome, but it requires very high performances of PC and long-lasting procedure.

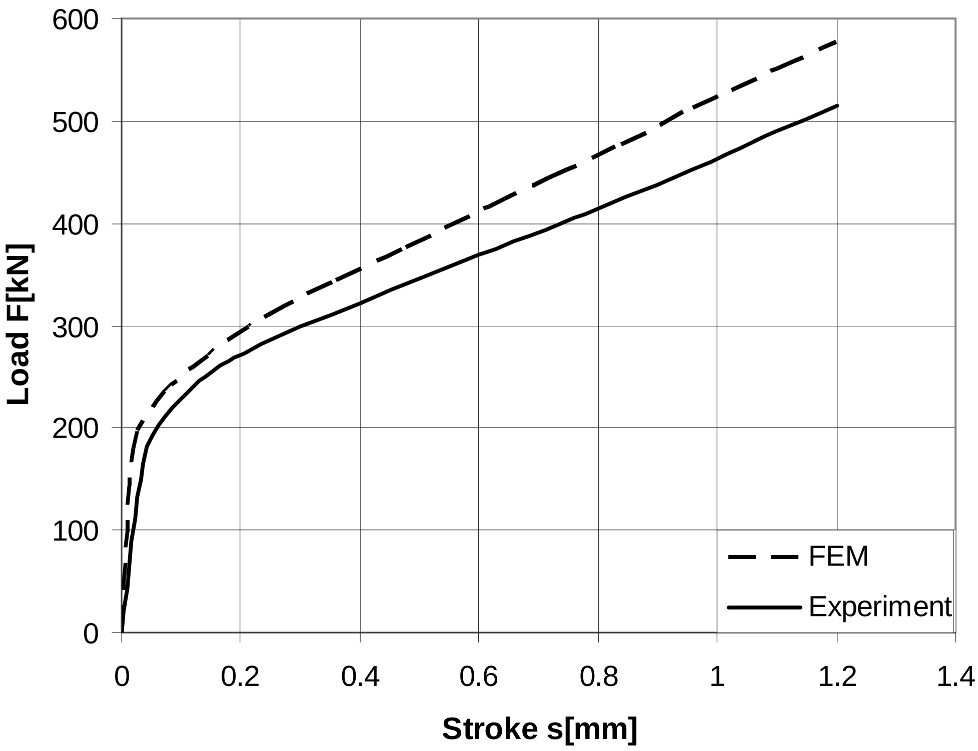


Fig. 14 - Load-stroke diagram for billet with flat forehead

Compared values of deformation load between different billets (Fig.14 and Fig.15), it can be seen that deformation load for same punch stroke is approximately 10% higher at indenting of billet with flat forehead in regard to billet with beveled forehead.

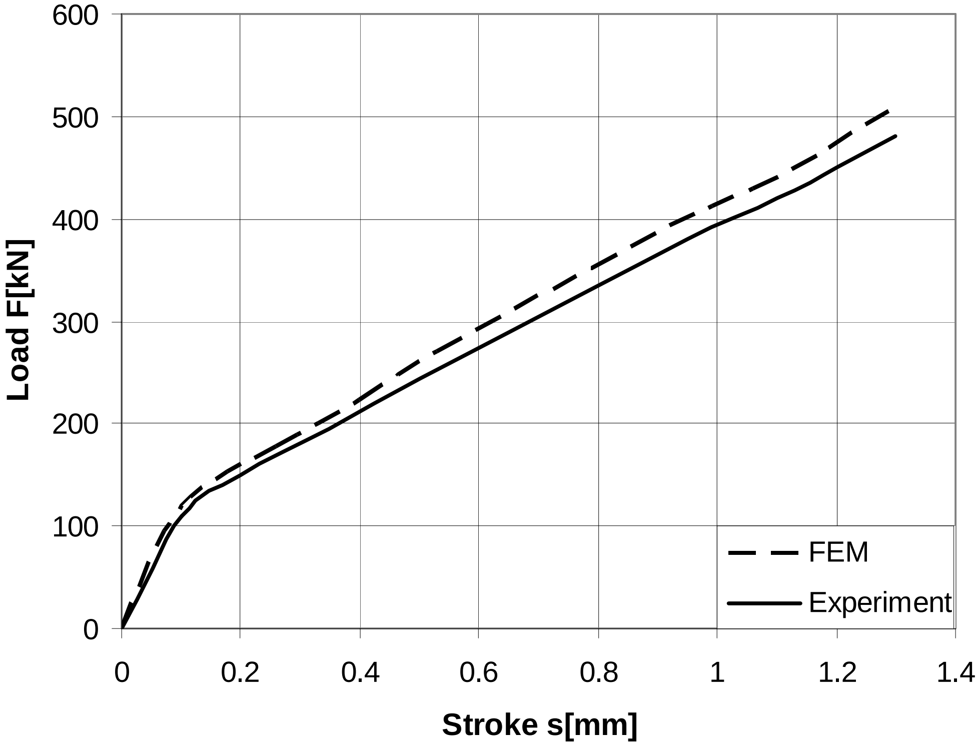


Fig. 15 - Load-stroke diagram for billet with beveled forehead

Recapitulating all previously mentioned, following can be concluded: For investigated cold indenting process, billet geometry has great influence to the all process parameters, including cavity filling process. For the same punch stroke, the height of extruded material, i.e. filling degree of central punch cavity is higher for case of indenting the billet with beveled forehead. Since the primary goal is to get punch with full cone profile it means that in manufacturing of punches by indenting procedure, the billets with beveled forehead should be used.

Extension of the investigation of the indenting process is planed and in further works different punch and billet geometry, as well as different billet materials and lubrications will be included. Also, attention would be paid to the neutral radius and its influence to the process of cavity filling.

ACKNOWLEDGEMENTS

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UTICAJ GEOMETRIJE PRIPREMKA NA PARAMETRE PROCESA HLADNOG UTISKIVANJA

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Vesna Mandi, Milentije Stefanovć

ABSTRACT

Hladno utiskivanje je tehnološka metoda obrade oblikovanjem koja se prevashodno koristi za izradu alata koji se mogu naći u različitim industrijskim granama. Na ovaj način mogu se izrađivati kako gravure u alatima, tako i odgovarajući profisilani žigovi. Pored veoma uspešne primene i značajnih prednosti koja ova metoda pruža u odnosu na klasične postupke izrade alata, još uvek postoje brojna ograničenja i problemi vezani za njenu još širu primenu. Ta ograničenja su pre svega vezana za nisku obradivost materijala, odnosno problem dobijanja alata većih dimenzij. Istrazivanja vezana za ovu oblast pokazala su da veliki broj parametara utilče na uspešnost primene ove metod. Ovo je naročito prisutno pri izradi žigova kao tehnološki zahtevnijeg postupka.

U ovom radu su prikazana teorerijsko-eksperimentalna istraživanja procesa hladnog utiskivanja pri izradi ziga sa konusnom glavom. Akcenat istraživanja bio je stavljen na analizu uticaja geometrije pripremka na tečenje metala u toku procesa utiskivanja, i određivanje osnovnih parametara procesa:efektivnih napona i deformacija, kao i deformacione sile. U tom smislu izvršena je simulacija procesa pomoću MKE i programskog paketa CAMPform 2D. Sam eksperiment je realizovan na hidrauličnoj presi od 6300kN pomoću specijalno konstruisanog alata

Ključne reči: Hladno utiskivanje, Žig sa konusnom glavom, Geometrija pripremka, MKE