A R C H I V E S O F M E T A L L U R G Y A N D M A T E R I A L S
Volume 60 2015 Issue 4
DOI: 10.1515/amm-2015-0446

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SOLUTION EXAMPLES OF SELECTED ISSUES RELATED TO DIE FORGING

PRZYKŁADY ROZWIĄZAŃ WYBRANYCH ZAGADNIEŃ ZWIĄZANYCH Z KUCIEM MATRYCOWYM

W artykule przedstawiono wybrane przykłady rozwiązań i ich zastosowań w przemysłowych procesach kucia matrycowego. Opisano zagadnienia i problemy, z którymi autorzy zetknęli się w trakcie wieloletniej współpracy z przemysłem kuzienniczym oraz metody ich analizy. Jak wykazano w licznych artykułach i opracowaniach parametry wpływające na procesy kucia matrycowego podlegają złożonym i wzajemnie powiązanym relacjom, które w znacznym stopniu komplikują analizę procesów kucia. Jest to powodem coraz częstszego sięgania po szereg narzędzi informatycznych: CAD/CAM/CAE, symulacje numeryczne oparte o MES, skanowanie powierzchni matryc i stempli, a także zaawansowane badania mikrostrukturalne, modelowanie fizyczne, czy też zastosowanie specjalnych systemów pomiarowo-kontrolnych do praktycznej weryfikacji zastosowanych rozwiązań. Przeprowadzone w pracy badania obejmowały głównie: analizę przygotowania wstępniaków, wpływu ich geometrii na jakość odkuwki, sposobu nagrzewania materiału i narzędzi, analizę warunków tribologicznych, a także optymalizację wybranych procesów ze względu na parametry siłowe, rozkłady odkształceń i temperatur oraz zminimalizowanie masy materiału wsadowego. Zagadnienia opisane przez autorów w artykule mają na celu przybliżyć problematykę współczesnych procesów kucia matrycowego i metody ich rozwiązywania oraz wskazać możliwe kierunki rozwoju tej technologii.

The paper presents selected examples of solutions and specific user applications associated with the industrial forging processes. Various process specific issues encountered during many years of bilateral collaboration with the forging industry are addressed and analysis methods are presented. As demonstrated in numerous articles and publications, the parameters influencing the die forging process are subject to complicated and mutually related dependencies, which can affect and complicate the methods of analysis. For this reason, researchers, more and more frequently, involve the use of additional support tools such as CAD / CAM / CAE, numerical modelling based on FEM, tool surface scanning methods, physical modelling, advanced microstructural research and dedicated control-measurement systems to validate engaged solutions. The research conducted by the authors included mainly: an analysis of the preform preparation, the impact of the geometry on the forging quality and the heating methods of the material and the tools, analysis of the tribological conditions, as well as an optimization of selected processes in respect of the force parameters, strain and temperature distributions and finally, a weight minimization of the input material. The issues discussed by the authors in the article intend, on the basis of the experience of its creators, to review the issues of the current forging technology and to indicate its possible solutions and development directions.

1. Introduction

The forging process belongs to the oldest branches of the metal processing technology and, despite the passage of years, is still frequently applied, being, in the case of some products, simply indispensible. At present, the most popular and commonly used forging method is die forging, which makes it possible to manufacture nearly every kind of product. Die forgings constitute from 50 to 80% of all the forged elements [1]. Such a wide application range of die forging as a material shaping method results from its many advantages, such as:

- a significantly more extensive, compared to other shaping methods, degree of material use, owing to a large approximation of the forging's shape to that of the ready product,
- high efficiency,
- very good mechanical properties of the forgings [2, 10].

This last merit of die forging is especially revealed when compared to other used methods, such as: casting and machining, as plastically and thermally treated elements have the best mechanical properties. Despite the fact that this technology is relatively well known, the increasing competition among the forging producers and the increasing demands of the users in respect of the precision and quality of the obtained products, as well as the economic and ecological

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aspects, stimulate a constant search for new solutions enabling to fulfill those expectations.

The technological process of die forging consists of several stages, which include delivering the material from the plant, its cutting and heating, as well as a thermal treatment of the final product. At each of the mentioned stages, there is a potential risk of an error causing a forging flaw. A factor affecting the forging quality is also the durability of the tool, as its too fast and intense wear causes change in the geometry of the manufactured product, and any surface defects (fractures, decrements) are reflected in the forged product. Among the most important factors influencing the course of the forging process, we can name: the precision of the input material cutting, the manner of lubrication and the factors related to the tool [3, 7].

2. Input material preparation

One of the more important aspects determining the quality of a ready forging is a proper preparation of the input material. A bad geometry and other flaws formed during the cutting, an insufficient heating of the input material or a badly-designed forging preform may result in the formation of underfills and laps, which eliminate the given product from further use. As for the case of significant irregularities of the technological process, such as an excessive volume of the input material or an insufficiently high temperature, there is a great probability of a rapid increase of the forming forces and stresses, which can lead to a press shut-down or a tool fracture. That is why elimination of flaws at this stage of forging is the basic condition for the production of a proper forging in respect of the quality as well as the size and shape [4-8].

2.1. Input material cutting

The cutting procedure of the input material can be implemented by means of various technologies, depending on the requirements set for the preforms. The currently used cutting methods include the use of shears and presses as well as a breaker, often at elevated temperatures. These methods are, however, not accurate enough, as the surface after the cutting is rough and the dimensional deviations can equal even a few mm. In the case of close die forging, where the weight of the prepared preforms corresponds to the weight of the forgings, it is necessary to apply more precise methods, such as cutting with the use of a saw or a hydromechanical shears, this being connected with minor material losses equaling about 1-2%. For example, the acceptable mass differences can equal 0,5-1%, the angular deviation in the cutting zone - up to 2°, and the circular deviation - 6% [8].

Fig. 1 presents an example of preform fracture during cold cutting from steel bars. The preforms characterized in an uneven surface, and there was a visible fault around the edge of the cut bar. The microstructural tests of the defected specimen revealed a significant decarbonization of the layer at the external surface. The ratios of the ferrite and pearlite percentage in this area equaled from 60% to 40% . This defect is especially risky, as it eliminates the produced preforms from further forging procedures. As a result of the decarbonization, a very thin layer of plastic ferrite was observed, which underwent local deformation during the cutting process. In this case, even shear bands are probable to be formed, which, meeting a harder pearlitic-ferritic structure, initiate the fracturing of the preform. The cut input material does not usually undergo a quality control, which would make it possible to eliminate the defected specimen. Such fracturing can be spotted on the forging only after it has been cleaned of the scale and graphite layer, and, in the worst case, it can be a hidden defect (Fig. 1c).

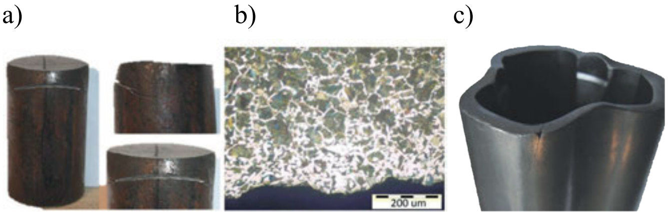

Fig. 1. A view of: a) fractured preforms, b) XC45 steel structure, surface layer and c) a forging formed from a fractured preform [8]

The authors performed numerical modeling of the cutting process of the preform bar with the use of the Forge program, in order to more thoroughly analyze, as well as solve, the problem of fracturing. A scheme of the cutting system is presented in Fig. 2. The basic parameter which undergoes regulation in the cutting process with the use of shears is the size of the gap between the upper and lower blade, which has an effect on the quality of the cut preform.

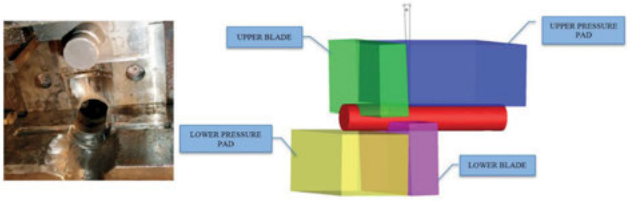

Fig. 2. Scheme of the cutting method: a) image of the shearing machine and b) numerical model of the cutting process after changes – introduced blade inclination

In order to select the appropriate parameters of the cutting system (value of the gap and the system inclination), a series of numerical FEM simulations of the cutting process was performed. The fracture model according to the Cockroft-Latham criterion was applied. Exemplary results are presented in Fig. 3.

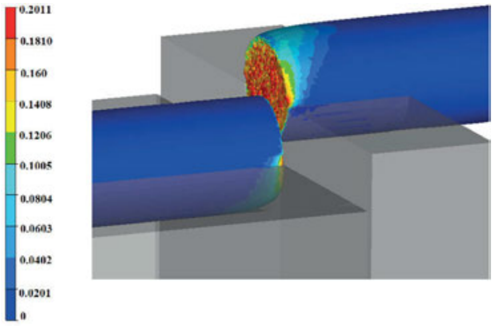

Fig. 3. Results of numerical modeling with the use of the Cockroft-Latham fracture criterion

The problem of fractures was solved by way of correcting the geometry of the blade's edge so that it would be parallel to the axis of the cut bar and not cause a bending stress in the bar.

2.2. Input material heating

In practice, the temperature control is implemented by way of a pyrometric measurement only on the surface of the input material. An inappropriate temperature of the input material may be a cause of the formation of many defects in the further stage of the forging process. At present, the most frequently used method of preform heating is induction heating. It assures a high effectiveness of the energy processing and thus a high efficiency, yet it is connected with the problem of adjusting the appropriate frequency of the current flowing in the conductor, depending on: the size of the input material, the type of the material (different theoretical power demand) as well as the required preform temperature. At lower frequencies, the layer of the input material through which the current flows is thick, which means that the current flows through the object into its centre and heats it through. Very high frequencies should be avoided due to the „skin effect", as in that case, the current flows only on the surface and the depth of the input's heating is very small. Due to the oxidation and decarbonization of the surface, the process of preform heating involves the use of various protective media, such as protective atmospheres (inert or active), a technological mechanical treatment allowance, a protective paste or a copper layer coating, or gradual heating. In the last case, the preforms are preliminarily heated up to about 100° C, and next, they are placed in a preliminary graphite coating chamber, heated up to the appropriate forming temperature. The purpose of the coating procedure is to reduce the wearing rate of the tools used for the hot forging of these elements.

The authors performed preliminary examinations (with a change of the current frequency) of the usability of a heater applied in a certain forge in order to verify the appropriateness of the heating of the input material in the form of a bar. The examinations aimed at stating whether the temperature distribution throughout the whole material's volume is uniform and whether the temperature of the input material reaching the press is constant for each detail leaving the heater. To that end, preliminary preforms were prepared, with apertures drilled at different heights of the preforms as well as at different depths (Fig. 4a). Numerical modeling of the temperature distribution in the preform was also performed with the purpose of a more thorough analysis of this matter (Fig.4b).

The performed studies showed that the frequency of the current has a significant effect on the temperature differences between the core and the surface of the heated material, whereas, on the surface itself, no significant temperature changes were observed between the centre and the bases of the preform.

How important is a proper heating of the input material can be evidenced by the results of the studies, performed by the authors, of the problems connected with the decarbonized layer in the forging of the expander. The conducted examinations showed the presence of a surface decarbonized layer in the forging after normalization. Due to the forging operation conditions, the thickness of the decarbonized layer should not exceed 0.1 mm (Fig.5 a). The metallographic tests showed a typical pearlitic-ferritic structure, whereas, in the surface layer, fractures were observed, which had been probably caused by the large deformations of the surface layer of the forging (Fig.5b).

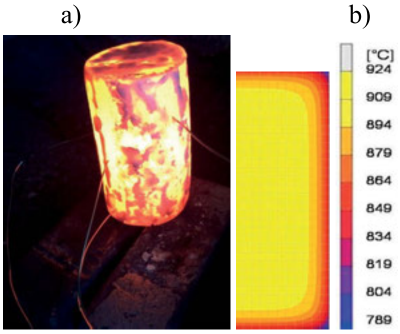

Fig. 4. A view of: a) a heated preform with thermocouples allowing for the determination of the temperature distribution in the whole volume of the input material and b) results of the FEM modeling of the temperature distribution in the preform

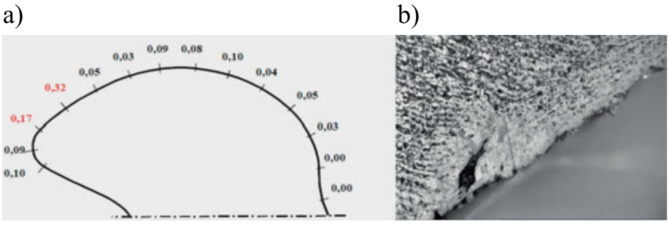

Fig. 5 A view of: a) size of the decarbonized layer on a schematic cross section of a forging, b) fracture in the decarbonized surface layer

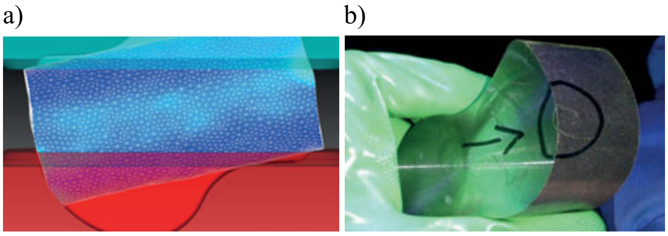

Fig.6 A view of: a) fracture identified in the surface layer, b) numerical modeling of the analyzed process – preliminary die forging

Further studies are currently being conducted, such as FEM modeling of the forging process, which aim at pointing to the causes of decarbonization of the forging and the formation of fractures (Fig.6 b). The first tests proved that a probable cause of the decarbonization can be a insufficiently perfected technology of the induction heating. The authors are considering the option of applying preliminary graphitization in order to eliminate this disadvantageous phenomenon, causing a decrease in the life of a forging as well as problems with its weldability.

The input material can be heated both in its whole volume and partially. An example of a local heating of preforms is induction heating of a concrete block carrying handle (Fig.7).

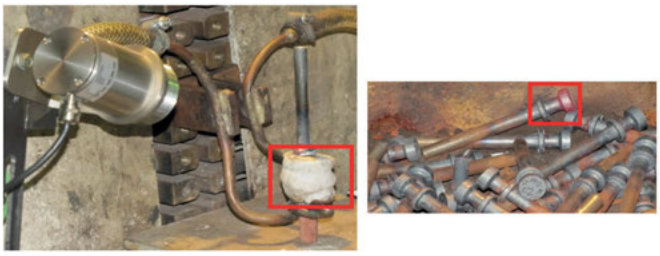

Fig. 7. Local induction heating of a forging

In the discussed case, a problematic aspect was the unstable heating temperature of the forging, which was connected with its improper control. The operator adjusted the temperature on the basis of the approximate heating time in the inductor, not taking into account the other factors related to the heater (e.g. the voltage loss in the whole supply system). With the purpose to solve this problem, the authors [9] constructed a control-measure station equipped with a pyrometer with a scope and a recording system, owing to which the heating temperature of the preform was set on the basis of an online measurement, with a compensation and an automatic heating shut-down, as well as an audiovisual signal given to the operator.

2.3. Optimization of the forging shape

So far, the optimal shapes of the passes and the preform have been obtained in forges by the trial-and-error method. At present, to that end, advanced programs are applied, which are based on the finite element method. An exemplary numerical analysis of the process of a yoke forging was performed by the authors of this work. The industrial process of the production of this element consists of 4 procedures: upsetting, flattening (with the same set of tools, after a 900 rotation of the forging), preliminary forging and finishing forging. The first stage of the studies was a numerical forging simulation according to the actual technological parameters of the process. In the analysis of the numerical modeling, it was noticed that an excessive outflow of the material in the preliminary forging operation can be limited by way of optimizing the shape of the tools at the preceding flattening stage. To that end, new tools were designed, i.e. the existing upper flattening pad was supplemented by an oblong shaping joggle, and the lower flattening pad – by walls blocking the excessive material outflow. A comparison of the shape of the tools before the changes and after the performed optimization is presented in Fig. 8.

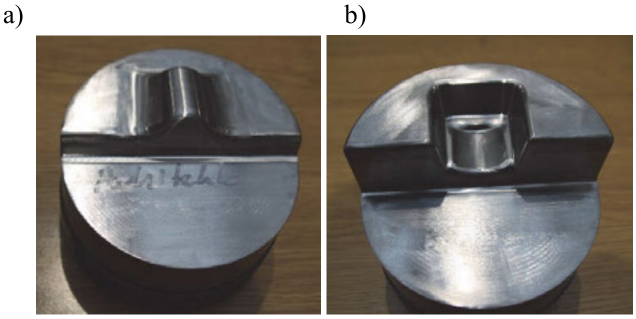

Fig. 8. A view of die inserts used in first operation (after the change): a) upper flattening tool (after the change) and b) lower flattening tools

The applied modification changed the manner of the material's flow in order to achieve a preliminary separation of the material in the area of the future fork of the yoke. This facilitated the filling of the flat and deep passes of the fork in the die insert as well as made it possible to reduce the amount of the material lost for the flash from the front of the forging. The numerical models of the forgings after the flattening operation in the current, as well as optimized, process are presented in Fig. 9.

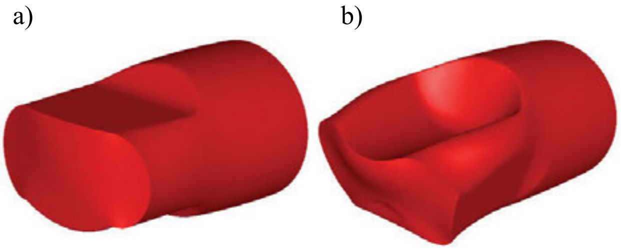

Fig. 9. Shapes of the forgings after flattening: a) before changes and b) after tool shape optimization

The performed forging trials of this element under industrial conditions confirmed the purposefulness of the introduced changes and the conducted numerical modeling (Fig. 10). We achieved a reduction of the input material's volume by over 10% and a significant decrease of the forging forces in the initial forging operation.

Fig. 10. Comparison of the forging shape: a) before tool modification and b) after tool modification [8]

3. Heating and lubrication of forging tools

A highly important parameter of the forging process, both in respect to the tool efficiency and the quality of the end product, is the temperature of the tools. Most forges currently apply old-fashioned, ineffective heating methods, which are often inefficient and difficult to control. This especially refers to the narrow tolerance ranges of the die and the small spaces between the movable and the immovable components of the tool systems, which can be blocked as a result of the thermal expansion of the material and the change in their dimensions. At a lower temperature, steel characterizes in a worse dynamic load resistance, and that is why a thermal shock caused by a high temperature gradient between the heated input material and the tool can result in its brittle cracking. The lack of control of the tool heating or an improper method of heating the dies by the heated preforms (Fig. 11), often met with in forges, prevents the achievement of the required temperature of the process. Additionally, this method exposes the surface layer of the tools to tempering, or even a damage to their layers and protective coatings. For example, in the analyzed process of a yoke forging, the maximal temperature on the surface of the tools equaled 160°C (Fig. 12), that is 90°C lower than the recommended temperature.

Fig. 11. Heating the tools by heated preforms

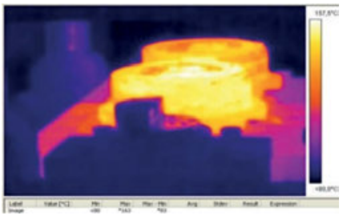

Fig. 12. Thermogram showing the temperature of the die inserts

Other tool heating methods are also used, such as the one applying gas burners (Fig. 13), or, in another case, the heating stage is entirely omitted.

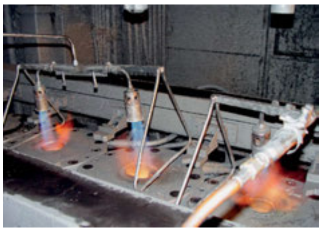

Fig. 13. Heating up the tools with gas burners

Fig. 14. Tools coated with foam used in welding without the necessity of pre-heating

In the analyzed forging process, coating the dies with a special foam used in the welding technology (Fig. 14), did not cause a drop in the efficiency of the forging tools.

3.1. Lubrication and cooling

The appropriateness of the shaping process largely depends on the used lubricant, whose task is not only a lubrication but also cooling of the tools. A lubricant should characterize in a high ignition point, so as not to lose its tribological properties at high temperatures, a low thermal conductivity, which makes it possible to both prevent a forging temperature drop and protect the tool from overheating, a proper viscosity at the working temperature and a low friction factor. Among the most frequently used in the forging process, we can name: graphite, Teflon, glass and other substances, as well as metallic interlayers of a low yield stress. The importance of lubrication for the tool temperature can be concluded on the basis of the die temperature course during the forging process (Fig. 15).

The authors constructed their own measuring system and performed a measurement of the temperature of the tools with the use of a thermocouple introduced into the die through a special groove. The measurement showed that a two-fold increase of the expenditure of the lubricant reduces the die temperature to about 100°C.

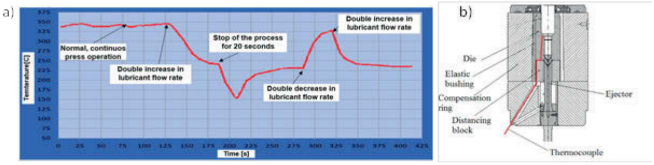

Fig. 15. A view of: a) die temperature course during forging with the marked most frequently occurring process disturbances, b) scheme of the thermocouple assembled in the tool [8]

Next to a proper selection of the lubricant, assuring its appropriate and uniform distribution is equally important. A proper lubrication not only determines the production of a forging without flaws, such as underfills, but also has a long-term effect on the tool wear and thus the shape of the manufactured product. Fig. 16 a) shows a standard lubrication technique used in crank presses.

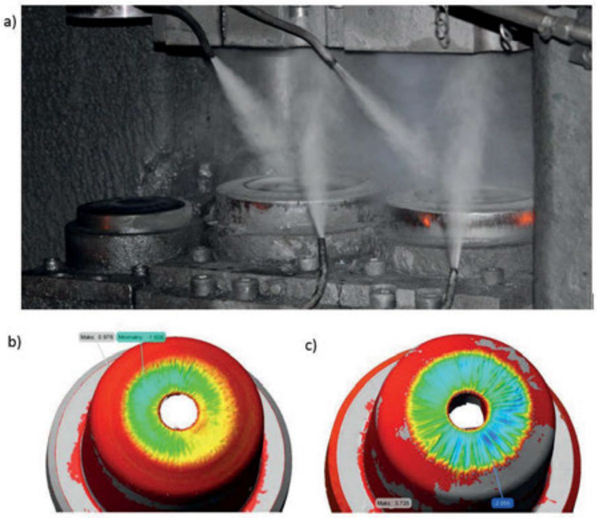

Fig. 16. A view of: a) standard technique of lubricant distribution, b) tool wear in the case of a uniform lubrication and c) tool wear in the case of a non-uniform lubrication

The angle and direction of the lubrication procedure largely depends on the manner in which the lubrication nozzles are set by the operator. No sufficient control of the lubrication process is the cause of a non-uniform wear (Fig. 16 b), which intensifies the damage and shortens the life of the tools, and in the case of a longer use, may affect the shape of the forging.

Also in the case of an automated lubrication manner, such as the one used in the forging of constant velocity joints, one can encounter problems related to tool lubrication. In this process, the tools are lubricated with the use of a specially designed ejector with nozzles. Six nozzles, uniformly distributed on the perimeter every 60°, deliver the lubricant at the moment of the forging's ejection, where the ejector is in the upper position. As a result, the inside surface of the die is coated with a layer of lubricant, with different intensities, depending on the proximity of the nozzle, and the degree of the wear in the joint perimeter is not uniform (Fig. 17).

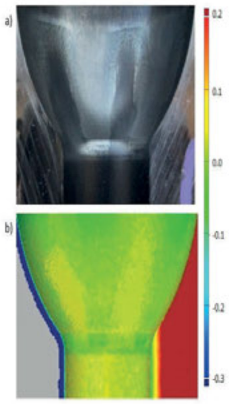

Fig. 17. Non-uniformly worn tool surface: a) digital image b) optical scan

On the surface of the tools, we can observe a clear difference between the bright areas (yellow areas, Fig. 17 b) and the dark areas, which was reached by a lesser amount of the lubricating liquid. In a tool which was not recognized as worn at the moment of the observation, one can clearly see a loss of the edge at the place of the narrowing. In the course of further use, the disproportion in the shape will be increasing, resulting in a shortened tool life. A solution to this problem can be eliminating the human factor for the sake of more accurate and properly controlled systems regulating the distribution of the lubricant agent.

An inappropriately selected dose of the cooling-lubricating agent can be the cause of premature fracturing of the tools and the creation of underfills. Such a problem was observed in the process of a yoke forging at the Jawor Forge. Fig. 18 presents a set of die inserts (upper and lower insert) for a yoke forging with the marked and zoomed area where fractures in the lower die can be observed. The increased value of pressure, caused by the presence of an air pocket in this area, accelerates the formation of microcracks and the, so called, Rebinder effect.

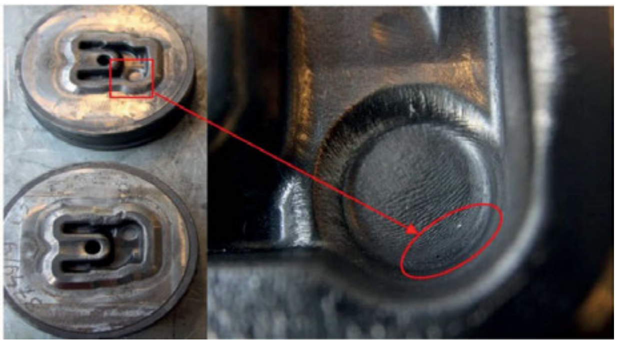

Fig. 18. Fracture in the corner of the die inserts and zoomed fractured area

As it was noticed, the excess of the lubricant, which has not managed to evaporate from the surface of the lower insert, causes the formation of underfills in the forging (Fig. 19 a). The numerical FEM modeling with an active 'trapp' function for air pocket detection, by means of the Forge program, showed that, during the initial forging process, empty spaces between the forging and the tool are formed, which contain air and the lubricant agent (Fig.19 b).

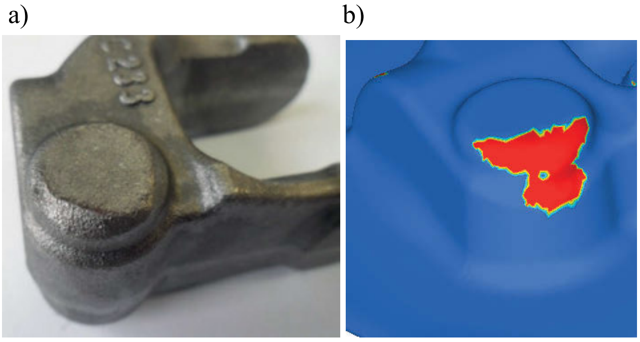

Fig. 19. Underfills in forging of yoke: a) actual forging and b) numerical model (underfilled air pocket area marked in red)

Fig. 20. A cooling-lubricating device regulating the supply of the lubricant agent

The formation of air-lubricant pockets causes an increase of the pressure in this area and often, also the presence of large underfills.

Providing the optimal working temperature and lubrication of the forging tools is very important from the point of view of optimizing their efficiency and assuring a high quality of the forgings. In order to stabilize and control these parameters, the authors constructed a special dosing device which assures a constant dosage of the lubricant-cooling liquid and the time of its application (Fig. 20). The device should minimize effects such as graphite accumulation on the surface of the dies, which, similarly to water accumulation, can cause the creation of air pockets, a non-uniform cooling of the tool surfaces, cooling of the forge as well as a constant dosage of the lubricant-cooling agent throughout the whole production time. The device allows for an adjustment of the dosage of the liquid ejected each time on the upper and lower tools as well as of the time of its application. The basic functional elements providing the repeatability of the lubricating cycles are the peristaltic pump powered by a stepper motor, which precisely regulates the liquid dosage, as well as a system of valves regulating the flow of the air which atomizes and pushes out the liquid, cleans the liquid distribution system and the head atomizing the applied liquid on the surface of the dies. A change in the supply time makes it possible to regulate the water content in a volume unit of the ejected air-water-graphite mixture. Longer supply times allow for a more effective cooling of the tool surface layer and leave the latter dry after the end of the cycle.

A properly selected time of lubricant ejection favours a proper liquid atomization, which hinders the processes of graphite accumulation in the bendings of the dies and the water residue on their surface.

The regulation of the liquid phase in the lubricant-cooling mixture consists in changing the opening time of the atomizing valve and the rate of the liquid flow to the atomizing head. The device is also equipped with an antisedimentary mixer, which maintains the homogeneity of the graphite suspension in the water, and this assures a constant amount of the lubricating agent. Maintaining the proper cleanness of the ducts supplying the head with the suspension is provided by the system controlling the pressures in the ducts. A change in the duct diameter, as a result of the graphite accumulation, increases the pressure in the lubricating system, which is inversely proportional to the fourth power of its diameter and which is constantly regulated by the controller. The device is equipped with an automated reverse air flow system, which is responsible for maintaining a proper flow capacity of the ducts.

4. Optimization and design

The most crucial issue determining the quality of the manufactured product is the design of the given production process. The stage of developing the given technology involves the determination of the shape of the final product, the required additional machining and the amount of the material lost for the flash. This also determines the wear of the tools and directly affects the production costs. Additionally, by properly directing the material flow, we can change its mechanical properties and thus affect its quality. That is why it is so important that the designing stage involve the use of all the available tools, such as the knowledge and experience of technologists as well as the modern software based on FEM, and, that the already existing processes be perfected during their use.

4.1. Development of the piston forging technology

Due to the increasingly restrictive ecological standards set for the modern motor industry, the requirements for particular vehicle components are constantly increasing. An example are engine pistons, which, because of the increasing combustion gas content limitations, are exposed to bigger and bigger loads. This results from the fact that, in order to obtain a less polluted combustion gas, we should increase the combustion temperature in the piston chamber, and this leads to its more rapid wear. In order to prevent this, the use of aluminum pistons is avoided for the sake of steel ones, and the technologists are challenged by the task of developing a demanding production technology which includes narrow, hard to fill, passes with high loads, related to the forming of steel. The main problems in the production of such a forging result from its complicated shape: thin side walls, causing high friction forces and a rapid cooling of the material, the effect of which is a premature forming of the flash (Fig. 21).

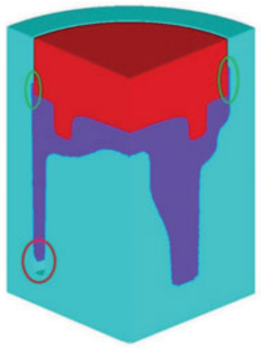

Fig. 21. FE model of a steel piston during its forming with marked areas: green – flash forming area, red – a still unfilled pass

During the design of the forging process, one should assure advantageous technological conditions of the element production, in respect of the maximal press load and the life of the tools, which is connected with additional limitations regarding the number and course of the particular forming procedures. FEM modeling for steel was performed by means of the software Simufact.forming 11.0. The technology of precise forging was assumed, according to which the element is produced in three procedures, and the thin flash flows out in the direction of the axis of the tool's movement. Next, in order to confirm the possibility to make a forging, physical modeling of the piston was performed with the use of lead as the model material. The shapes of the forgings after each procedure are presented in Fig. 22. Due to a possible load of the press, the tests were run in the scale 1:2.

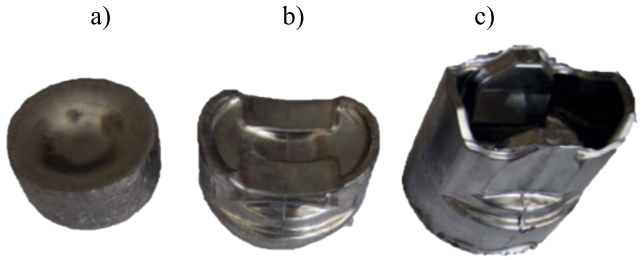

Fig. 22. Forging shapes after operations of: a) flattening, b) initial forging and c) finishing forging of a lead piston

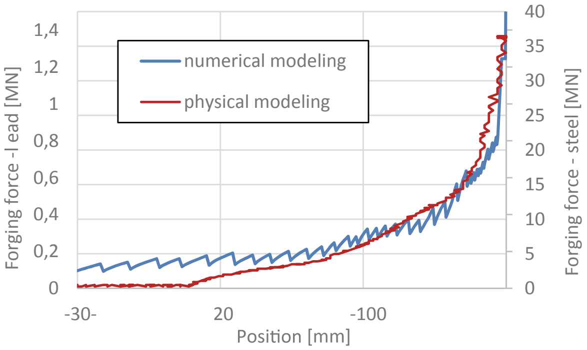

Fig. 23. Comparison of the forming force courses obtained from the physical and numerical modeling

As can be observed, the extrusion force is over 27 times higher for lead than in the case of the numerical model for steel formation (after scale consideration). The shape of the extrusion curves is similar. The obtained results confirm the validity of the set assumptions in FEM, which proves the appropriateness of the designed process.

4.2. Mass reduction of flange-type elements

In the case of improvements of the already existing processes, software applying FEM provides a detailed review of the performed production process and allows for introducing many refinements. The most frequent reason for modifying the existing technologies is the attempt at cutting the costs, which is usually connected with the reduction of the flash. An example of this can be the case analyzed by the authors, i.e. the hot forging process of a flange with a neck, implemented in 3 procedures: upsetting, initial forging and finishing forging. A numerical simulation with the consideration of the forging symmetry (with the use of 1/8 of the model) was performed by means of the program MSC.Marc 2013. We analyzed the shapes and filling of the forging pass and the numerical models; we also proposed changes aiming at a reduction of the mass of the input material and the maximal forging forces (reaching the values of about 2500 tons). As the possible ways of material reduction, we assumed a change of the inclination angle of the ejectors and a reduction of the thickness of the bottom in the centre of the forging, which serves as an outside flash, in order to increase the temperature of the upper part of the neck (Fig. 24).

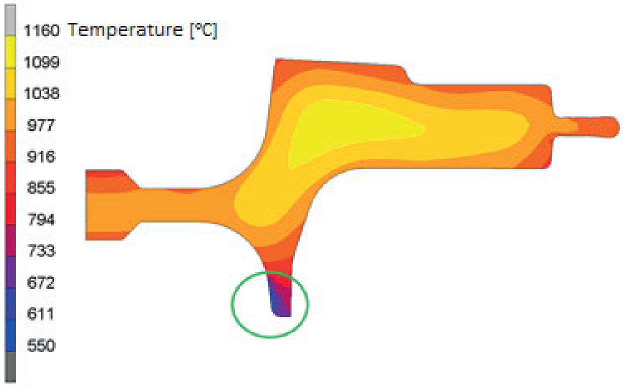

Fig. 24. Temperature distribution in the cross section of a flange-type forging with the marked area of cooling after die forging

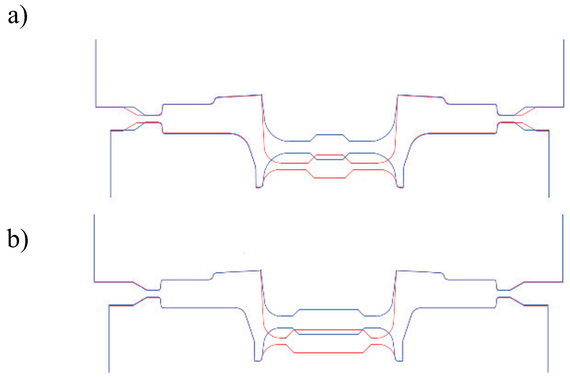

Fig. 25. Comparison of the die pass shapes before (blue color) and after(red color) modifications for: a) initial and b) finishing forging

Additionally, in order to limit the flash formed in the third procedure, we reduced the differences in the passes in the inserts between the second and the third procedure, thus reducing the shaping of the forging during the finishing forging to minimum. The shapes of the forgings after the particular procedures before the changes and after the change of the tool geometry are presented in Fig. 25.

The performed mass reduction of the forging process of a flange with a neck resulted in a reduction of the preform mass by over 6%. Additionally, it was possible to transfer a portion of the forming process from the second to the third procedure, at the same time, limiting the value of the forming forces for the initial and finishing forging procedure (Fig. 26).

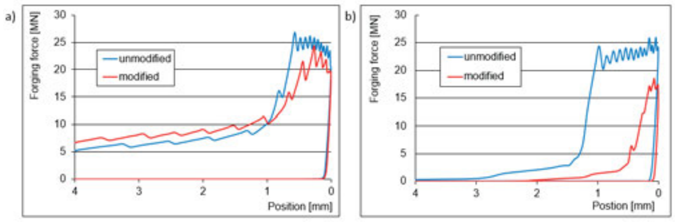

Fig. 26. Compilation of the forming forces for die forging: a) preliminary and b) finishing, before and after the introduced changes

At present, works on the implementation of optimization techniques are being employed, based on the Rosenbrock method, with the consideration not only of the location and thickness of the bottom, but also of the size of the bridge opening, as well as on transferring the introduced changes to other flange forgings.

5. Summary and conclusions

A properly designed and implemented forging process, which allows for the production of a repeatable series of forgings without flaws requires the selection of optimal technological parameters, such as a proper design and manufacture of tools, including the material selection and thermal treatment, and an optimization of the preform shape. A typical technological process of die forging consists of many stages, including: material delivery from the plant, its cutting, heating and forging, as well as a thermal treatment of the final product. At each of the mentioned stages, there is a potential risk of an error causing a forging flaw. As it has been proven in numerous articles and elaborations, the parameters affecting the die forging processes undergo complex interrelations, which significantly complicate the analysis of the forging processes. By using a series of techniques, such as physical and numerical FEM modeling, as well as many other computer supported information tools, the authors presented the methods and specific solutions to selected issues related to the die forging process. Further studies in this area and the constant technology progress should help solve such problems and improve the quality of the manufactured products, as well as increase the productivity and reduction of maximum forging forces. The results of preliminary numerical simulations of incremental forming and conventional forging proved that the presented forming method offers opportunity to reduce significantly required press load and to obtain more uniform strain distribution in a workpiece.

Acknowledgement

This research was carried out as part of project WND-POIG.01.03.01-02-063/12 “Development and implementation of accurate forging technology in Forge Jawor SA”

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Received: 15 September 2014.