INCREASING THE LIFETIME OF FORMING TOOLS

Bílik, J.; Pompurová, A. & Ridzoň, M.

Abstract: The paper presents an analysis of the causes of exclusion forming tools for hot forming from activities as well as analysis of factors affecting their life. These basic factors such as material of tool, tools design, production method, the method of heat treatment, thermal and mechanical stress of tool and conditions of forming. The paper also presents some options for increasing the life of forming tools for hot forming. These include the possibility of boriding, duplex treatment (plasma nitriding and PVD coating) and work hardening of surface layers.

Keywords: Life of die, die wear, surface layers work hardening, dies production

1. INTRODUCTION

The issue of lifetime of die is difficult due to the amount of factors that may affect the life of die. Improving processes, technologies of production, heat treatment and surface treatment gradually leads to solving the life of die. Currently in the life of the die is mainly about economic efficiency of production, i.e. is necessary in view of the number of such procedure of production die to choose the forgings produced have achieved the best economic effect. In some cases, the choice of the procedure and renovation of the dies leading to the maximum basic life and overall life may not lead to maximum economic effect. It depends on the type of forging and, in particular, from type of production. The arrival of major car manufacturers in Slovakia there was pressure on suppliers from the point of view of reducing production costs. In the production of formed part and therefore also an important item in the cost of production of forgings entering is also the price of forming tool. Therefore, solving the problem of life is currently forming tools in the present.

2. CAUSES OF REMOVAL OF THE DIE FROM THE ACTIVITY

Among the causes of removal the die of the activities at the disposal of certain operating conditions include:
• Wear abrasion cavity dies – dies are the most seen in those parts of dies, where there is the largest movement of material during forging to (Fig. 1). Wear depending on conditions in the field of forming material and the surface of the tool may be in the nature of the contact abrasive and adhesive character of wear. Abrasive wear is caused mainly forging on oxide particles (splatter), or hard foreign particles from the environment or the structure of the hard phase forming material. Adhesive wear is caused by adhesive forces of the meeting between contact surfaces of die and forming material.
• Bruising exposed parts of die – bruising, in particular die for disembarking the parts of the cavity. Exposed locations to drop from the standpoint of bruising are shown in Fig. 1. Studies have shown that the depth of the cavity power hammer dies after forged about 1000 forgings changed to 0.8 to 1.1 mm when the average number of 4 to 6 strokes is necessary to forged one forging is deformation 0.0005 to 0.0003 %. Studies on the changes of the
dimensions of the cavity further has shown that most are changing dimensions of cavities in the early stages of using dies (600 to 1000 forgings to forged). Then followed by a phase of relative stabilization of the dimensions and, therefore, it is appropriate to propose the optimal forging, which can increase the lifetime of the tolerance that 30 to 40%.

- Formation of networks of fatigue cracks due to thermal fatigue and the scorching the surface layer – after the formation of fatigue cracks, the effect seems itself more intense tan, as it creates the conditions for pulling out larger particles of the material surface. Occur while the leaking material to crack difficult if the collection of forgings resulting in the disposal of the die. On Fig. 1 are the sections where the reflected surface of the tan dies. In small transient radii to drop on them quite pretty much tearing of thermal fatigue cracks. Therefore, e.g. from R3 to R6 radii zoom in some cases can lead to an increase in life span 2 to 3 times.

Fig. 1 Ways of die cavity wear in die forging with flash; 1 – bruising, 2 – abrasion wear, 3 – scorch, 4 – fatigue [1]

Fig. 2 The predominant types of wear of power hammer dies [1]; I – bruising, II – abrasion, III – scorch

On Fig. 2 are the predominant types of wear of power hammer dies depending on the weight of falling parts. On Fig. 3 are the predominant wear types of dies for presses. Fig. 3 shows that the bruising in the die for press plays a smaller role than die for power hammers, rising significantly affect scorch, increasing the impact of attrition, especially in small presses and there are also reasons for exclusion due to die cracking.

Fig. 3 The predominant wear types of dies for presses depending on the strength of the press [1]; I – bruising, II - abrasion, III – scorch, IV - crack

In some cases it is also due to the emergence of deep cracks in the discarded prematurely die that arise more frequently in the dies for presses and are called thermal cracking. The cause of their formation is the tensions arising from the pressure of forged, sudden changes in temperature and irreversible deformation of the material associated with the cyclical changes of temperatures. Thus has greater thermal expansion and the bigger is the material of the instrument by the cavity to the accumulation of tension rather that may lead to the emergence of deep cracks and premature discarding dies from the activity. Among the reasons for the early disposal of the dies from the activities may include incorrect heat treatment dies (e.g., failure to comply with the prescribed procedure of heat treatment,
hardness, failure to comply with the bursting of the dies in heat treatment etc.), defects in the materials of the dies, incorrect handling of die (in particular the wrong pre-heating dies before forging), errors in the construction of dies.

3. FACTORS AFFECTING THE LIFE OF THE DIES

The main factors affecting the life of the dies may include material of die, design of die, method of die manufacturing, method of heat treatment and quality of the die, thermal and mechanical stresses in the die forging, forging conditions. The material for the production of dies are places certain requirements and conditions of the type of hardware. The material is very important factor influencing life of dies, is paid too much attention but in view of the limited scope of the contribution is not possible given all the factors sufficient space. In the selection of suitable steel for dies, it is necessary to take into account the quantity of the produced forgings, shape and dimension of forging, the size and type of forging machine and its operating conditions for the forgings, the possibility of carrying out proper heat treatment dies. In the construction of dies must be respected the principle of guaranteeing the proper functioning of the dies and its sufficient durability life. Regards compliance with size transition radii and taper to comply with the shape and dimensions of the die and flash space, and compliance with surface roughness, etc. Design principles are to some extent the norm but also the experience and knowledge of the constructor plays an important role. Currently, aid for the construction of the dies provide computer programs intended for simulation of forging processes (e.g. FORGE 2, FORGE 3, FORMFEM, FORM 2D, SUPERFORM, SUPERFORGE, DEFORM), which allow to optimize the forging process.

Method of production of dies (machining, forming and casting) also affects the life of dies. From this point of view, the best way of forming dies appeared. Production of dies by forming is more limited in terms of size and shape and size of the cavity itself dies [3]. Therefore, attention is drawn to the possibility of additional improvements to the surface layer. The method of heat treatment and quality of currently manufactured die crucially affects their life. Therefore, it is necessary to pay attention to the heat treatment. Heat treatment of materials of dies most frequently includes:
- normalizing – especially if they were forged die blocks,
- soft annealing, before production of dies from conventional machining, or before production,
- the production forming dies (by pressing, shooting),
- stress relieving
- hardening of the manufacture or die, respectively before production of the cavity itself (using the methods of cultivation to enable machining of hardened materials)
- tempering the hardness required (usually 46 to 48 HRC)

Thermal and mechanical stresses of the die in the process of forging also significantly affect their life in. The cyclic heat and mechanical stress is causing by the thermal and mechanical fatigue and, consequently, the emergence of a network of fine surface fatigue cracks. On the thermal fatigue affecting the mechanical and physical properties of the die materials, the nature of the macrostructure in cross-section dies, mechanical and chemical and thermal treatment the surface of the die cavity, the operating conditions of the work dies. The hardware conditions that affect the life of dies can be included methods of preforging of forming material, size, power forging machine, forging temperature level, the method of heating the material, method of removing scale,
the method of preheating the die, the die height of the working temperature (frequency and duration of forging cycle) method and type of lubrication, cooling, and another dies, the mode of operation and treatment die, method of storage and recovery (renovation) die. Determination of the proportion of the various factors on the life of the die and the respect of the production and technological parameters of the resulting in the manufacture of dies as well as in the manufacture of forgings is quite difficult, and therefore also the lifetime of dies for the same forgings may vary considerably.

4. SOME OF THE OPTIONS TO INCREASE THE LIFE OF DIES

The surface layer is crucially affects the base and also the overall life of the dies. Among the methods of work hardening surface layers applicable for dies can be included:
- chemical-thermal treatment, i.e. nitriding, boriding,
- ion implantation
- PVD coating and PAPVD,
- duplex treatment - plasma nitriding and PVD coating,
- mechanical hardening of surface layers produced by machining cavities such as dynamic shot peening prior to heat treatment (achieving finer in granulometry martensitic structure in the surface layer) or after heat treatment (increase in fatigue strength, etc.) [1, 2].

In the article specified only some of the listed methods increasing life of dies. Boriding is the saturation of the surface of steel with boron to increase wear resistance to abrasive friction, sliding friction and friction at elevated temperatures. Typical boriding layer consists of borides FeB and Fe₂B and is shown schematically in Fig. 4 [5].

Boriding process is carried out routinely in the temperature range 800 to 1050°C. Boriding layer thickness is usually in the range of 0.1 to 0.3 mm and boriding time 3-6 hours. Carbon and alloying elements slow the growth layers of borides. The application process is boriding of tools for cold and hot molds for pressure casting of non-ferrous metals, the beams to pull wires, rods, etc. Microhardness of borides FeB reaches 1900 to 2100 HV. Alloying elements W, Mo, Mn, Cr slightly increased hardness. Boride Fe₂B a microhardness of about 1650 HV hardness Fe₂B alloying elements affect. The borid FeB is stable when heating to 800°C and borid Fe₂B is stable to 1000°C. Duplex treatment lies in the fact that after the standard of heat treatment of plasma nitriding of die place under conditions that ensure the creation of diffusion layers without nitriding surface layer of nitride. This is followed by deposition or PVD CrN coatings PAPVD, TiCrN, TiN/TiCN (Cr/CrN) x 3 and (CrN/TiN) x 3 Duplex treatment was successfully applied to smaller die used i.e. the fittings on automatic forging machines type Hatebur. In the case of processing dies, depending on the type of coating, reached the increase of life from 1.3 to 1.5 times [4]. On Figure 5 is the diagram of the basic life of the die steel 1.2713 (55NiCrMoV6) after application of mechanical reinforcement coating by shot peening.
In the face of the forging process is necessary to maximize the life of shall in particular:
– observance of the correct temperature of heating of forged material and preheating of dies,
– to vote by minimizing the possibility of heating formation of oxides, i.e. direct electric heating,
– to elect the most suitable ways of minimizing material flow preforging as in the finishing cavity, forging pressure reduction and the elimination of scale,
– to elect the most suitable ways of lubrication and the removal of scale from cavity dies,
– meet as regularly as possible with the hardware cycle by shortening the maximum contact with the die forged so as to avoid excessive overheating of the surface layers,
– the correct choice of forging machine and its technical condition and under.

5. CONCLUSION

The aim of this paper is to highlight the factors affecting in particular the basic life of dies as well as some of the options to increase the life of dies. In the paper are specified only some methods of improving the surface layers that can be used to increase the base and the overall life and die or other shaping tools for hot working. A separate chapter of the life of the dies is lining renovation and dies (by reducing the die cavity with a deepening, surfacing and smaller die also impressed or gun nailing). However, this is not lining and renovation must complement the contribution.

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AUTHORS

Bílik, Jozef, Pompurová, Anna & Ridзоň, Martin
Slovak University of Technology
Faculty of Materials Science and Technology in Trnava
Institute of Production Technologies
Bottova 25
917 24 Trnava, Slovakia
jozef.bilik@stuba.sk
anna.popurova@stuba.sk
martin.ridzon@stuba.sk