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OPTIMIZATION OF PROTECTING WALL TOOL FOR MANUFACTURE AND ASSEMBLY

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Professional paper

Many tools for metal forming manufacturing are made by copying similar tools with only minimum adaptation regarding the new product. Since such tools are not optimized for manufacture and assembly, it provides a variety of topics for bachelor theses for candidates at the mechanical engineering faculties. In this paper, the optimization of the metal forming tool for protecting wall regarding manufacture and assembly, performed in a bachelor thesis is presented. The optimization is based on approaches known as Design for Assembly and Design for Manufacture. The resulting tool model shows that there is enough space for improvement that can be done and that considered design approaches could be a source for several new interesting bachelor theses.

Keywords: *Design for Manufacture (DFM), Design for Assembly (DFA), Computer-Aided Design (CAD), Metal Forming*

Optimizacija alata zaštitne kadice za proizvodnju i sklapanje

Stručni članak

Mnogi alati za oblikovanje metala deformiranjem su rađeni na osnovi sličnih prethodnih alata i uz minimalne izmjene koje zahtjeva novi proizvod. Kako takvi alati nisu optimizirani za proizvodnju i sklapanje, predstavljaju dobar izvor tema za diplomske radove na strojarskim fakultetima. U ovom se radu predstavlja optimizacija alata zaštitne kadice za proizvodnju i sklapanje izvedenu u diplomskom radu. Optimizacija je utemeljena na pristupima poznatim kao "Dizajn za sklapanje" i "Dizajn za proizvodnju". Model izmijenjenog alata pokazuje kako ima dovoljno mjesta za poboljšanja i kako korišteni pristupi mogu biti izvor za brojne zanimljive diplomskih radove.

Ključne riječi: *Dizajn za sklapanje, dizajn za proizvodnju, računalom podržan dizajn, oblikovanje metala deformiranjem*

1 Introduction
Uvod

Design of new tool for metal forming is usually based on copying of an existing similar tool. Therefore changes in the design are minimal. There are several reasons why tool designers in manufacturing companies use such an approach: saving time and money during design; not enough interest in making greater changes; not accepting new ideas, etc. Usually, the main reason is lack of time for an additional sophisticated adjustment. Designing tool this way leaves room for designers to make methodical changes that can reduce price and time of manufacturing. These changes can be done by using various approaches, such as Design for Manufacture (DFM), Design for Assembly (DFA) [5] or Design for Quality (DFQ).

The tool considered in this paper is used for manufacture of the protecting wall. The tool was used in the bachelor thesis as an example of optimization of an existing tool [1]. The main goal of the bachelor thesis was to improve the tool while keeping the same or better quality of the final product. The author of this thesis was the first author of this paper. During his research, the candidate received help from his mentor Full Professor Niko Majdandžić and from Senior Assistant Tomislav Galeta, both from Mechanical Engineering Faculty in Slavonski Brod, Croatia. The candidate was asked to make parametric and feature based model and technical drawings of the initial tool, to propose and discuss optimization, and then to make a model and drawings of the optimized tool. The candidate had to decide on his own which Computer-Aided Design (CAD) system to use. 3D CAD system was used because of its convenience for Design for Manufacture (DFM) and Design for Assembly (DFA).

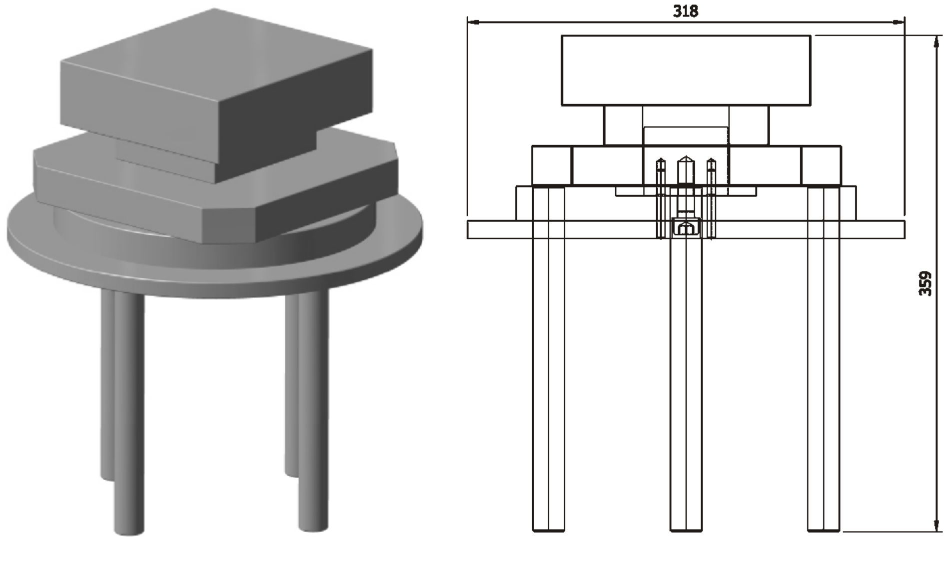

Figure 1. Assembly of the tool
Slika 1. Sklop alata

Every time the candidate wrote one chapter, he gave it to Senior Assistant Tomislav Galeta for a review. Senior Assistant gave advice to the candidate on how to write the graduation thesis, helped him with CAD system, with word processing, document management and with the final presentation. The final review was done by Full Professor Niko Majdandžić who approved the thesis.

A significant contribution to the thesis was given by Mr. Antun Jukić, the owner of the company Kreire Metal Ltd. who provided initial tool documentation and other relevant information [2]. Mr. Antun Jukić provided important information on the tool and parts of the tool which helped the candidate with ideas for optimization.

The considered metal forming tool is used in manufacture of the protecting wall by deep drawing (Fig. 1). The protecting wall is used for a key of a chimney door (Fig. 2).

Manufacturing of the protecting wall is semiautomatic. A sheet of protecting wall needs to be put to a press plate manually. The motion of a stamp and sheet forming process is caused by the press. The material of the base sheet is S220JR with thickness 0,8 mm. Approximately 3000 protecting walls are produced per year.

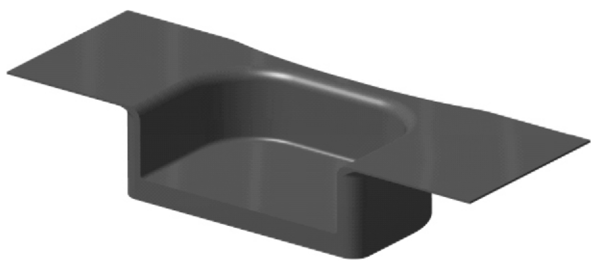

Figure 2. Protecting wall
Slika 2. Zaštitna kadica

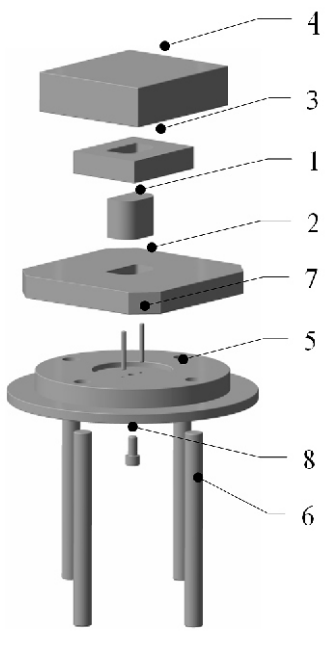

Figure 3 Parts of the initial tool
Slika 3. Dijelovi izvornog alata

The initial tool is made of eight steel parts (Fig. 3): 1 - stamp (34Cr4), 2 - press plate (S235JR), 3 - matrix (34Cr4), 4 upper plate (S235JR), 5 - lower plate (S235JR), 6 - slide (20MnCr5), 7 - pin (C45), 8 - bolt (ISO 4762 8.8). Calculated mass of the initial tool is 45,13 kg; volume is 5,75 l and surface area is 0,5494 m^2. Calculated mass matches the actual weighed mass according to the tool technical documentation [2].

2
Optimization method
Metoda optimizacije

The chosen method for optimization of the tool was Design for Manufacture and Assembly (DFMA). DFMA is a combination of two well-known methods "design for manufacture" (DFM) and "design for assembly" (DFA) [5]. The main purpose of DFMA is to simplify manufacturing and assembly of the product [3]. That can be achieved by various operations like simplification of parts and reducing their number, etc. The main goal of DFMA method is to reduce price of the final product.

DFMA is used for three main activities: (1) As the basis for engineering studies in simplifying product structure, to reduce assembly and manufacture cost, and to quantify the improvements; (2) As a tool to study competitor's products; (3) As a tool to determine price of the product.

DFA alone is driven by three questions: Does a part relatively move? Only greater movements can be taken in consideration. Does a part need to be made of another material? Does a part need to be separated from other parts? This is important because sometimes a part can stop assembling or disassembling the product, if it is put wrong.

DFMA method can be very successfully applied to the product model designed in parametric and feature based CAD systems, also known as Mechanical CAD (MCAD). The most important information that can be acquired from MCAD system is the shape of a product and parametric features. The shape of a product is the basis for all activities in the process of manufacturing, which is important for DFMA. Logical integration of the considered method and MCAD is that DFMA guidelines lead the user of MCAD system. It is important that MCAD is included with DFMA in early stages of making designs. In this way the best optimization can be achieved. Therefore, in the beginning the candidate designed a model of the tool in the chosen MCAD system.

In his thesis, the candidate has chosen Autodesk's Mechanical Desktop 2006 for MCAD system. The choice of MCAD system was based on the candidate's knowledge of MCAD possibilities and license availability at the Faculty. It was also chosen because it has parametric possibilities. MCAD system helped the candidate in his thesis because he used it for quicker design of the initial tool and then for optimized tool and for making technical drawings. The candidate could instantly see the changes made at the tool and its parts. Although the candidate had second thoughts about choosing another MCAD system like CATIA from Dassault Systems [4], he decided to use this MCAD system because there was no time to learn a new MCAD system.

3
Proposed tool changes
Predložene promjene alata

Regarding DFMA principles and tool production parameters, the candidate proposed several tool changes. Tool parts affected by proposed changes are: matrix, upper plate, press plate and lower plate.

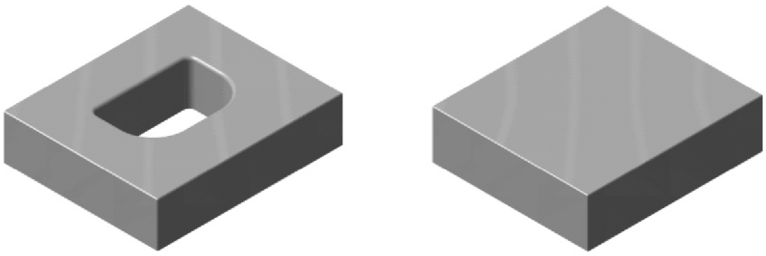

Figure 4. Matrix and upper plate before optimization
Slika 4. Matrica i gornja ploča prije optimizacije

3.1
Joining matrix and upper plate
Spajanje matrice i gornje ploče

The first proposed change was to join the matrix and the upper plate. With this change, the matrix and the upper plate became one part (produced from the same raw material). In the initial tool, the matrix and the upper plate were welded together; therefore it was not possible to separate them without destruction (e.g. when eventual replacement, caused by wearing, was needed). Furthermore, relatively small quantity per year of produced walls with the tool induces small wearing and rare replacement of the matrix. The suggested common material for the new part is high grade steel 34Cr4, because it is suitable for hardening.
Fig. 4 shows the matrix and the upper plate before optimization. Fig. 5 shows the matrix and the upper plate joined together.

3.2
Suppressing one pin
Izbacivanje jednog zatika

The second suggested change was to suppress one pin. The original tool had two pins and one bolt (Fig. 6). Suppressing one pin influences the shape of the stamp and lower plate. After suppression there is only one pin; and one hole needs to be drilled for the pin and one hole for the bolt (Fig. 7).

The role of pins is to prevent turning of the stamp. Therefore, the pins are affected by only small shear stresses. The hexagonal bolt could easily take over the role of one discharged pin.

3.3
Press plate simplification
Pojednostavljenje potisne ploče

The third proposed change was shape simplification of the press plate. At the press plate a chamfer of vertical edges should be reduced. The edges were chamfered at 29 mm under 45 before optimization. The proposed change is that edges are chamfered at 0,5 mm under 45. Fig. 8 shows the press plate with reduced chamfers. Chamfered edges are applied to prevent injuries.

3.4
Lower plate simplification
Pojednostavljenje donje ploče

The fourth proposed change was shape simplification of the lower plate (Fig. 10). The lower plate would be shaped as a simple disc with drilled holes for pin, bolt and slides. Fig. 11 shows the lower plate after the changes.

After all changes are implemented, the mass of the tool will be 47,85 kg, the volume 6,09 l, and the total surface of the tool 0,5269 m^2. Fig. 12 shows the assembly of the tool after all proposed changes are applied.

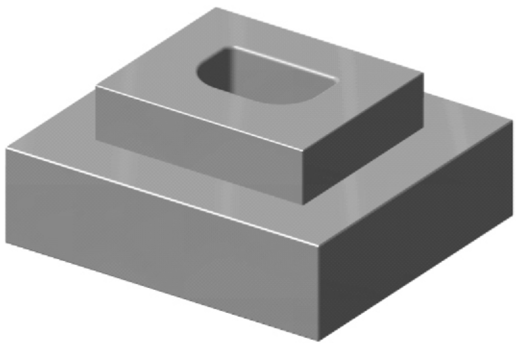

Figure 5. Joined matrix and upper plate
Slika 5. Spojene matrica i gornja ploča

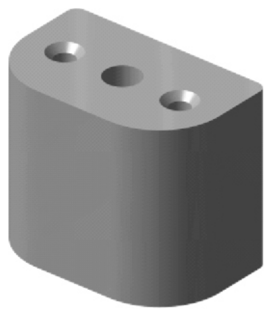

Figure 6. Stamp before suppressing one pin
Slika 6. Žig prije izbacivanja jednog zatika

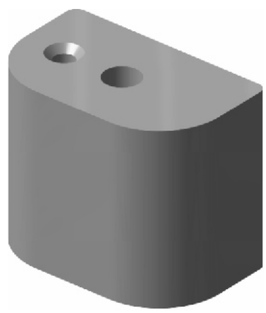

Figure7. Stamp with one pin suppressed
Slika 7. Žig s jednim zatikom izbačenim

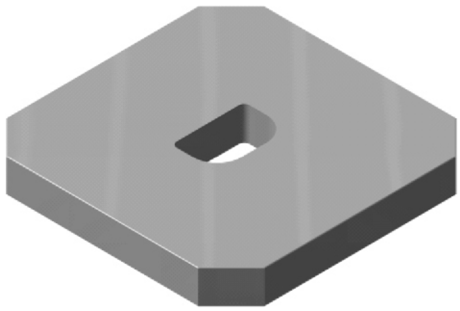

Figure 8. Press plate before reducing chamfers
Slika 8. Potisna ploča prije smanjenja skošenja

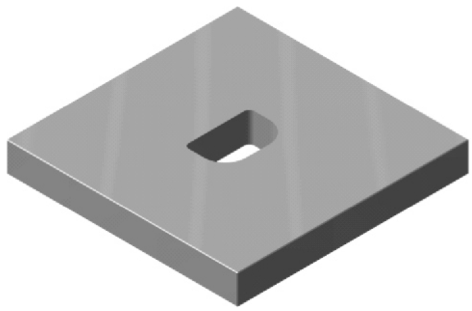

Figure 9. Press plate with reduced chamfers
Slika 9. Potisna ploča sa smanjenim skošenjima

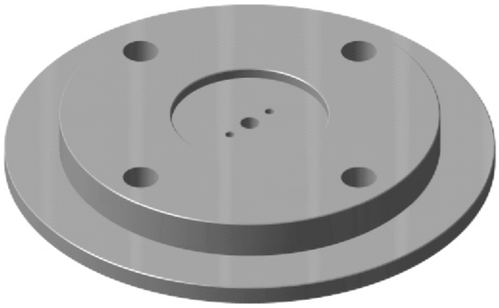

Figure 10. Lower plate before simplification
Slika 10. Donja ploča prije pojednostavljenja

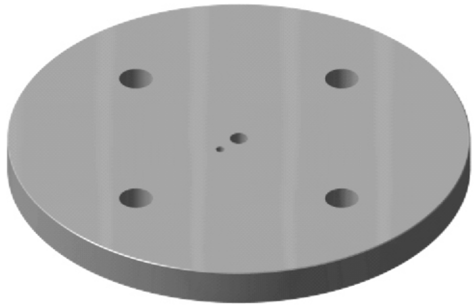

Figure 11. Simplified lower plate
Slika 11. Pojednostavljena donja ploča

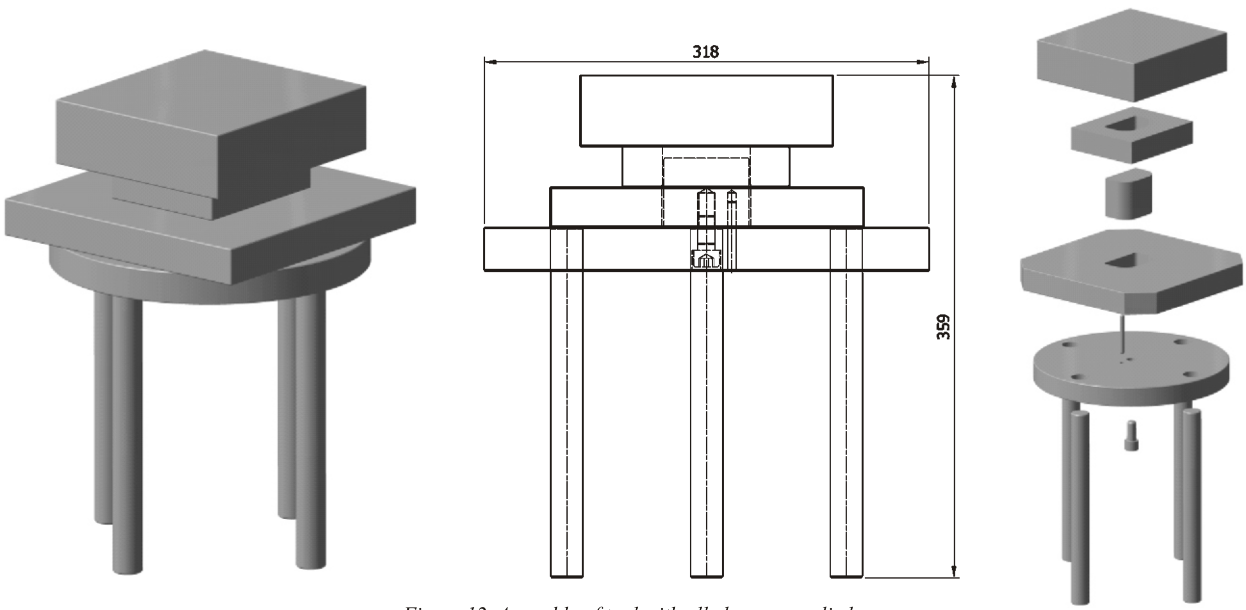

Figure 12. Assembly of tool with all changes applied
Slika 12. Sklop alata sa svim promjenama

4 Discussion
Diskusija

Design changes are proposed in order to simplify and shorten time needed for the tool manufacturing and the tool assembling.

By joining the matrix and the upper plate, the number of total parts is reduced. In addition, it is not necessary to machine one surface of the matrix or to weld the matrix on the upper plate. Therefore, the expected cost of joined parts should be lower. Thesis reviewers find that costs due to this change should be evaluated in more detail, since common material is proposed and heat treatment is involved.

The number of parts is further reduced by suppressing one pin and it also reduces the number of machining operations. This change should have no effect on the total mass of the tool and on the time needed for the tool assembling.

The expected advantage of reducing vertical edges on the press plate is shorter machining time because there are fewer surfaces for machining. The cost of the press plate after optimization is also reduced because of less machining although the new press plate has a bigger mass than the initial one. Since both the initial and the changed press plates are produced from the same raw material by metal cutting operations, a higher part mass does not increase the costs. Press plate mass increase is not so significant as to have negative impact on assembling increase is only 0,38 kg compared to the initial press plate.

The proposed simplified shape of the lower plate demands one machining operation less. Unlike the press plate, the mass of the lower plate will be increased which could affect the assembling increase is 2,3 kg regarding the initial lower plate. The reduction of machining operations will have a huge influence on the lower plate cost.

Some changes are considered but not proposed. The first rejected change was joining of the stamp and the lower plate. It was rejected because the lower plate is used for other stamps. Another rejected change was changing the shape of the stamp, the internal shape of the matrix and the internal shape of the press plate. It was rejected because it would influence the shape of the protecting wall which is not acceptable. The next rejected change was changing the shape of the upper plate and circular shape of the lower plate. Because the plates are adapted for the specific press, those changes could not be implemented.

There were also considerations about new materials but initial materials remained because a change of materials demands thorough evaluation that exceeds the scope and the time frame of one bachelor thesis. Therefore, it can be pointed out that the study of DFMA approach could be a source for several bachelor theses dealing with different areas (subjects) like computer aided design, stress analysis, computer aided manufacturing, production planning, cost estimation etc.

5 Conclusions
Zaključci

FMA approach gives a new view on the production of metal forming tool. Metal forming tools that are designed and used in small and midsize manufacturing companies like Kreire Metal Ltd. are usually not optimized for manufacture and assembly. The market pressure leaves no space for optimization. Such a situation provides a wide spectrum of bachelor thesis based on DFMA approach for students at the mechanical engineering faculties. To obtain more complete evaluation of changes based on DFMA approach, future papers should combine more detailed cost calculation with production planning, assembling time estimation or stress analysis. Faculty professors should consider proposing several theses (based on some DFMA subject). Such a subject can connect several areas and several faculty departments.

The work on the thesis is the result of direct cooperation with a manufacturing company which provided many opportunities for the candidate, the professors at the Faculty and the engineers from Kreire Metal Ltd. The candidate gained experience and valuable reference by working on the concrete task in the area of metal forming. This experience and established connections could actually help the candidate to get a job in that area. The faculty professors and assistants utilized work on the thesis to establish and attune communication protocols with manufacturing companies and with future candidates.

Acknowledgment
Zahvala

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