International Journal of Analytical, Experimental and Finite Element Analysis (IJAEFEA), Issue. 2, Vol. 2, June 2015.
e-ISSN: 2394-5141, p-ISSN: 2394-5133, pp 64-66

Designing A Forging Die for Hanger Bolt using CAD

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***Abstract*— The life of a forging die and the amount of flash produced in forging are the main issues of concern in all forging operations together with material wastage, overall cost and post process trimming costs. While proper control of the flash is essential to ensure die filling, the service life of hot forging die depends mainly on thermal, mechanical and combined stresses. Geometrical design of the pre-form has significant relationship with the forging load and flash amount in forging complex parts. This paper deals with flash reduction of forging die for a Hanger Bolt, commonly used in lifts, by using flash less forging approach. It is revealed that the preform can be accurately designed to control volume distribution, complete filling of the cavity and to avoid overloading the dies. Application of CREO software has been demonstrated in designing the die with the objective of minimizing the flash.**

***Index Terms*—** forging, flash, die design, preform, die design.

I. INTRODUCTION

Hot forging, which is also referred to as drop forging, it is a process that used in producing a wide variety of parts of most metals. It is a near net shape process. The principles and practices of hot forging are well established and the basic procedure for hot forging is relatively straightforward. Several improvements have been made over the years in equipment, lubricants, and the ability to process the 'more difficult to forge' materials [1]. Computer aided design and analysis is being increasingly made use in the recent years to increase die life and productivity. The proposed work relates to development of a flash less die using CAD to control the amount flash produced in forging operations.

A metal billet is heated in the starting in the hot working temperature range to enhance ductility. Then material is squeezed to change the billet into the finished shape [2]. Flash a scrap part is produced in forging unavoidably. For good die filling, particularly for elevated, slender shape features, controlled amount of flash is essential. Since flash is nothing but a scrap, its generation beyond permissible limits amounts to material wastage, increase in overall cost as well as the cost of the post process trimming and finishing operations that yield the finished product. The extent of the flash produced is sometimes more than 50% of the final part volume [3]. This is indeed a matter of great concern to forging industries not only from material and finishing costs cost point of view but the electrical energy that is normally spent for heating the performs in furnaces.

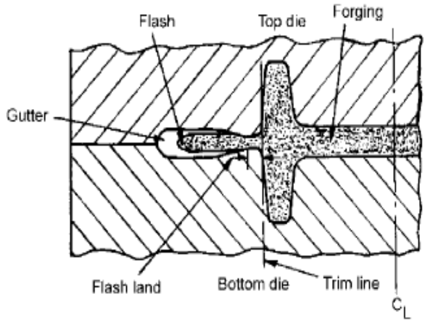

Fig. 1. Flash land and flash gutter configuration.

II. IMPORTANCE OF A FLASH IN THE PROCESS FORGING

The amount of flash produced in a forging operation increases with the complexity of the part [4].

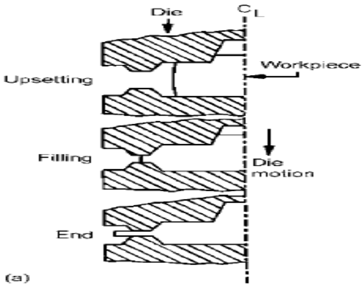

Fig. 2. Forging of a simple axis symmetric part

If material is to be forced to move into the extremities of the die cavity, this sideways material flow must be restricted. Provision of a narrow flash land around the split line of the dies restricts the sideways flow of the material [5]. A typical arrangement for the flash land and the flash gutter on a forging is shown in Fig. 2. The gutter must be large enough to accommodate the flash produced. The choice of the appropriate width and thickness of the flash land is an important part of the forging process design. If the geometry is wrong, the dies may not fill completely or the forging loads may become excessive.

TABLE 1. EMPIRICAL RELATIONS USED TRADITIONALLY FOR DESIGNING FLASH LAND GEOMETRY [6].

Reference	Flash thickness, T_f (mm)	Flash land ratio, W_f/T_f
Brachanov and Rebelskii [3]	$0.015A_p^{0.5}$	—
Voiglander [4]	$0.016D + 0.018A_p^{0.5}$	$63D^{0.5}$
Vierrege [5]	$0.017D + 1/(D+5)^{0.5}$	$30/[D\{1 + 2D^2/(h(2r+D))\}]^{0.33}$
Neuberger and Mockel [6]	$1.13 + 0.89W^{0.5} - 0.017W$	$3 + 1.2e^{-1.09W}$
Teterein and Tarnovski [7]	$2W^{0.33} - 0.01W - 0.09$	$0.0038ZD/T_f + 4.93/W^{0.2} - 0.2$

A_p, forging projected area (mm^2); W, forging weight (kg); D, forging diameter (mm); Z, forging complexity factor.

The following empirical relationships based on earlier studies are conventionally calculates flash area in forging [7].

Flash thickness,
Tf = 1.13 + 0.0789 *V0'5* - 0.0001347.

Flash land ratio,
Wf/Tf = 3 + i.2e-ao°85W.

The recommendations vary significantly. The length of the flash line is multiplied by the land width, *Wf* of the finish forging die as presented in Table 1 above. However, availability of modern computational and analysis tools have paved the way for optimally designing the flash formation and do away with the empirical rules.

III. FLASH CONTROL TECHNIQUES

Flow material depends on the following [8]:

1. Geometry of the cavity.
2. Geometry of the flash opening.
3. Initial and intermediate billet geometry.
4. Percentage of flash.
5. Heat transfer between the tooling and the billet.

The first method to make a coarse preform from a non-porous billet and hitting in a press until the final shape get. This methods outcome is 20±40% material waste in the form of flash [8]. Advantage of closed-die forging with flash is, preform volume can vary within a wider range than that of flashless forging, but a trimming process is required to remove the flash.

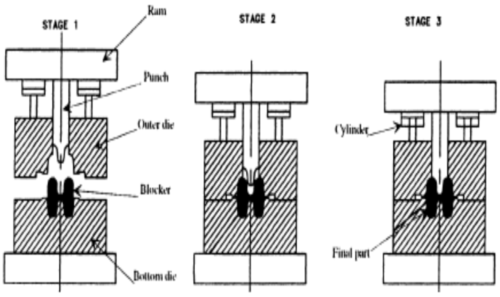

Fig. 3. Concept of tooling in forging for flash control.

Another method is flashless forging. The preform is completely enclosed in the die cavity to do not allow flash. In that process no material waste in impression forging. Though, fixed volume control of the preform is necessary for insuring cavity filling and avoids trimming.

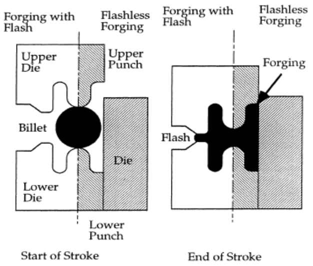

Fig.4. With and without flash closed-die forging

Requirements to perform a successful flash less forging process are [9]:

- The volume must be same for initial preform and cavity at the end of the process.
- There is neither volume excess nor shortage, so the positioning of the preform and mass distribution is exact.
- If there is a compensation space in the dies, the real cavity must be filled first.

IV. HANGER BOLT DIE DESIGN METHODOLOGY

This paper is concerned with the design of a forging die for manufacturing hanger bolts such that the flash produced is the minimum possible. First of all the original hanger bolt is designed and tested to know whether it is safe or not in terms of the strength for envisaged application.

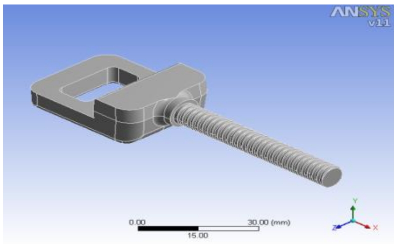

Fig.5. Original hanger bolt.

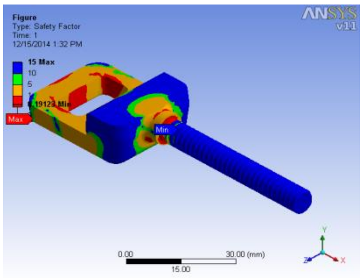

Fig.6. Hanger bolt with a safe design.

V. EXISTING DIE DESIGN

The existing die of a hanger bolt produces a flash of about 2 mm to 2.25 mm. This is aimed to be reduced by improvising the die design.

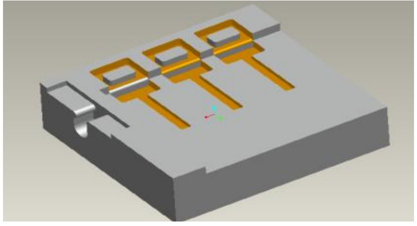

Fig.7. Existing three-stage die for a hanger bolt.

This die is containing three cavities i.e. rough, blocker and finish. To get the finish product billet have to pass through each cavity. This process is time consuming because of multiple operations done at the same die. Existing die is operated under hammer forging. In this the flash is produced is required to be removed by another operation to get a final product.

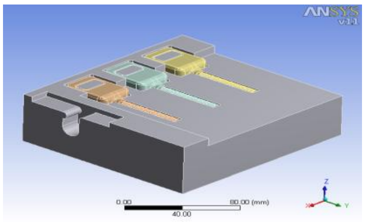

Fig.8. Existing die

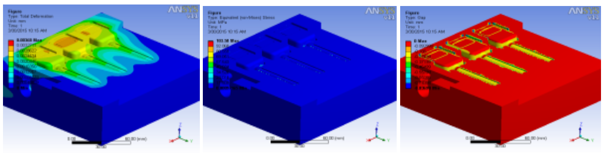

Fig.9. Failure analysis of existing die -total deformation, equivalent stress, gap formation

VI. SINGLE SIDED DIE

To avoid multiple processes and time, a new flash less die has been designed for operation on a hydraulic press. This single sided die provides final product without flash because the new design does not have gutter and flash land which are the main factors for the flash. The proposed single sided die consists of only the final single cavity which, as compared to existing die with three cavities, is easier to design. Besides, it saves die sinking time.

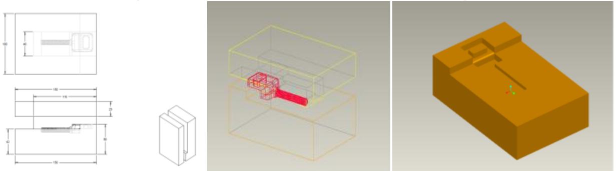

Fig.10. Single sided die design for a hanger bolt

Failure analysis of a single sided die is presented below for comparison.

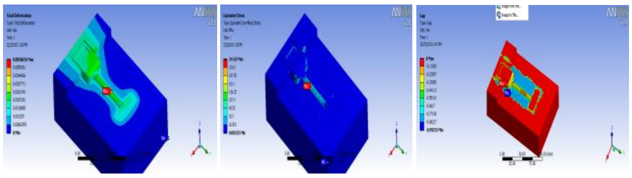

Fig.11. Failure analysis of single sided die - Total deformation, equivalent stress, gap formation

V. CONCLUSION

For designing and developing a forging die main parameters are selection of material, temperature, die design and flash produced. This paper is focused on these parameters for good life of a die and to control flash produced in forging. The dies must be kept under compressive stress state as the forging pressure applies tensile stresses on the dies which will cause failure under tension. This precaution is necessary taken to avoid failure of die. Mechanical stress is nearly 10 times less than thermal stress at the die cavity surface, the most probable failure location. So the die material should be selected with high room temperature, specific heat capacity and temperature-sensitive. As flash is a necessary part of the process and so some scrap is inevitable.

TABLE 2. COMPARISON OF TWO DIE.

Material Properties For alloy Steel	Young's Modulus (Mpa)	200000
	Poisson's Ratio	0.3
	Density (kg/mm3)	0.00000785
	Die 1	Die 2
Mass	8.7026 kg	11.542 kg
Volume	1.1086e+006 mm^3	1.4703e+006 mm^3
Total Deformation	5.6656e-003 mm	6.8355e-003 mm
Equivalent Stress	241.65 MPa	86.861 MPa
Shear Stress	34.74 MPa	14.351 MPa
Max Shear Stress	134.5 MPa	46.972 MPa
Gap Formation	-0.99255 mm	-1.414 mm

A single sided die is a better solution in the existing production situation and is recommended for production of hanger bolt by forging.

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