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BIMETALLIC MICRO-PUNCHES FOR MICRO-BLANKING PROCESSES

Rapid development of micro-machines, which partly needs metallic micro-parts, is nowadays a fact. A very promising way of micro-parts manufacturing is micro-blanking. For a quite complicated 2D shapes, like micro-gears, dies might be rather easy manufactured by wire-cutting. Production of micro-punches seems to be much more difficult. In this article a solution of manufacturing of micro-punches consisting of two components: punch body based on standard micro-punches and mechanically joined end – bimetallic micro-punch – is proposed. Joining process is based on the extrusion, after which a shaped end must be hardened and finally sharpened. Within this work an experimental stack-up equipped with a special measuring system and unique flexible micro-tools was developed. Simplified processes of bimetallic micro-punch manufacturing was completed as well as FEM analysis.

Keywords: microforming, micro-blanking, bimetallic micro-punches

1. Introduction

During last decades one may observe fast development of micro-machines, pre-stressed [1,2] and complex [3] micro-dies and micro-manipulators [4,5]. Evolving miniaturization of the electro-mechanical devices causes rapid demand for metal parts of dimensions lower than 1 mm. The reason of that progress is the variety of application fields, such as maintenance and inspection in the industry, micro-surgery in medicine, micro-operation in biology, etc. These equipment consist of many micro-parts that mainly are metallic and should be manufactured with a high accuracy [6]. Microforming [7,8], that is a part of metal forming technology, may possibly provide sufficient quality of manufactured micro-products. Micro-blanking process [5] seems to be appropriate because of the specific way of formation of the separation surface. It might be formed by plastic deformation because, under special conditions, no cracking occurs. It results in a very smooth surface [10].

Micro-blanking as a production process for metallic micro-parts is quite easy to apply for "two dimensional" micro products like micro-gears, micro-levers, micro-cams, etc.. Practical process of micro-gear manufacturing by micro-blanking is shown in Fig. 1. It consists of two operations: piercing of rectangular hole and blanking of outside surface of a micro-gear. In this example, Fig. 1c, die might be relative easy manufactured by wire cutting. However punch and counter-punch, Fig. 1d, that are necessary for this process, are much more difficult for manufacturing. This difficulty is increasing with decreasing of punch dimensions. This is the reason of bimetallic micro-punches – BiMPs – concept proposition for micro-parts manufacturing by micro-blanking technology.

2. Bimetallic micro-punch for micro-blanking – BiMP

The idea of the BiMP manufacturing process is based on the CMEX (Complex Micro-Extrusion) concept previously proposed [11]. Example design of the BiMP for micro-gear manufacturing by micro-blanking is shown in Fig. 2a. It consists of cylindrical punch body – *1* and shaped end – *2*. Shaped end is formed and mechanically joined to the punch body by combined micro-extrusion process. The manufacturing process of the BiMP is schematically shown in Fig. 2 b, c, d and e. Standard micro-punch for piercing is precisely grinded on its end to create an axis-symmetrical shape with under-cut. Micro-punch with initially manufactured end is then used as a punch for compound micro extrusion process. Process steps are shown in Fig. 2: load of billet (b), compound micro-extrusion (c) and ejecting (d). Mechanically "assembled" punch has still soft "shaped end", which must be then hardened in one of the standard ways. After that, punch nose might be grinded to obtain sharp cutting edge [8]. Grinding a punch nose surface is also a method for frequently sharping.

3. Laboratory stand for investigation of the BiMP production

Laboratory stand is based on a standard high precision testing machine Hounsfield H10KS, additionally equipped with piezoelectric force transducer, laser displacement transducer and ccd camera, Fig 3a. Flexible micro-tooling with ejecting system, Fig. 3b, is mounted on the testing machine table. Flexible micro-

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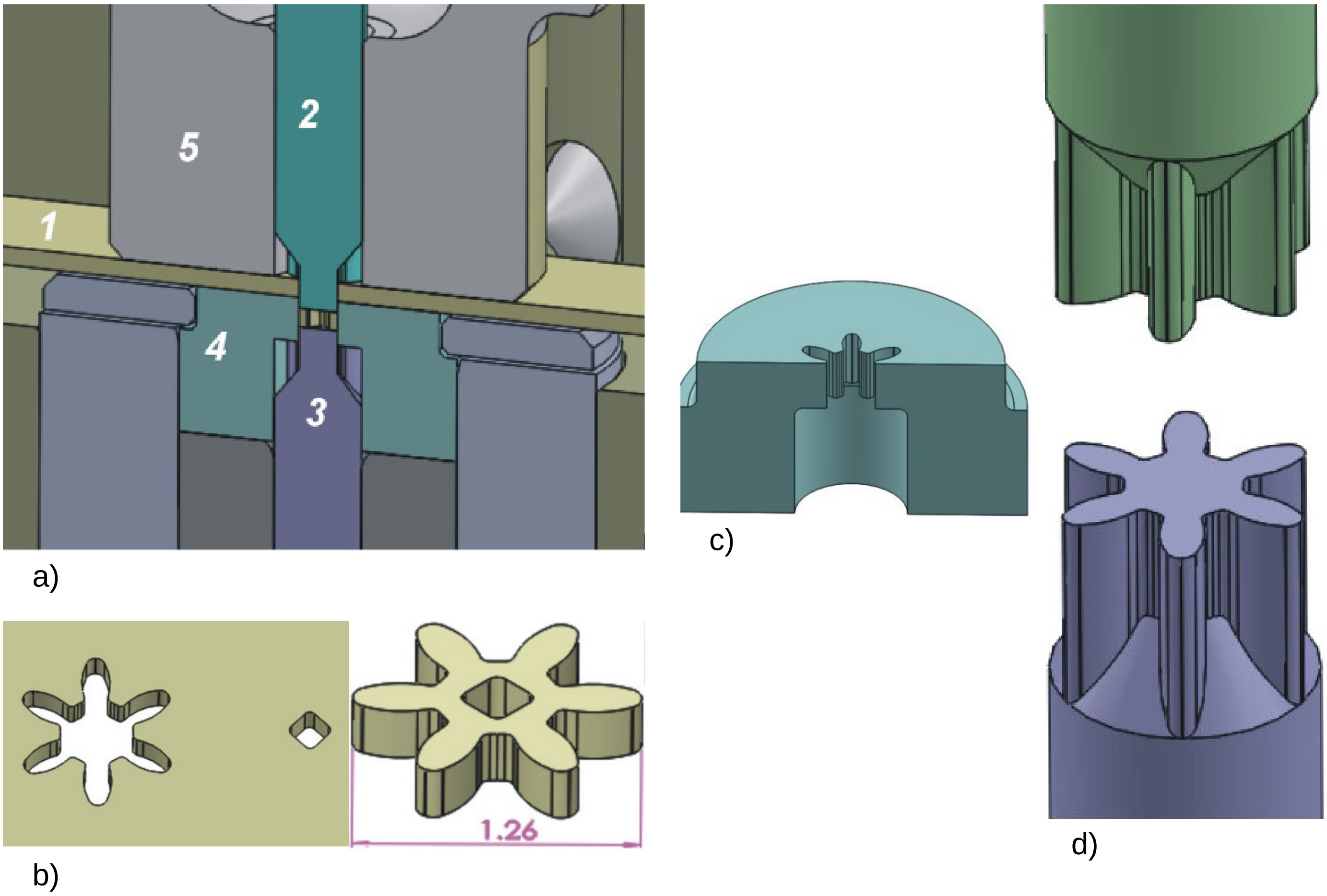

Fig. 1. Example of possible manufacturing process of 2d-part, micro-gear: (a) process design, *1* – strip, *2* – punch, *3* – counter-punch, *4* – die, *5* – blank holder , (b) strip and blanked micro-gear, (c) die, (d) punch and counter-punch

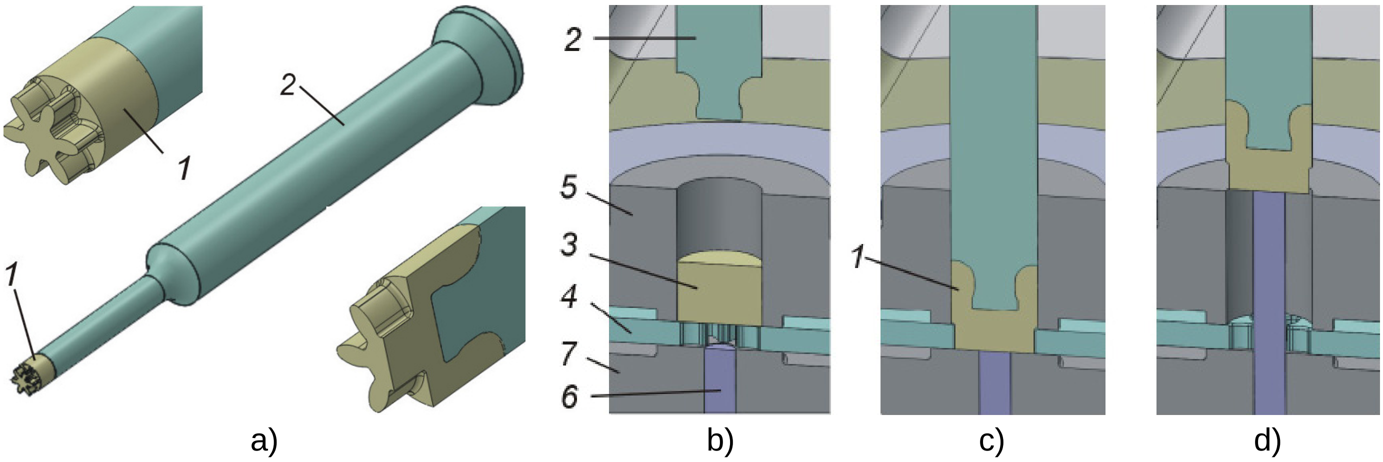

Fig. 2. Example of the BiMP for micro blanking of a gear (a), manufacturing of the BiMP body – grinding the end of standard punch for piercing (b), manufacturing of the BiMP: billet load (c), compound micro-extrusion (d), ejecting the BiMP (e), *1* – shaped end, *2* – punch body, *3* – billet that becomes shaped end, *4* – shaped die, *5* – cylindrical die , *6* – ejector, *7* – ejector guide

die – *1,* is fixed with bolts – *2,* inside die holder – *3*. Die lays on the lower guides – *4*, *5*, for ejector – *6*. Punch – *7*, is guided by upper guides – *8* (blank holder) and *9*, which are inside the movable housing – *10*. Flexible micro-die, Fig. 3b, consists of the ring – *1.1*, cover – *1.2* and removable die inserts – *1.3*, that might be applied depending on specific application.

4. Experiments and numerical analysis

Recently, the initial stage of the analysis have been performed. The main aim was to verify the key idea of the concept: possibility to obtain enough strength of the joining between main punch core and its end which is formed by combined extrusion.

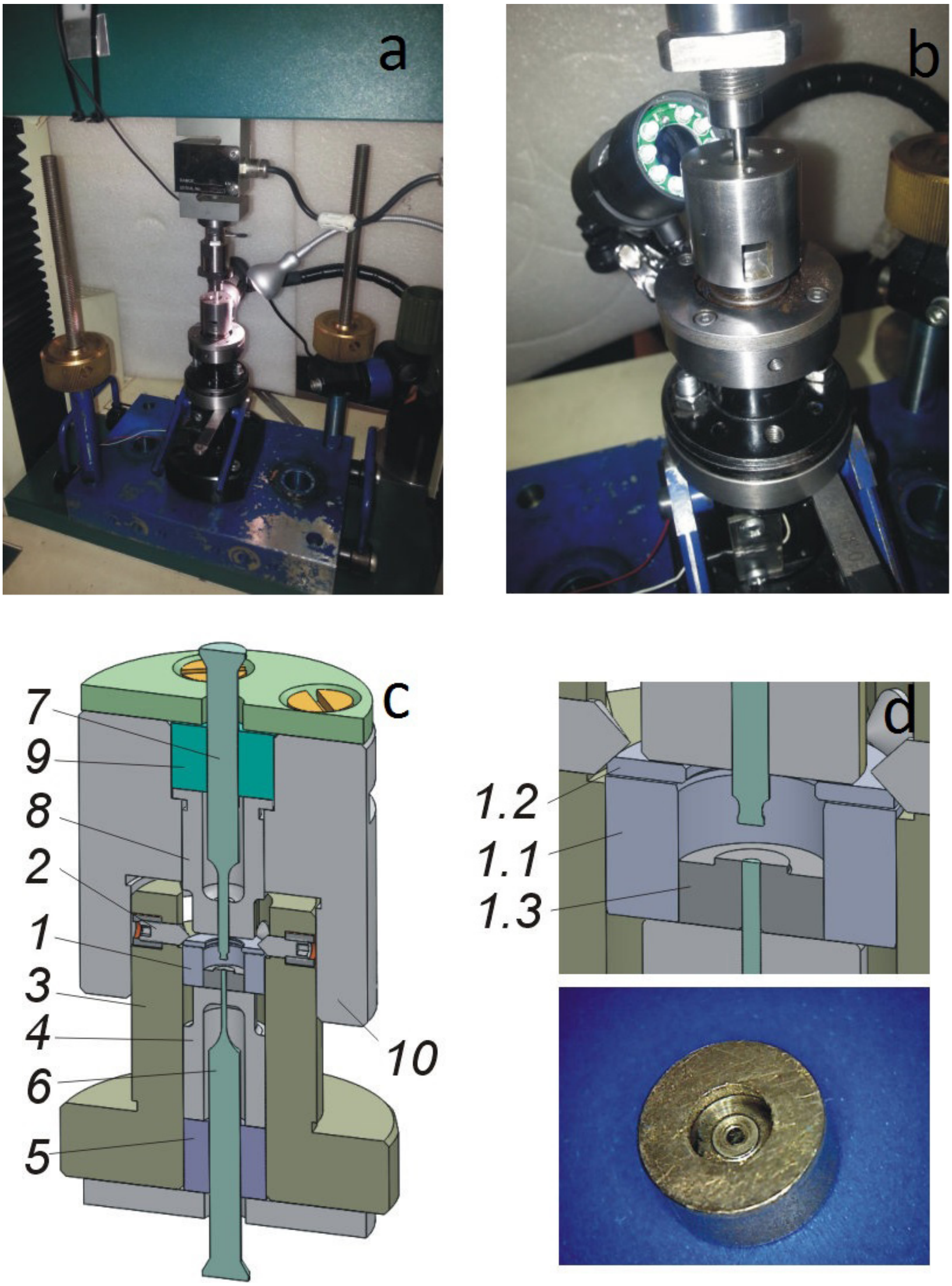

Fig. 3. Laboratory stand for investigation of the BiMPs manufacturing: (a) working area, (b) micro-tooling with ejecting system, (c) micro-tooling design: *1* – flexible micro-die, *2* – fixing bolts, *3* – die holder, *4*,*5* – lower guides, *6* – ejector, *7* – body of the BiMP, *8*, *9* – upper guides, *10* – housing, (d) flexible micro-die, *1.1* – ring, *1.2* – cover, *1.3* – example insert

The simplified process steps, tool design and FEM models are shown in Fig. 4. Billet is inserted into the die cavity – a, then blank holder moves down and mechanical joining process is performed – b. After that, ejector moves up to prevent from eventual clearance of join by friction on the die surface – d. It is likely to happen, since the BiMP's end material is in soft condition. Two processes, which FEM models are shown – e, have been simulated with assumption of 2d axis-symmetrical state, using MSC.Marc commercial software, based on the FEM. Billets for investigations were prepared by micro-blanking processes [12,13] from two kinds of sheets: 1 – aluminum alloy of 0.8 mm thickness, which properties are described by Young modulus E = 75000 MPa, Poisson ratio $\nu = 0.32$ and the stress-strain curve $\sigma_p = 306\ \varepsilon^{0.189}$ MPa, 2 –0.75 mm thick copper sheet, which properties are described by Young modulus E = 107000 MPa, Poisson ratio $\nu = 0.33$ and the stress-strain curve $\sigma_p = 390\ \varepsilon^{0.3}$ MPa.

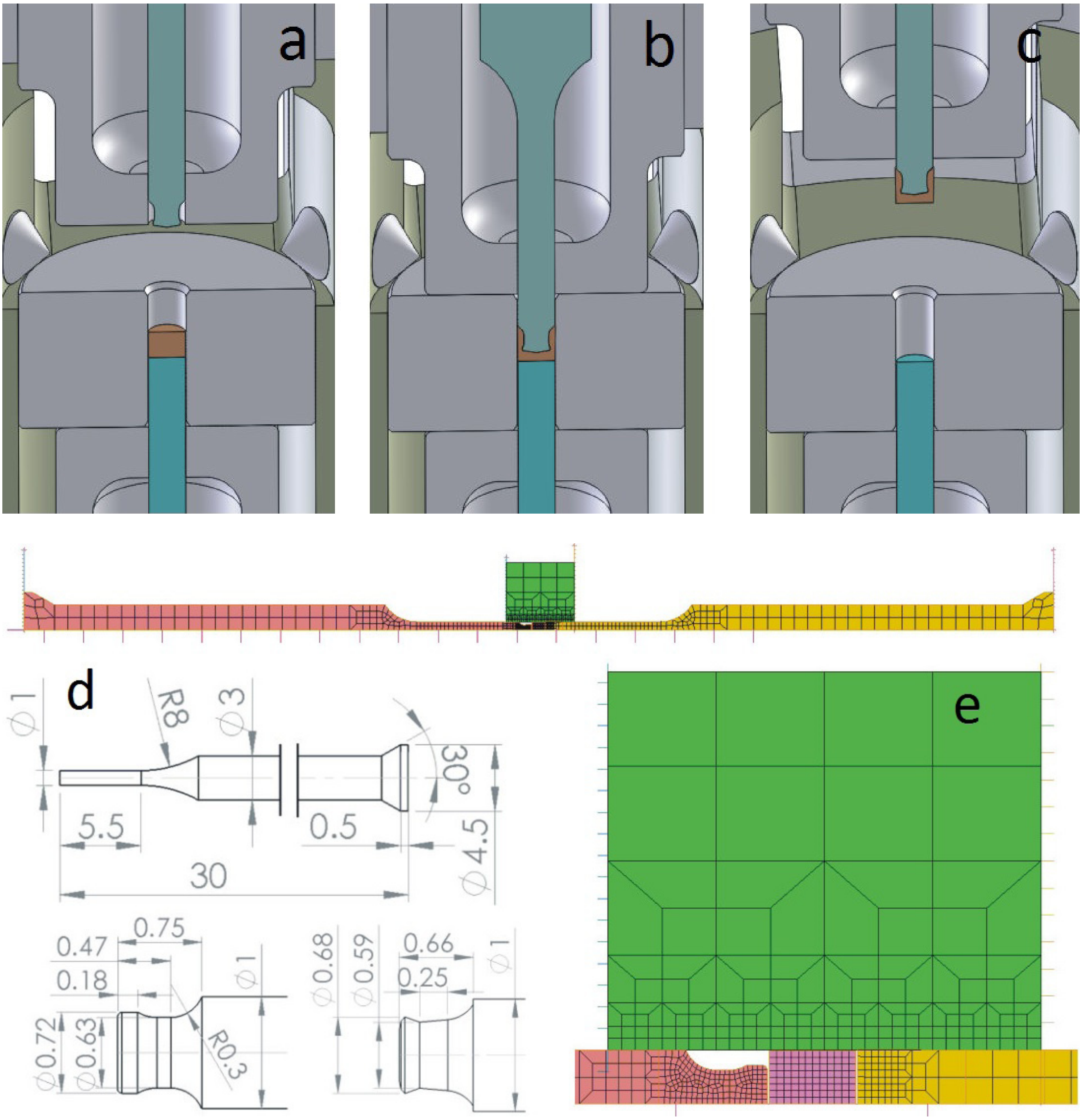

Fig. 4. Simplified process of the BiMP manufacturing: (a), (b) and (c) – process steps, (d) standard punch before shaping, dimensions of two BiMP punch bodies after grinding, (e) FEM models of BiMP formation

5. Analysis of results

Simplified BiMPs processes for aluminum and copper billets were successfully performed. Examples of simple BiMPs are shown in Fig. 5a. The BIMPs manufacturing process starts with upsetting of a billet. This phase represents initial part of force-distance curve, at Fig. 3b section *0-1*. It ends at point *1*, where extrusion process starts – Fig. 5d.1. Than extrusion process continues with a slight force increase up to the point *2* – Fig. 5d.2. At this stage material starts to flow radially, clamping around the punch core, forming a mechanical joint. Material flow is to some degree similar to that, which can be observed during clinching processes [14,15]. An empty space inside undercut is fully filled at point *3* – Fig. 5d.3. Then, force starts to grow rapidly, up to the end of the set shift – Fig. 5d-4. At this stage the load depends on the ram distance only and might be the reason of tool's overload. From the join quality point of view, continuing the process beyond point *3* seems to be useless and it is strongly recommended to stop the process at this stage.

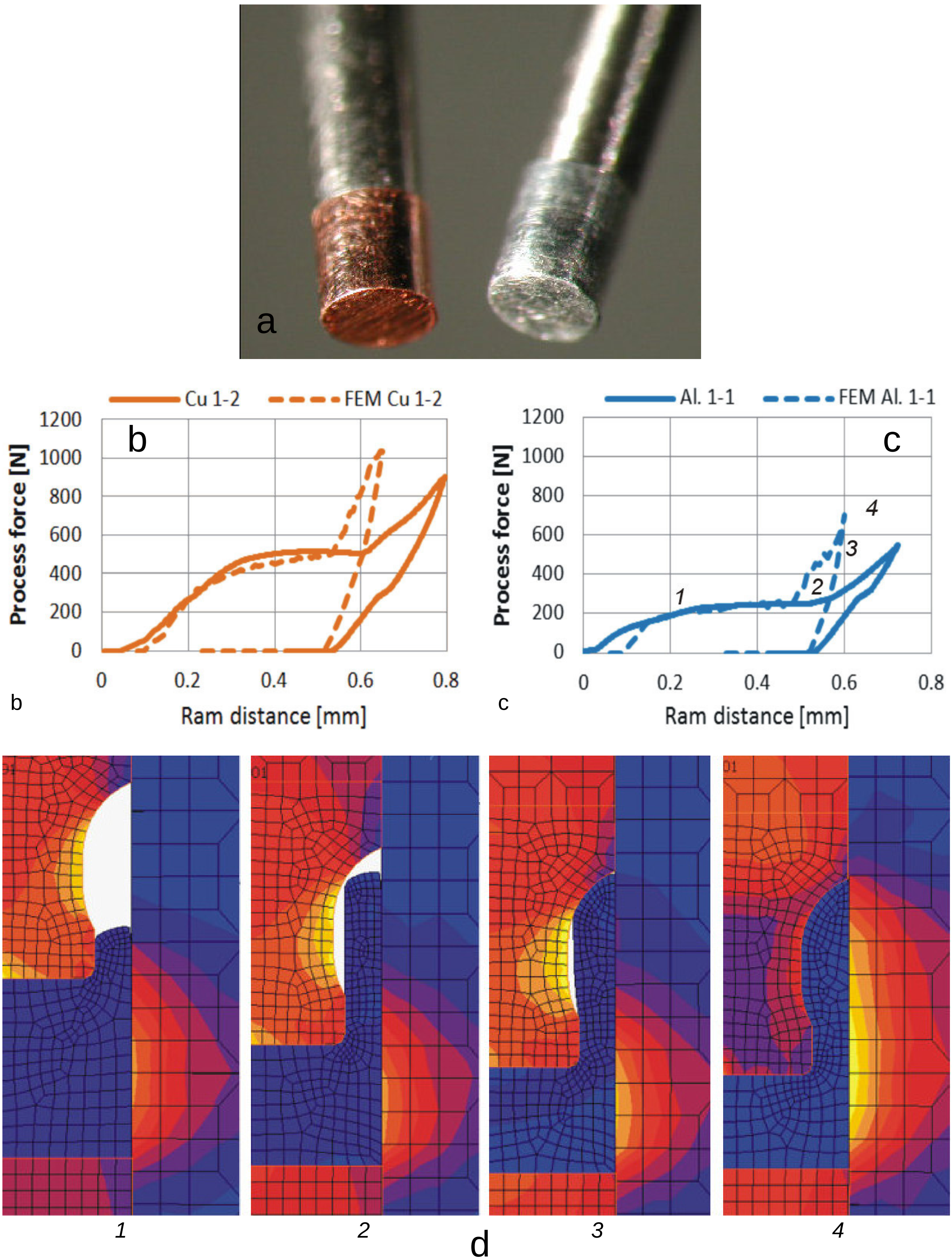

Fig. 5. Experiments and FEM results: (a) BiMPs, (b) force progress for aluminum billet, (c) force progress of copper billet, (d) von Mieses stress distribution for characteristic points of process force curve – marked at figure (b)

6. Conclusions

- A research method of investigation of Bi-metallic Micro-Punches – BiMPs – for micro-blanking has been worked out. It includes experimental stand based on high precision testing machine equipped with unique, specially designed micro-tooling, flexible micro-tools and precise measuring system.
- There has been successfully performed simplified processes of the BiMPs production by mechanically joining of micro-punches bodies with aluminum and copper ends.
- FEM analysis of the BiMPs manufacturing have been examined. They are in technically acceptable agreement with reality.
- During joining process of micro-punch ends, the critical point has been established, which might cause a risk of tool overloading. Process should be stopped at second rapid rise of force. At this point joint is already formed.

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