Die Life Prediction of Connecting Rod SIFL-175

P.D. Skariya[1], M. Satheesh[2], J. Edwin Raja Dhas[3]
Assistant Professor, Vidya Academy of Science and Technology, Thrissur, Kerala, *skariya2005@gmail.com*
Assistant Professor, Noorul Islam University, Thuckalay, Nagercoil, *satheeshudaya@gmail.com*
Professor, Noorul Islam University, Thuckalay, Nagercoil, *edwinrajadhas@gmail.com*

***Abstract*—**This work mainly focuses on the life prediction of hot forging dies of connecting rod SIFL-175. This prediction helps the forging industry in estimating the quantity of products forged before reworking or resinking and thereby can supply the forgings to the customer at reasonable lower price and this will also escalating the demand from the customer. The prediction of die life is vital to satisfy demands for lower cost and shorter production preparation times. The prediction helps the company to make an accurate production planning process and can take necessary steps and actions to utilize the maximum quantity of products before die failures.

Keywords- *Forging, Die life, SIFL-175*

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I. INTRODUCTION

Steel and Industrial forgings Ltd (SIFL) is one of well known forging companies in India and is an ISO 9001 – 2000 certified organization. The SIFL-175 is a connecting rod manufacturing by SIFL for Indian railways. The major objective of the project is to predict the life of hot forging dies of connecting rod SIFL-175. The forging dies of SIFL-175 are made up of classic die steel or hot working steel and the grade is DIN-2714 as per the German standard. Life of forging die depends on several factors including die material and hardness, work metal composition, forging temperature, condition of the work metal at forging surfaces, type of equipment used and work piece design, and a variety of other factors. [1] The die life prediction of connecting rod SIFL-175 is calculated using various parameters.

II. LITERATURE REVIEW

2.1 Forging process

Forging is the process of heating metal by the application of sudden blows or steady pressure and makes use of the characteristic of plasticity of the material. A metal such as steel can be shaped in a cold state but the application of heat lowers the yield point and makes permanent deformation easier. [2] Forging by machine involves the use of dies and is generally used in mass production. Thus, forging refers to the production of medium size and heavy parts in large scale using closed heating furnaces and heavy hammers, forging presses and machines.

2.2 Optical pyrometer

Optical pyrometer is an instrument used to measure the temperature of a product or material. A single laser light is the source of the instrument. The temperature range is 200^0C to 1800^0C. The sensor in the instrument senses the temperature using laser light and indicating the temperature in the display. The instrument is used in the study for measuring the temperature of the billet and dies.

2.3 Portable Brinell hardness tester

It is an instrument used to measure the hardness of a material. The range of the hardness is 100 to 450 BHN. It is light weight and is used in the study to check the hardness of the die. The hardness is indicated in the display of the equipment. The Rockwell hardness tester is used to check the hardness above 450 BHN.

2.4 Tensile testing

The tensile test is done using universal testing machine (UTM) and is one of the most widely used mechanical tests. A tensile test helps determining tensile properties such as tensile strength, yield strength, % elongation, % reduction in area and modulus of elasticity.

2.5 Life prediction of forging dies

During the hot forging process, the temperature of a die increases due to the contact between the dies and the hot deforming material. The rate of temperature rise can be attributed to several factors, such as the initial temperature of dies and billet, the contact time and pressure, the die material and surface treatment conditions. [3] The thermal softening induced by this temperature rise gradually reduces die hardness, and finally leads to the plastic deformation of a die.

The longer contact time at the elevated temperature gives rise to a decrease of the surface hardness of a die. In order to consider the thermal softening effect in estimating die service life against plastic deformation, it is required to introduce the tempering parameter, M.

$M = T \times (C + \log 10\ t) \times 10^{-3}$ [4]

Where T is the tempering temperature (K), C is the material constant and‘t’ is the tempering time. Also, from starting to deform until ejecting the forged part, the temperatures of die surface change during forging, so the introduction of equivalent temperature is required. The equivalent temperature, T_{eq}, can be approximately expressed as shown in equation given below.

$T_{eq} = (2T_{max} + T_{Min})/3$ [4]

Where T_{max} and T_{min} are the highest and lowest temperatures during forging respectively.

To estimate die service life for the plastic deformation of a die induced by thermal softening, the tempering time t, is replaced with hardness holding time t_h, where t_h is the time which takes until initial die hardness gradually reduces to reach the critical hardness by thermal softening, as shown in equation given below.

$t_h = e \times ((M_{yield} \times 1000)/ T_{eq}) – C)$ [4]

Where M_{yield} is the M value where initial die hardness equals the corresponding hardness of the yield strength of the die.

When the material is a perfect plastic, the hardness (BHN) of material is about one third of the yield strength of material. The die steel had the first tempering for 20 h at 600 ^{0}C and the second tempering for 19 h at 570^0 C. Therefore, for estimating the die service life considers the first and second tempering time, t_1 and t_2 as shown in equation given below.

$t_h = e \times ((M_{yield} \times 1000)/ T_{eq}) – C) - t_1 – t_2$ [4]

Then the die service life is expressed as the maximum possible production quantity.

III. EXPERIMENTAL DETAILS

A lot consists of 20 billets and a single billet is selected for study. The study is conducted in ten such lots. The die temperature after the forging of the final product is checked. The maximum die temperature observed from the ten lots is 456^{0}C or 729K and based on this temperature die life predicion is calculated. The contact time is calculated using stopwatch. The material constant of die steel is 20. [5] The contact time is 0.32 sec or 8.88 x 10^{-5} hr.

3.1Tempering parameter

The tempering parameter is calculated using contact time, contact temperature and material constant. [4] The tempering parameter from the calculation is 11.63.

3.2 Equivalent temperature

The maximum and minimum temperature during the forging of the final billet in the particular lot is measured using pyrometer and using the formulation equivalent temperature is calculated. [4] The maximum temperature is 729K and the minimum temperature is 694K. The equivalent temperature obtained from the calculation is 717K.

The initial hardness of the die is checked by the portable Brinell hardness tester and the die Hardness is358 BHN. The yield strength of the die is calculated using the tensile testing machine (UTM).

3.3 Tensile testing

The standard diameter of the tensile testing specimen is 12.5 mm and the calculated area is 122.66 mm^2. The load at the yield point is 119 KN obtained from the experiments and converted to mass is 12142.86 Kg. Using the load at yield point and area of the specimen, the yield strength can be found out and strength is 99 Kg/mm^2. The M_{yield} obtained from the calculation is 41.86.

3.4 Hardness holding time (t_h)

The hardness holding time is expressed as the die life. The hardness holding time is calculated using M_{yield}, material constant and equivalent temperature. [4] The hardness holding time t_h obtained from the calculation is 103.61 hrs.

3.5 Die life

The die life is obtained by substracting the first and second tempering time from the hardness holding time. The die life is expressed in hours.

3.6 Tempering of die steel (Heat treatment)

The heat treatment of die steel consists of three stages i.e. normalizing, hardening and double tempering. The soaking time of the first tempering of die steel is 20 hrs and the soaking time of second tempering of die steel is 19 hrs. The first tempering, t_1 is 20 hrs at 600 ^{0}C and second tempering, t_2 is19 hrs at 570 ^{0}C. The die life obtained from the calculation is 64.6 hrs.

3.7 Production quantity

The production quantity is expressed as the maximum quantity. The time of forging for one product is two minutes and fifty two second. So the time taken for forging one product is 2.86 min. Therefore twenty one products can be forged per hour and the maximum quantity obtained is 1357 pieces.

IV. RESULTS AND DISCUSSION

4.1 Therotical calculations

The maximum quantity obtained from theoretical calculations is found out and tabulated. The parameters in theoretical calculations is found out using standard formulas [4] and the results directed towards the calculation of the maximum production quantity. The parameters and results are tabulated in table 4.1.

Table 4.1. Standard parameters and results

SI No.	Parameters	Results
1	Tempering parameter	11.63
2	Equivalent temperature	717K
3	Yield strength	99 Kg/mm^2
4	M_{yield}	41.86
5	Hardness holding time	103.61 hrs
6	Die life	64.6 hrs
7	Production quantity	1357 pieces

4.2 Die set

There are six set of dies i.e. A,B,C,D,E and F. A single set consists of top and bottom dies. When a top die of A set is rejected, the forthcoming die is named as A set. The top die of C set is considered for this study.

4.3 Die history of C-set

The die history card contain the details of dies which include die failure correction and number of component forged before each failure correction. Die run number means how much time use this particular die. The details is shown in the table 4.2.

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Table 4.2. Life history of top die of C set

SI No.	Die Run No.	Top die	No. of pieces forged
1	C01	Fresh sinking	492
2	C02	G&P	806
3	C03	Bulging grinded & resinked	680

4.4 Comparison of theoretical & experimental study

The total no of pieces forged before rework is calculated experimentally and theoretically. The differnce in the quantity is found out from the theoretical die life prediction and the actual number of products forged i.e. experimentally. The number of pieces forged after fresh sinking is 492 pieces. The number of pieces forged after grinding, polishing and plaser of paris is 806 pieces. The number of pieces forged after profile bulging, surface cracks occurs and die resinked is 680 pieces and the Die broken after 680 pcs. The total no of pieces forged using the C-set die is 1978 pieces. The number of products forged before resinking is 1298 pieces. The difference in the quantity calculated from the die life prediction and the actual no of products forged is 59 pieces.

4.5 External factors affecting the die life

The major external factors affecting the die life are given below.

1.Sticking of billet to the die cavity: It is due to the improper lubrication or the low temperatue of the billet.

2.Handling delay: When delay happens while transferring the billet from the furnace to the forging press, the temperature of the billet drops and the number of blows will be increased for complete forging.The increase in the number of blows will lead to the surface cracks in dies.

3.Forging time : Due to the lack of skillness of the operator, the contact time during forging is more and this leads to the increased heat transfer in dies results in the profile bulging or surface cracks.

V. CONCLUSION

A detailed experimental investigation was carried out at SIFL for the calculation of life prediction of hot forging dies of connecting rod SIFL-175. The calculation of die life prediction can estimate the quantity of products forged before reworking or resinking and the company can take preventive measures for increasing the die life. The comparison of theoretical and experimental study and the study of external factors affecting the die life proves that the prediction is almost accurate.

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