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CLOSE-DIE FLASHLESS FORGING IN AUTOMOTIVE INDUSTRY

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ABSTRACT

This paper describes the possibilities and conditions of the closed-die flashless forging process using conventional mechanical presses and equipment. The technique of driven gear forging with an internal flash or with special die design has been developed. The quality of forgings is comparable to that achievable on Hatebur presses.
Furthermore the problem of how to increase shift production under the same conditions so that the same quality and accuracy are achieved will be discussed. The material flow in the die cavity is affected by die design. Numerical simulation was used to optimise this process.

1. INTRODUCTION

The importance of precision close-die forging is constantly increasing. The reason for this is the remarkable improvements in other manufacturing methods and economic pressures from international competition. The necessary conditions for the success and survival of today's forges is: reduction of machining allowances, production of draftless forgings with small tolerances for dimensions, and increased die life. All these requirements mean changes in our philosophy in our approach to die design together with the necessity of numerical simulation usage.
Different methods can be used to improve forging accuracy [1]. The solution is dependent on technical development, machine and equipment level, and the investment possibilities of individual forges. In the case of mass production, automatic forging machines are used, e.g., HATEBUR, and forging transfer presses. Another approach is to improve the die design, and the accuracy of the total forging process. The techniques used are precision forging methods. The die design principle corresponds to the name of the process as flashless and/or draftless forging, forging with an internal web, precision forging in closed dies with closing elements [2].

SKODA-AUTO a. s. is the main car manufacturer in the Czech Republic. The SKODA forge produces parts for Fabia, Octavia cars, for the MQ 200 gearbox and for the EA 111 03D engine. Due to the MQ 200 gearbox production project the decision has been taken to develop a new technology for precision gear forging. The basic requirement was to use the present forging machinery, but to increase forging quality and accuracy with reduced machining allowances.

2. THE ORIGINAL PRODUCTION METHOD

The input material is hot-rolled round bars with a diameter of 40±0.4 mm, length 5000 mm. Material grade CSN 41 4141 (DIN 34Cr4). Shearing is done on the automatic TNS 63 shearing machine. The weight of the slug is 0.62 kg with a tolerance of + 0.02 kg. Billets are induction heated to 1150ºC with a tolerance of 50ºC. The induction coil is equipped with an automatic slug feeder from the vibrating container. A heated billet enters the working die area by means of a gravity conveyer.

The forging machine is a mechanical LZK 1000-P vertical press with a nominal capacity of 10 MN and an idling speed of 100 rpm. The universal LU 160 mechanical press with a nominal load of 1.6 MN is used for the trimming and punching operation. The forging operations are the following: -Upsetting between flat dies,

-Forging in the finish dies,

-Punching and trimming.

The goal was to improve the present forging process for the third gear specifically, but the present machinery (mechanical presses and shears) with induction heating and an old die holder must be used.

3. THE HISTORY OF DEVELOPMENT

Phase I

Objective The development of the principle of precision forging for mechanical presses using our current mechanical equipment and types of tools.

Result The technique of precision forging in three forging steps. A slug is cut from a bar with a tolerance of H11 and the slug has a mass tolerance of + 0.01 kg.

However in comparison to the original forging process this new technique led to a reduction in shift performance.

Phase II

Objective To increase shift performance while still using the flashless principle.

Result The development of the flashless principle in two forging steps where the finishing operation uses the spring-load part of the die. The technique developed enables the use of hot-rolled round bars. A convenient technique for simpler forging shapes.

Phase III

Objective To increase shift performance, to make possible the forging of more complex forgings.

Result For the forging of more complex shapes of forgings, where multi-shape operations are necessary, originally developed a technique of precision forging with on internal flash was used, where the forging transfer between operations was accomplished by a transfer device.

A slug is cut from a hot-rolled round bar.

TECHNIQUE	Closed die forging	**PHASE I** Forging with an internal flash	**PHASE II** Flashless forging	**PHASE III** Forging with an internal flash
PREFORM	Hot-rolled round bar	Peeled bar	Hot-rolled round bar	Hot-rolled round bar
Forming operations	Upsetting Finish forging Piercing Trimming	Upsetting Preforming Finish forging Piercing	Upsetting Finish forging Piercing	Upsetting Preforming Finish forging Piercing
Duration of cycle	8.2 secs.	14 secs.	8.2 secs.	5.5secs.
SLUG WEIGHT	0.62 + 0.02 kg	0.48 + 0.01 kg	0.48 + 0.02 kg	0.48 + 0.01 kg

4. THE DEVELOPMENT OF PRECISION FORGING WITH AN INTERNAL FLASH

The following conditions have to be fulfilled: to reduce billet weight, to lower machining allowances, to minimise forging defects, and to increase die life. The present shears are able to keep the billet weight tolerances during the shearing process in the range of +0.01 kg. For safety reasons the design process should be done in such a way as to permit a weight tolerance of up to + 0.025 kg.

To meet these requirements it was necessary to use precision forging on the LZK 1000-P forging press in three forging steps. The new technology is based on the principle of flashless forging and adapted die design to prevent machine overloading, and to decrease the admissible mismatch. Special centring elements were used in the second and third forging operations. Due to the demand for the minimisation of machining allowances and possible surface defects it was necessary to use the peeled bars with a tolerance of H11.

4.1 The Methodology of the Die Design

In conventional dies the excess material flows into a flash. For flashless forging it is necessary to design a cavity (hole) for this material. One possibility is to use an internal web. This web is created while preforming operations and is usually located in the place that will be punched.

The first forging step is upsetting. The purpose of this operation is to remove the scale and to change the billet shape in such a way that the preform can be placed exactly into the blocking impression.

Fig. 1 Punched forging

The second forging step is preforming. The design of this impression is critical. The shape should allow for the creation of a space for the application of the principle of internal flash and the cavity should not be entirely filled during the flow of the material. The cavity underfill at the final die position is a function of weight tolerance. These requirements are achieved by the combination of two factors: the position of the internal dividing parting line and the shape of the upper die - usually the punch shape and its rounding. This task must already be solved beforehand by numerical simulation. The Russian software QForm has been used for this purpose [3].

In the third forging step the shape is finished and the excess material is pushed into the central web. The design of the finishing die has to ensure that the filling will be controlled by the pressure gradient. The design has to ensure not only the capture of excess material, but also the creation of sufficient pressure for the forming of forgings within the allowed tolerance limits of heating temperature and slug mass.

The final operation is piercing on a punching press. The high quality of piercing and the elimination of mismatching are accomplished by the guidance and exact positioning of the forging in the punching die, Fig.1.

The press stiffness, play in bearings, and surface clearance have a great influence on forging quality. Each forging operation has its specific forging load. Changes in load mean changes in machine behaviour and different forging heights. The forging operation with the highest forging load has the highest spring-back. A forging operation with a lower load has a lower spring-back. This phenomenon should be considered when adjusting the distance between die inserts during upsetting. The preform shape and dimensions are changed according to the load. Details are explained in the lecture " Near Net-Shape Closed-Die Press Forging ", CO-MAT-TECH 2000.

4.2 Trial production results

The required forging quality and tolerances on dimensions were achieved during our trial production in operating conditions. The three-operation forging sequence increases the forging quality and accuracy, but at the same time reduces output.

5. THE TWO-OPERATION FORGING SEQUENCE

We had decided to develop a new technique that will combine both effects. High shift output achieved during the original forging process with flash in two forging steps and the quality of the three-operation precision forging process with high accuracy and lower material consumption. A further requirement was to cut down the time needed for tool change.
The problem of quick tool exchange was solved by the development of a special die holder. The principle used was that only die inserts are changed, but the holders themselves remained fixed to the press ram. The advantage of such a solution is that it is not necessary to readjust the dies to avoid mismatch when the inserts are exchanged.

5.1 Tool design

In a two-operation forging sequence the final shape of forging is created in one forging operation only. Thus preforging is possible only during upsetting. The second function of the upsetting operation is to ensure the exact position of the preform in the final impression.
The positioning is made possible by means of the inner diameter of the final cavity. But the external diameter of the billet after upsetting varies due to the changes in billet weight and heating temperature. Heating temperature deviations thus influence both the preform volume change and the preform shape.
The maximum admissible heating temperature and maximum slug weight are the decisive factors when designing how to fix the position of a preform in the final impression. At the same time it is necessary to solve the problem of oblique sheering surfaces that cause the deviation of outer diameter roundness.
The final die has been designed in a different manner than the die design in the three-operation forging sequence. The basic difference is that the die has a spring operated inner part. The pre-loading has to be set up on such a level that the cavity is filled in the range of allowed heating temperatures and billet weights. The forging load increases dramatically towards the end of the die-filling process. The movement of this spring-operated element compensates for this rapid load

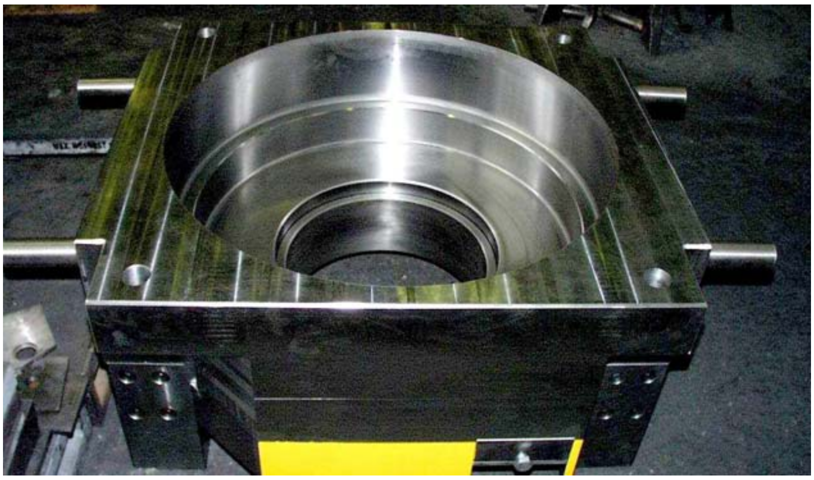

Fig.2 Upper part of the jig

increase. The excess material, forging volume, machine positioning and shape changes due to the temperature and slug weight are included in this movement. The result is a deviation in forging height. The final height tolerance is thus influenced by the billet weight tolerance rather than by the temperature deviation.

The development of the whole jig was made possible only with the aid of the DEFORM 2D simulation software. The proposed design has been optimised from two standpoints: the jig stress state and temperature field during forging.

To achieve the highest possible forging quality, it is necessary to ensure the material flow in a prescribed manner. The critical part for flashless forging is the outer parting plane usually in the upper part of the die. The cavity should be completely filled before the material reaches this place. Acceptable underfill of this corner is a measure of overloading (i.e. the spring-loading of the spring-operated element was set at a lower value). The most important factor was the position of this parting line and the value of fillet radius.

A new type of jig was designed to meet the given requirements, Fig. 2. The upper part is guided in all four corners. This principle enables the very precise guidance of the upper and lower die holders. The maximum possible alignment of both dies (upper and lower) is achieved by means of a circular guide. The movement of the lower holder in two axes provides for the exact setting of the die holders. The die inserts are fixed into die holders. Their exchange is made directly in the machine by loosening several screws.

A special device is placed in the upper part of the jig. The purpose of this device is to transfer the preset load on the spring-loaded element of the die. The preset load can be changed according to the course of the forging load on stroke.

5.2 Results

This forging technique with a so-called spring-loaded element has been tested to determine the limiting range of billet weight tolerances. The lower limit for a given forging has been set according to the minimum forging height, and with respect to the acceptable degree of edge

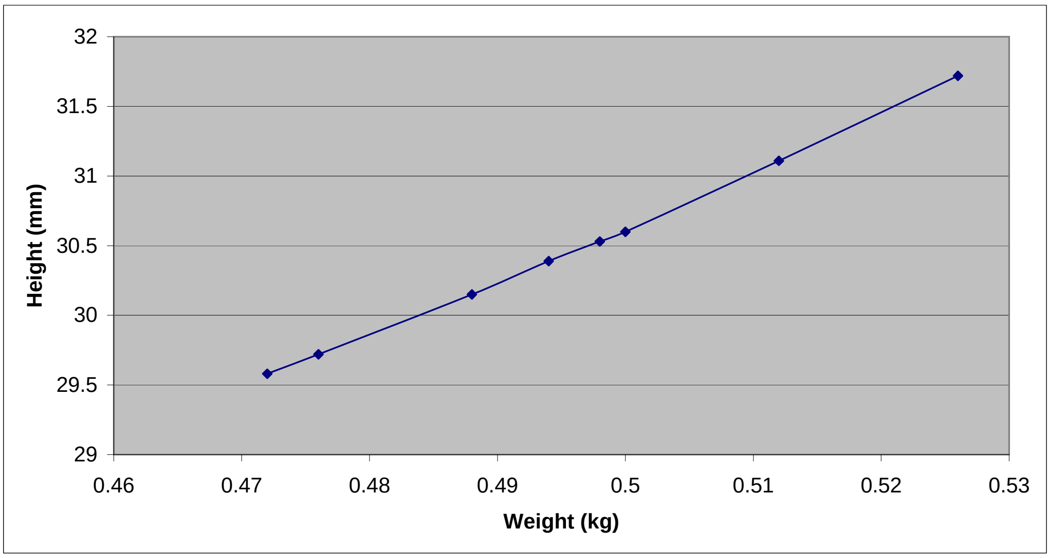

Fig.3 Height of gear part as a function of billet weight

underfill. The upper limit has not been set because increasing the billet weight only increases the height of the forging with little influence on material flow, (Fig.3). Thus the billet weight tolerance is a compromise between the possibility of precise slug cutting and forging height tolerances, (Fig.4).

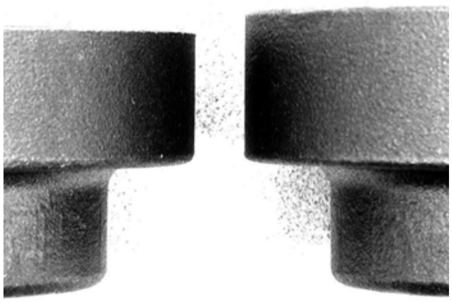

Fig. 4 The forging height difference

6. PRESS FORGING WITH A TRANSFER FEEDER

The three-operation forging sequence (see Article 4) has the advantage of being able to minimise die wear due to flashless forging and optimise material flow. The disadvantage of this technique is a lower shift output. Forging with an automatic feeding system between individual stations is one of the ways to solve this problem. This forging technique is also being developed in the SKODA forge shop. The forging is fed into a constant machine cycle by the transfer feeder. The vertical LZK 1600 (nominal capacity 16 MN) forging press has been chosen for this task as it has a large working area. All forging operations are involved, including punching. The implementation of trial forging is currently being planned.

7. CONCLUSIONS

The flashless forging process using conventional mechanical presses and equipment is possible only if special precautions are used for die design. Numerical simulation is a fundamental condition.

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KOVANJE U ZATVORENOM KALUPU

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REZIME

Značaj preciznog kovanja u zatvorenom kalupu je u stalnom porastu. Neophodni preduslovi za uspešnu primenu kovanja u savremenim uslovima su: smanjenje dodataka za obradu, otkovci sa uskim tolerancijama kao i povećana postojanost alata. Sve navedeno zahteva suštinske promene dosadašnje koncepcije procesa kovanja i konstrukcije alata. Pored toga neophodne su i numeričke simulacije procesa kovanja.

Različite metode se primenjuju u cilju povećanja tačnosti kovanja. Koja od metoda će se primeniti zavisi od opšteg tehničkog nivoa razvoja, nivoa opreme kao i od sposobnosti za investicije. U masovnim proizvodnjama koriste se automatske kovačke mašine (npr. Hattebur) kao i kovačke transfer prese. Drugi pristup je povišenje tačnosti alata i celog procesa kovanja (tj. precizno kovanje).

Rad daje prikaz mogućnosti primene kovanja u zatvorenom kalupu korišćenjem konvencionalnih mehaničkih presa i opreme. Razvijen je novi postupak kovanja pogonskog zupčanika. Kvalitet otkovka je identičan onom koji je dobijen na Hattebur presi. Korišćena je i numerička simulacija procesa.

Istraživanja su fokusirana na otkovke koje se proizvode u firmi ŠKODA – AUTO (Češka Republika) gde se kuju otkovci za proizvode Fabia, Octavia, MQ 200 i EA 11 03D.

Novo razvijeni metod morao je ispuniti zahtev da bude sprovodljiv na već postojećoj opremi a da – i pored toga – daje precizni otkovak, sa smanjenim dodatkom za obradu.