Simulation of a hot forging Process for 42CrMo4 Connecting rod in application of reduction in Unfilling

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Abstract

The objective of this paper is to find an optimum temperature range in which no unfilling is found in hot forging of connecting rod made of 42CrMo4. Connecting rod is one of the most important components in automobile. It is very helpful in machines where reciprocating motion is converted into rotary motion.The current rejection rate due to unfilling is 2.1 %. So, process parameters affecting Unfilling were identified. Other parameters affecting were also discussed in detail in So, in order to achieve the required objective of minimizing Unfilling, simulation of temperature at which billet is forged (the most affecting parameter for unfilling defect) is done using DEFORM 3D software, which is a powerful tool for analyzing material flow. The validation of the simulated range will be taken and experimented in the industry.

Keywords: Forging, Forging Defect, Unfilling, Simulation, DEFORM 3D*, FEM*

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1. INTRODUCTION :

Forging is defined as a metal working manufacturing process in which the useful shape of work piece is obtained in solid state by compressive forces applied through the use of dies and tools. The required shape is obtained from a simple shape like billet, bar, ingot into the desired shape in one or more stages. It is one of the oldest methods in metalworking operations, dating back at least 4000 B.C. Forging were first used to make jewelry, coins and various implements by hammering metal tools made of stone. Traditionally, forging was performed by a smith using hammer and anvil. Using hammer and anvil is a crude form of forging. The smithy or forge has evolved over centuries to become a facility with engineered processes, production equipment, tooling etc.[O]

Various forging products are: crank hook, connecting rod, gear, pinion, crown wheel, crankshaft etc. In the forging process, starting material has comparable simple geometry; then the material is plastically deformed in one or more operation using heat and applying load into a product of relatively complex configuration. In forging product, elongation occurs plastically, and usually exhibits much better ductility in a direction parallel to that of plastic elongation. Grains are oriented parallel to elongation due to plastic deformation. Defects are defined as imperfections that exceed certain limits due to unexpected occurrences. There are many imperfections which are considered as being defect, ranging from those traceable to the starting material to those caused by one of the forging processes or by post forging operations like trimming, coining or cooling.[O]

Classification of Forging:

a) ***Hot Die Forging (Most Widely Used):-*** In this type of forging, the process is carried out at a temperature above the recrystallization temperature of the metal. The recrystallization temperature is known as the temperature at which the new grains are formed in the metal. Extreme heat of this kind is very necessary in avoiding strain hardening of the metal during deformation.

Advantages: High strain rates and hence easy flow of the metal, Recrystallization and recovery are possible. Forces required are less.

Disadvantages: Lubrication is difficult at high temperatures, Oxidation and scaling occur on the work piece, Poor surface finish, less precise tolerances, Possible warping of the material during the cooling process. [O]

b) ***Cold Forging:*** Forging is carried out at or near room temperature (below the recrystallization temp.) of the metal. Carbon and standard alloy steels are most commonly cold-forged. Cold forging is generally preferred when the metal is already a soft, like aluminum. This process is usually less expensive than hot forging and the end product requires little or no finishing work. Cold forging is also less susceptible to contamination problems, and the final component features a better overall surface finish.

Advantages: Very high production rates with better die life expectancy; mechanical properties are improved; friction is very less between die surface and work piece; easy lubrication; neither oxidation nor scaling on the work.

Disadvantages: Occurrence of residual stresses; requirement of heavier and more powerful equipment; stronger tooling is needed; tool design and manufacturing are very hard. [O]

2. MATERIAL SPECIFICATION :

The material used in forging of connecting rod is DIN – 42CrMo4

	Elements (%)	**Lower limit**	**Higher limit**
Constituents of 42CrMo4	C	0.38	0.45
	Mn	0.5	0.8
	Si	0.15	0.35
	Cr	0.9	1.2
	Mo	0.15	0.25
	S	-	0.035
	P	-	0.035
	Hardness (BHN)	260	300
	Tensile strength (N/mm^2)	865	1005

Table 1: *Material Specification [O]*

3. NUMERICAL SIMULATION USING DEFORM-3D :

DEFORM is a Finite Element Method (FEM) based process simulation system designed to analyze various forming and heat treatment processes used by metal forming and related industries. It is also used dynamic analysis. It will be useful to know about the flow of material in die cavity after simulation.

For hot forging, it has its own module under FORMING category. The billet here is heated up to a certain temperature after which the required shape is achieved after material is plastically deformed on application of compressive forces on the billet.

In this paper, the forging problem of UNFILLING which occurs a lot in connecting rod is analysed and an optimum temp range is found at which forging of workpiece may give completely filled cavity. The material used is as said above – DIN 42CrMo4.

3.1 Building of die to be used in DEFORM with the help of NX-11.0:

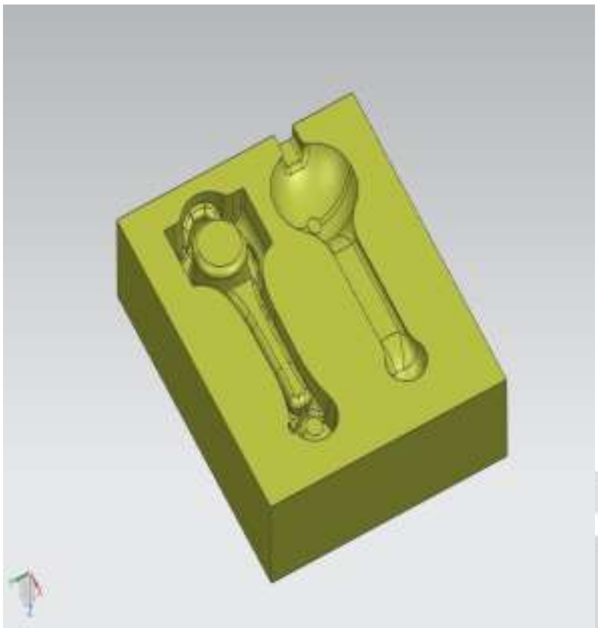

Fig 1: *Upper die*

Fig 2: *Lower die*

Die dimensions – 1.5% dimensions of the connecting rod to be used in project

Fig 3: *Connecting Rod*

3.2 Preprocessor steps :

The dies built in NX-11.0 are uploaded into DEFORM 3D in form of **.stl** whose tolerance is 1e-5.Besides this, all the other input parameters are also provided. These input parameters include the material of the workpiece and the dies, object meshing, temperature range, friction-coefficient, positioning of workpiece etc.

The input parameters used are as follows:

Other Parameters Included	
PARAMETERS	VALUES

Environment Temperature	35⁰C
Top and Bottom die temperature	150⁰C
Displacement	100mm (resized after original 12 foot)
Friction co-efficient	0.3
Heat transfer co-efficient	5
Convection co-efficient	0.02
Tolerance for Geometry	1e-5
Drop Hammers	2.5 tons
Mesh density	75000

Table 2*- Input parameters*

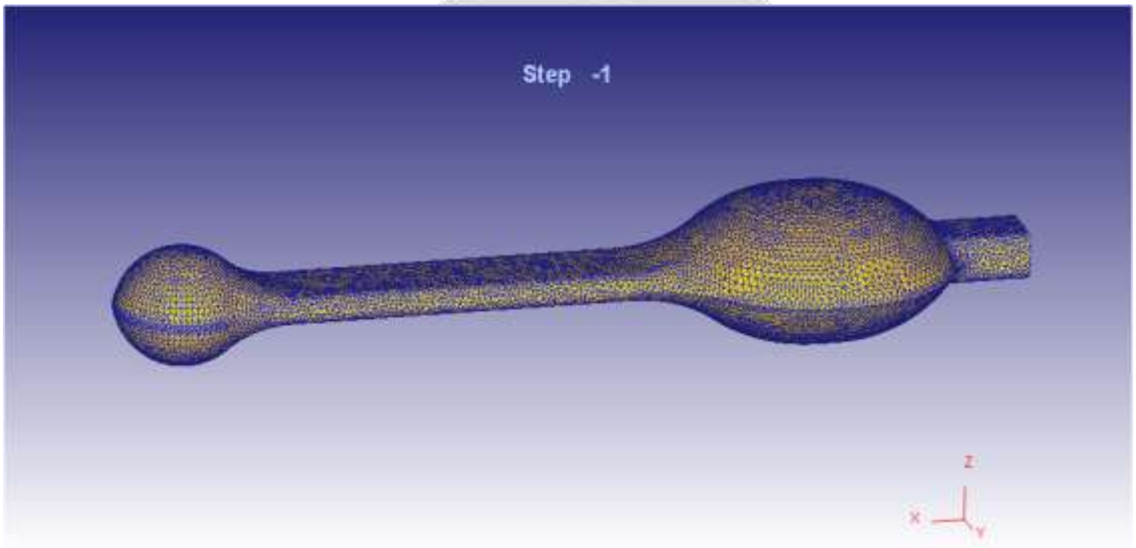

Fig 4: *Meshing of billet*

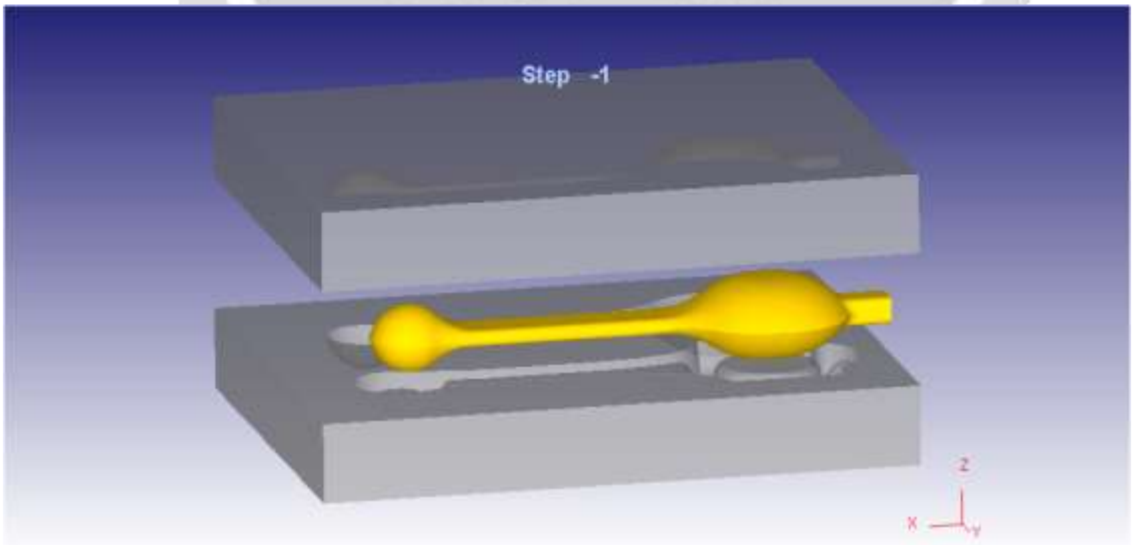

Fig 5: *Positioning of w/p for starting simulation process*

3.3 Simulator steps :

Data is checked after the preprocessing is completed and database is generated from it. The simulation is run after tht. The simulation can be paused in between and we can check whether the material flow is uniform in the die cavity or not.

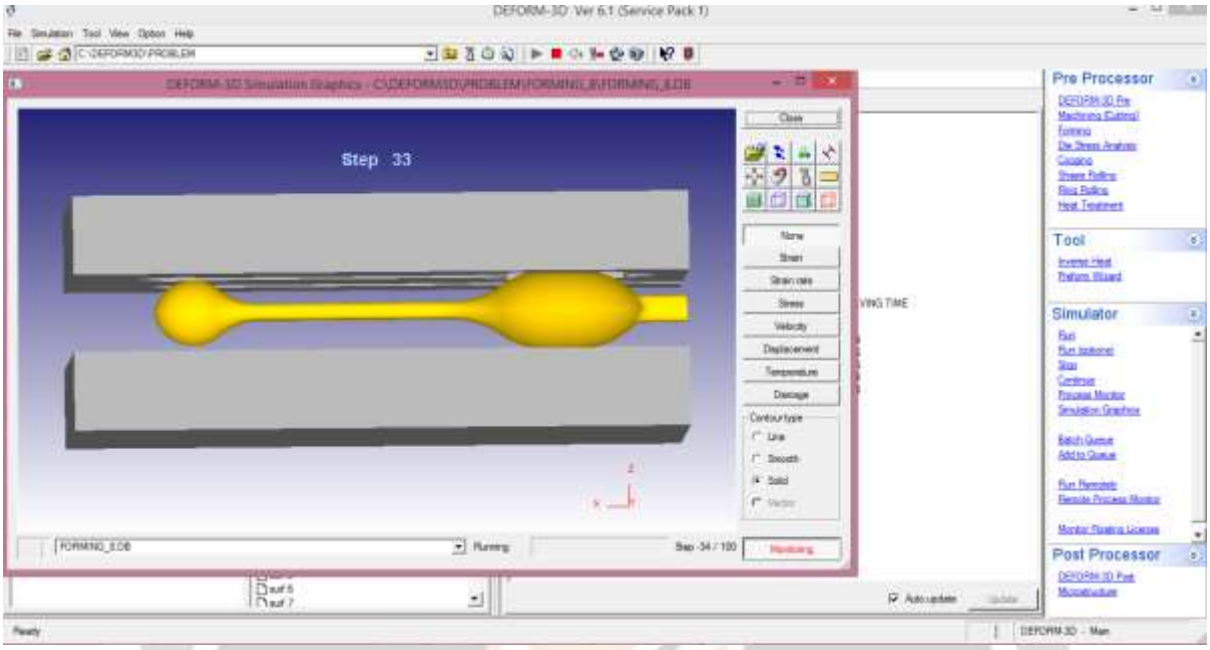

Fig 6: *Ongoing steps and material flow can be analysed using simulation graphics*

3.4 Post-Processor :

The results of the simulation are seen in the post-processor along with some other options as well. Even animation of all steps combined as full process can be seen.

4. RESULTS AND DISCUSSION :

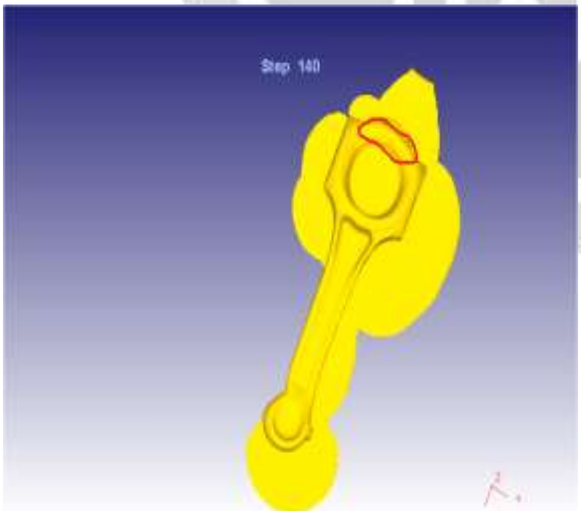

Fig 7: *Unfilling at 1120⁰C*

Fig 8: *Unfilling at 1160⁰C*

Fig 9: *Fully filled at 1200⁰C*

Fig 10: *Fully filled at 1250⁰C*

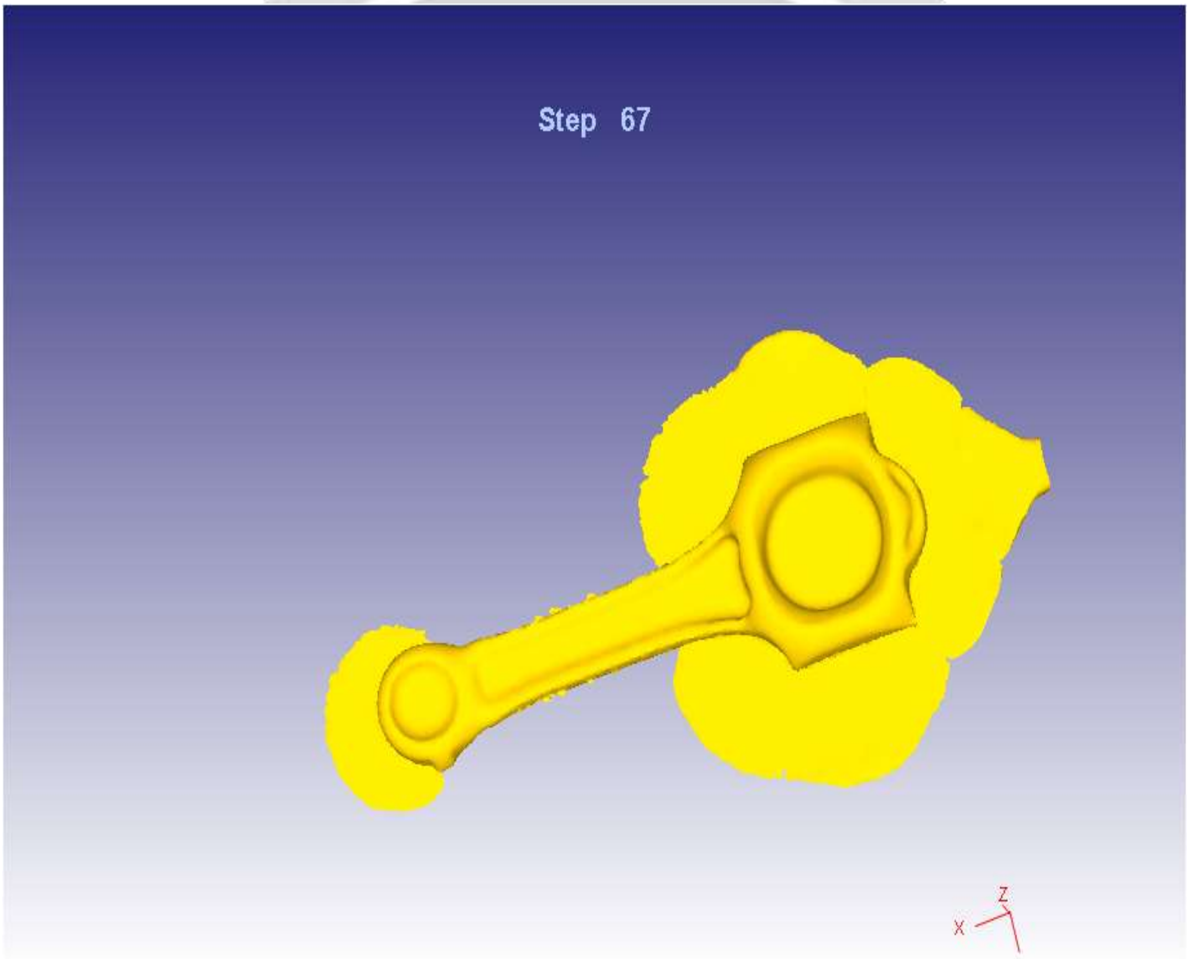

Fig 11: *Fully filled at1230⁰C*

It is concluded from above 5 simulations that unfilling defect is found at 1120^0C &1160^0C. No Unfilling defect is found at 1200^0C, 1230^0C and 1250^0C. So, 1200 - 1230^0C is the temperature range of 42CrMo4 where no unfilling is found. Simulation is carried out at finishing stage. Drop in temperature after rolling process is 20^0C. So, experiments to be carried out is from range 1220^0C - 1250^0C.

5. EXPERIMENT FOR VALIDATION OF SIMULATION RESULT

After finding the temperature range from the simulation, validation is necessary for the results so 15 experiments at different 15 temperatures has to be carried out.

Step 1:- Rods are cut in to proper size from billet 75 x 75 and length 186mm by using band saw or billet shearing machine.

Step 2:- Heating of billet into oil fire furnace up to 3 forging temperature ranges i.e. from 1240ºC-1270ºC and approx. 15 different ranges of temperature.

Step 3:- Placing billet in between upper & lower die using tong and completing forging in two stages i.e. forging rolling and finishing.

Step 4:- Visual Inspection is carried out after completion of forging

Temperature (^{0}C)	Output (after Inspection)
1220	No Unfilling Found
1223	No Unfilling Found
1226	No Unfilling Found
1228	No Unfilling Found
1230	No Unfilling Found
1234	No Unfilling Found
1236	No Unfilling Found
1238	No Unfilling Found
1240	No Unfilling Found
1240	No Unfilling Found
1242	No Unfilling Found
1244	No Unfilling Found
1246	No Unfilling Found
1246	No Unfilling Found
1250	No Unfilling Found

6. CONCLUSION :

Thus, with the help of DEFORM-3D, simulation was carried out at different temperature ranges for forging of connecting rod. From the simulation it is seen that 1220ºC- 1250ºC is the optimum temperature range where no unfilling is found. So, further experiments were carried out to validate the simulation results by performing 15 experiments. Result found was very satisfactory with no defects at all which in turn served as validation for simulated range.

7 REFERENCE :

A) Md. Israr Equbala, Randhir kumarb,Mohammad Shamimc, R.K. Ohdard, A grey-based Taguchi method to optimize hot forging process, Procedia materials Science 6(2014) 1495-1504, 2014 Elsevier

B) S Debin and Y Lin, Hot Forging, Comprehensive materials Processing, Volume 5 2014 Elsevier.

C) Z.J.Zhang , G.Z. Dai, S.N.Wu, L.X.Dong , L.L.Liu, Simulation of 42CrMo steel billet upsetting and its defects analyses during forming based on the software DEFORM-3D,Materials Science and Engineering A 499 (2009), 49-52, 2008 Elsevier

D) Mahendra G. Rathi, Nilesh A. Jakhade, An effect of forging process parameters on filling the job weight:-An Industrial case study,International Journal of Scientific and Research Publications, Volume 4, Issue 6, June 2014 ISSN 2250-3153

E) J.P. Fuertes, C.J. Luis , R. Luri , D. Salcedo , J. Leon , I. Puertas , Design, Simulation and manufacturing of a connecting rod from ultra-fine grained material and isothermal forging, Journal of manufacturing Processes 21 (2016) 56-68, 2015 Elsevier.

F) Mr.Bhavesh V Patel, Dr.Hemant R Thakkar, Prof. Shruti B.Mehta, Review of Analysis on Forging Defects for Quality Improvement in Forging Industries, Journal of Emerging Technologies and Innovative Research (1407054) , Volume 1, December 2014

G) Hyunok Kima, Taylan Altanb, Effects of surface finish and die temperature on friction and lubrication in forging, Procedia Engineering 81 (2014) 1848 – 1853 , 2014 Elsevier

H) Mahendra G. Rathi, Nilesh A. Jakhade, An overview of of Forging process with their defects, International Journal of Scientific and Research Publications, Volume 4, Issue 6, June 2014 ,ISSN 2250-3153

I) Aju Pius Thottungal, Sijo.M.T, Controlling Measures to Reduce Rejection Rate due to Forging Defects, International Journal of Scientific and Research Publications, Volume 3, Issue 3, March 2013 ,ISSN 2250-3153

J) A.D. GUNDKA, A.D. JADHAV, A.L. KIRAD, T.S. DIMBLE, Billet Sorting Mechanism for Reducing the Rejection Rate in Forging Operation,ISSN 2393-8471 International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME) Vol. 2, Issue 1, pp: (36-47), Month: April 2015 – September 2015

K) Pankaj Chandna,Arunesh Chandra, Quality Tools to Reduce Crankshaft Forging Defects: An Industrial Case Study, Journal of Industrial and Systems Engineering Vol. 3, No. 1, pp 27-37 Spring 2009.

L) Taylan Altan, Victor Vazquez , Status of process simulation using 2D and 3D finite element method 'What is practical today? What can we expect in the future?' , Journal of Materials Processing, Technology 71 (1997), 49-63, 1997 Elsevier

M) YANG Qingchun,QU Shengnian,ZHU Qi,MIN Naiyan , FE simulation method for a forging system, Journals of Materials Processing Technology 63 (1997), 678-683, 1997 Elsevier

N) Marek Hawryluk ,Joanna Jakubik, Analysis of forging defects for selected industrial die forging processes, Engineering Failure Analysis (2015), 2015 Elsevier

O) Lakhan Thakkar, Hardik Chauhan, Manoj Sheladiya, A review on Unfilling defect Found in Hot Forged 42CrMo4 Connecting Rod, Trends in Mechanical engineering and Technology, Volume 7, Issue 1, STM Journals 2017.

P) Zakaria Allam, Eric Becker, Cyrille Baudouin, Régis Bigot, Pierre Krumpipe, Forging process control: Influence of key parameters variation on product specifications deviations, Procedia Engineering 81 (2014) 2524-2529, 2014 Elsevier