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A Survey of FEA-Based Field Research Topics in the Forging Process

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***Abstract-* One of the fundamental manufacturing processes is forging. It establishes the mechanical characteristics of the item in the first stage of manufacture because it is a main metal forming technique. A good forging is defined by an aligned grain flow pattern and sound metal flow. The many forging research fields are covered in the current publication. The many fields are essentially the angles from which to create a high-quality product. The untapped study areas that still need to be investigated are also provided.**

Keywords- Forging, Finite Element Analysis, Numerical Simulation, Forging Defects, Optimization

I. INTRODUCTION

One of the main methods for creating metal is forging. It has an advantage over other procedures since it produces goods with greater mechanical qualities and uses the least amount of material during manufacturing. Because forged parts are strong and durable, they can be used in important and highly stressed applications including bevel gears, crankshafts, axles, and connecting rods. The material properties of the workpiece, such as its strength, ductility, rate of deformation, temperature sensitivity, and frictional properties, as well as the preform design, die design, and die material, all have an impact on the forging operation. The type of forging press or hammer being used, the friction between the die and the workpiece, the forging load, the speed at which the press operates, the number of strokes needed, the temperature of the workpiece and the dies, etc. are all process parameters. [67, 68]

LITERATURE REVIEW

The literature for forging is divided into various categories depending on the research done like defect removal, optimization of process, design of preform for forging, etc. The techniques used in the papers, the modifications done, results observed and case studies have also been discussed.

A. Defect Removal

Defect removal is a critical area of forging research because of the high losses resulting from rejections or rework in forging industry. The various geometrical defects that occur are lapping, mismatch, scales, quench cracks, underfilling, etc. [Thottungal and Sijo, 2013]. These can result from a poor design or poor execution of manufacturing or due to material related problems. These defects were investigated and rectified by various researchers using case studies of integral axle arm [Mathew, Koshy and Varma, 2013], axially symmetrical and flanged components [Chan, Fu and Lu, 2010], synchronizer ring [Chen, Zeng and Zheng, 2010], stud bolt [Doddamani and Uday, 2012], steel end plate used in automobile axles [Gulati et al., 2012], etc. The table1 describes the techniques used, modifications done, software used and the observed results in detail.

TABLE I DEFECT REMOVAL

Reference	Aim of Research Work	Technique used	Modification done	Software used	Component	Results observed
[Thottungal and Sijo, 2013]	Controlling Measures to Reduce Rejection Rate due to Forging Defects	FEA	Material flow, proper lubricant, anti-scale coating, venting process to prevent underfilling	-	General	Better quality of forgings
[Mathew, Koshy and Varma, 2013]	Study of Forging Defects in Integral Axle Arms	Pareto chart, Cause and effect diagram	Process and design parameters	-	Integral Axle Arms	Proper scale removal resulted in complete filling of die, lap formation was reduced
[Chan, Fu and Lu, 2010]	FE Simulation-Based Folding Defect Prediction and Avoidance in Forging of Axially Symmetrical Flanged Components	FEA	Variation of geometry parameters and identification of the sensitivity of each parameter to folding defect	-	Automotive part	Material flow was improved and folding was removed
[Chen, Zeng and Zheng, 2010]	Numerical analysis and defects of forging technology for synchronizing steel ring of automobile	FEA	Change in workpiece diameter, die structure and friction factor	DEFORM 3D	Synchronizing ring	Defect free forging, relation between maximum load and friction factor, effective strain distributions, effective strain rate distributions, effective stress distributions, velocity distributions and the load-stroke curves
[Doddamani and Uday, 2012]	Simulation of Closed die forging for Stud Bolt and Castle Nut using AFDEX for prediction of defects	FEA	Process and design parameters	AFDEX	Stud bolts and castle nut	Effective stress, complete filling of die, load stroke curve
[Gulati et al., 2012]	Simulation and optimization of material flow forging defects in automobile component and remedial measures using deform software	FEA	Change in positioning of billet	DEFORM 3D	Steel end plate used in automobile axles	Defect free part, temperature distribution, scrap volume

B. *Ease of Manufacturing*

Viability of manufacturing components is another aspect that is of importance to the industrialists which aids in the manufacturing of part with minimum forging load [Lei and Lissenden, 2001]. It can be executed through a proper die design, optimum billet shape and size and optimum process conditions [Mangshetty and Balgar, 2012]. These have been explained through various case studies have been taken up by researchers which include parts like wear specimen and centre guide [Lei and Lissenden, 2001], helical forging [Yang, Chang and Wang, 2010], aluminium alloy wheel [Zhu et al., 2010], etc. The details are given in the table II.

TABLE II EASE OF MANUFACTURING

Reference	Aim of Research Work	Technique used	Modification done	Software used	Component	Results observed
[Lei and Lissenden, 2001]	FE simulation of ausforming of austempered ductile iron components to investigate the viability of manufacturing of the component	FEA	Change in design of perform and die set geometry	DEFORM 3D and ABAQUS	Wear specimen and centre guide	Optimum forging load, equivalent plastic strain distribution and the final geometry
[Yang, Chang and Wang, 2010]	Predictions of Maximum Forging load and Effective Stress for Strain-Hardening Material of Near Net-Shape Helical Gear	FEA, Abductive network	Variation of material parameters like yielding stress, strength coefficient and strain hardening exponent	DEFORM 3D	Helical Gear	Optimum forging load, effective stress
[Zhu et al., 2010]	Forging Simulation of Aluminum Alloy Wheels	FEA	Process parameters like billet temperature, punch speed, lubrication	SUPERFORM/ SUPERFORGE	Aluminium alloy wheel	Reduction in the number of steps of forging required, Reduction of billet weight, elimination of folding defect, complete filling of wheel rim
[Nefissi, Bouaziz and Zghal, 2008]	Prediction and simulation of axisymmetric forging load of aluminium	FEA	Process and design parameters	DEFORM	Basic upsetting	Load stroke curve, load prediction
[Mangshetty and Balgar, 2012]	Billet shape optimization for minimum forging load using FEM analysis	FEA	Use of Fem and ADPL algorithm and modification of billet shape	ANSYS	General	Crack free forgings, minimum forging load, von mises stress, displacement plot, radial and hoop stress plot, contact pressure plot, strain values

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C. Process Optimization

The forging process can be optimized by variation of various process parameters like punch velocity, friction coefficient, temperature, etc. [Feng and Hua, 2010]. An optimized process is a good approach because it gives a good quality forging with minimum forging load. Various components have been studied like automotive starter motor ring gear [Wang et al., 2010], compressor blade [Zhang et al., 2010], helical gears [Feng and Hua, 2010], pneumatic clamp [Milutinović et al., 2011], spindle and gear [Bonte et al., 2010], reservoir forging [Chiesa et al., 2004], screw head and clinched joint [Chenot et al., 2011], etc. The following table III gives the details.

TABLE III PROCESS OPTIMIZATION

Reference	Aim of Research Work	Technique used	Modification done	Software used	Component	Results observed
[Wang et al., 2010]	Numerical simulation and Analysis of Forging Process for Automotive Starter Motor Ring Gear	FEA	Optimization of process parameters	-	External boss and internal gear for automobile	Proper metal flow, stress distribution and strain distribution
[Zhang et al., 2010],	Process Optimization for Isothermal Forging of TiAl Compressor Blade by Numerical Simulation	FEA	Modification of perform dimensions	DEFORM 3D	Compressor blade	Optimized process, effect of friction coefficient on forging load, thickness of flash and microstructure
[Feng and Hua, 2010]	Process parameters optimization for helical gears precision forging with damage minimization using FE simulation	FEA	Modification of process parameters like punch velocity, friction coefficient, temperature	DEFORM 3D	Helical Gear	Optimized process, maximum damage factor vs punch velocity, friction coefficient, temperature and distribution of damage factor
[Schaeffer, Brito and Geier, 2005]	Numerical simulation using finite elements to develop and optimize forging processes	FEA	Process and design parameters	Q Form 3D	Billet	Optimized process, flow curves at different temperatures and strain rates
[Milutinović et al., 2011]	Design of hot forging process of parts with complex geometry in digital environment	FEA	Process and design parameters	Simufact	Pneumatic clamp	Reduced flash, complete filling of die, effective stresses, reduced material required for preform
[Bonte et al., 2010]	Optimization of forging processes using Finite Element simulations	FEA	Use of metamodel algorithms to optimize forging	-	Spindle, gear	Decreased energy consumption and folding susceptibility of gear, sound results
[Chiesa et al., 2004]	Parallel Optimization of Forging Processes for Optimal Material Properties	FEA	Process and design parameters	PRONTO2D	Typical reservoir forging	Yeild strength contour, stress states
[Chenot et al., 2011]	Numerical Simulation and Optimization of the Forging Process	FEA	Process and design parameters	Forge 3	Screw head, clinched joint	Von mises stress distribution, tension test, surface response

D. Preform Design

Preform design includes the changing the billet shape, flash thickness and width, corner and fillet radii for reduced forging loads and complete die filling [Equbal et al., 2012]. A good preform design aids in the proper distribution of metal in the die cavity. The case studies taken up by researchers include rail rection and 3D metal hub [Thiyagarajan and Grandhi, 2005], pinion and helical gearing [Kang, Kim and Kang, 2007], connecting rod [Equbal et al., 2012], gear [Haider, Pathak and Agnihotri, 2010], etc. The tableIV defines clearly that FEA has been widely used for analysis.

TABLE IV PREFORM DESIGN

Reference	Aim of Research Work	Technique used	Modification done	Software used	Component	Results observed
[Thiyagarajan and Grandhi, 2005]	3D preform shape optimization in forging using reduced basis techniques	FEA, reduced basis techniques	Change of billet shapes	DEFORM	Rail section and 3D metal hub	Strain variance, flash volume, underfill volume, load
[Kang, Kim and Kang, 2007]	Numerical analysis and design of pinion with inner helical gear by FEM	FEA	Design of preform	DEFORM 3D	Pinion and helical gearing	Effective strain, load stroke curve, harness distribution
[Equbal et al., 2012]	Preform Shape Optimization of Connecting Rod using Finite Element Method and Taguchi Method	FEA, Taguchi method	Modification of billet shape, flash thickness and width, corner and fillet radius	DEFORM 3D	Connecting Rod	Forging load, defect free forging, complete die filling, metal flow
[Haider, Pathak and Agnihotri, 2010]	Preform design for near net shape close die gear forging using simulation technique	FEA	Modification of preform	Simufact	Gear	Effective stress, load stroke curve, maximum effective plastic strain

E. Damage Models

Damage models define the behavior of the system during forging. Various failure criteria are available, the suitability of which can be figured out using experimentation which can define the workability limits of forging [Rao, Kumar and Ramakrishnan, 2007]. The damage models can be compared using FEA technique to find out which one depicts the damage effectively [Christiansen et al., 2013]. The details are given in tableV.

TABLE V DAMAGE MODELS

Reference	Aim of Research Work	Technique used	Modification done	Software used	Component	Results observed
[Rao, Kumar and Ramakrishnan, 2007]	Investigation of the effectiveness of theoretical failure criteria in the estimation of Workability Limits in Cold Forging through FEA	FEA	Variation of failure criteria	ABAQUS	Upsetting	Maximum principle stress, hydrostatic stress, effective strain, Gurson's RD, hoop stress, axial stress
[Christiansen et al., 2013]	Modelling of Damage During Hot Forging of Ingots	FEA	Use of different ductile damage criterion	-	Upsetting of flanged part	Damage criterion, stress triaxiality, equivalent plastic strain, element strain loading paths
Meidert, Walter and Pohlandt]	Prediction of fatigue life of cold forging tools by FE simulation and comparison of applicability of different damage models	FEA	Application of various damage models	DEFORM and ANSYS	Cold forging tools	Damage after deformation of workpiece

F. Die Analysis

Die life is an important parameter in forging industry because of the high cost of die involved. Fatigue analysis of dies using FEA can give a good estimation of life of forging die and punch [Horita et al., 2012]. The surface texture of die is also an essential criteria because it affects the coefficient of friction and hence the metal flow in forging [Menezes, Kishore and Kailas, 2010]. The wear of die can be reduced by changing the rotational speed of the upper die, feed rate of the lower die, diameter workpiece [Han and Hua, 2013]. The details are given in the tableVI.

TABLE VI DIE ANALYSIS

Reference	Aim of Research Work	Technique used	Modification done	Software used	Component	Results observed
[Horita et al., 2012]	Fatigue Analysis of Forging Die	FEA	Forgings tests, bending fatigue tests	SIMUFACT, CYBERNET, ANSYS	Forged part	Load vs stroke, fatigue analysis of forging die, stress distribution, stress intensity factor
[Menezes, Kishore and Kailas, 2010]	A Study on the Influence of Die Surface Textures during Metal Forming Using Experiments and Simulation	FEA	Compression tests and variation of friction coefficients	DEFORM 3D	Cylinder	Variation of coefficient of friction with sliding distance, surface roughness, surface texture, load stroke curve, effective stress, maximum principle stress, strain rate
[Han and Hua, 2013]	3D FE Modeling Simulation for Wear in Cold Rotary Forging of 20CrMnTi Alloy	FEA	Modification of rotational speed of upper die, feed rate of lower die, outer/inner diameter of the ring workpiece	ABAQUS	Cold rotary forging of ring	Contact pressure, slip distance response, wear response, friction calibration curves, energy curves of deforming workpiece

G. Comparison of Constitutive laws

Constitutive equations define the flow stress of material. Forging force, stress and strain can be studied to compare the constitutive laws to find out which one gives better results [Pantalé and Gueye, 2013]. The details are given in the tableVII.

TABLE VII COMPARISON OF CONSTITUTIVE LAWS

Reference	Aim of Research Work	Technique used	Modification done	Software used	Component	Results observed
[Pantalé and Gueye, 2013]	Influence of the Constitutive Flow Law in FEM Simulation of the Radial Forging Process	FEA	Comparison of different constitutive flow laws	-	2D axisymmetric component	Forging force, product thickness, strains, stresses and CPU time

Various researchers have done similar research works the details of which are given in table VIII.

TABLE VIII USE OF FEA

Reference	Aim of Research Work	Technique used	Modification done	Software used	Component	Results observed
[Chenot, Bouchard, Fourment and Lasne, 2011]	Numerical Simulation and Optimization of the Forging Process	FEA	Process and design parameters	Forge 3	Screw head, clinched joint	Von mises stress distribution, tension test, surface response
[Zhbankov and Perig, 2013]	Study of Forging of Ingots Without Hot Tops and shrinkage cavities	FEA	Modification of geometric parameters, solidification conditions and steel chemical composition and the use of preliminary upsetting by plates with holes instead of hot tops	-	Ingot	Equivalent plastic strain, deformation of upset
[António, Castro and Sousa, 2005]	Eliminating Forging Defects the use of Genetic Algorithms to calculate optimal shape geometry and temperature	Genetic Algorithms	Modification of preform design and workpiece temperature	-	Axisymmetric H shaped component	Highest temperature detected during forging
[Fu et al., 2006]	A methodology for evaluation of metal forming system design and performance via CAE simulation	FEA	Development of quantitative design evaluation criteria	-	Forged part	Deformation load, damage factor, stress distribution
[Qingping, Huanyong and Yuzeng, 2010]	Process Design for Cold Precision Forging of Bevel Gear using finite element method	FEA	Change in forming laws, material plastic behavior and changed geometries	-	Bevel gear	Effective strain, effective stress, load stroke curve
[Hu et al., 2010]	Study on precision forging process of spur gear in parking brake using fem	FEA	Change in process parameters like forging temperature and different contact conditions	DEFORM 3D	Spur gear in parking brake	Temperature fields, velocity distribution, equivalent strain fields, load stroke curve

[Wang et al., 2010]	Research on Finite Element Modeling Technique of Precision Forming Simulation for Complex Precision Forging Part	FEA	Process and design parameters	DEFORM 3D	Hooke's Joint	Equivalent strain, stress and velocity fields,
[Liang and Pin, 2010]	Numerical Simulation and Technology Research on the Precision Forging for Speed-Reducer Shaft of Auto Starter	FEA	Process and design parameters	-	Speed-Reducer Shaft of Auto Starter	Equivalent stress, equivalent velocity field, punch force vs displacement
[Wang et al., 2010]	Numerical simulation and Analysis of Forging Process for Automotive Starter Motor Ring Gear	FEA	Process and design parameters	DEFORM 3D	Forging of external boss and internal gear for automotive	Metal flow, stress strain distributions
[Gronostajski and Hawryluk, 2008]	The main aspects of precision forging	FEA	Tool and preform temperature, slug geometry, press settings, process speed, lubrication and cooling, tool shape	MSC. Marc	Arch and conical dies for forging CV joint tulips	Die and slug thermal field distribution, material flow, plastic strain, vector distribution of unit pressures, hoop stress distribution, von mises stress distribution
[Skunca et al., 2006]	Relations between numerical simulation and experiment in closed die forging of a gear	FEA	Process and design parameters	MSC. Marc Mentat	Tooling design for radial gear extrusion	Strain field distribution, grain size vs strain, force stroke curve, total equivalent plastic strain
[Chyla et al., 2011]	Closed die forging of turbine disc to fix blades from inconel	FEA	Change in forging temperatures, tools temperature, friction, deformation size in upsetting operation	-	Turbine disc	Mean stress distribution, maximum load
[Jolgaf et al., 2008]	Closed Die Forging Geometrical Parameters Optimization for Al-MMC	FEA	Billet, radius, the rib height/width ratio, fillet radii, draft angle	ANSYS	Circular H shaped part	Equivalent strain distribution, contact gap
[Gontarz and R.Myszak, 2010]	Forming of external steps of shafts in three slide forging press		Process and design parameters	-	Stepped shaft	Nomogram
[Maria, Roque and Button, 2000]	Application of the Finite Element Method In Cold Forging Processes	FEA	Upsetting and ring compression test	ANSYS	Basic	Stress strain material curve, material flow, forming force
[Lacki, 2009]	Numerical analysis of the void evolution during metal plastic deformation	FEA	Process and design parameters	ADINA system	Rolling bearing	Plastic strain distribution, better quality of products

[Rith et al., 2009]	Experimentally validated approach for the simulation of the forging process using mechanical vibration	FEA	Process and design parameters	FORGE 2008	Basic upsetting	Force vs displacement curve, forging load vs displacement curve, forging load reduction vs normalised speed
[Wang et al., 2010]	Evaluating interactions between the heavy forging process and the assisting manipulator combining FEM simulation and kinematics analysis	FEA	Process and design parameters	DEFORM 3D	Rounding of quadrangle cast blank, drawing of a rotor from an octagonal cast blank	Displacement and velocity variation with time, variation of load, temperature distribution, variation of reaction load
[Sun, Tzou and Zheng, 2013]	Processing animation simulation and FEM analysis of multi-stage cold forging of stainless automotive battery fastener	FEA	Process and design parameters	DEFORM 3D	Automotive battery fastener	Effective stress, effective strain, velocity field, forging force
[Liang and Pin, 2010]	Numerical Simulation and Technology Research on the Precision Forging for Speed-Reducer Shaft of Auto Starter	FEA	Process and design parameters	-	Speed-Reducer Shaft of Auto Starter	Equivalent stress, equivalent velocity field, punch force vs displacement
[Kakimoto et al., 2009]	Process Design of Extend Forging Process Using Numerical Simulation Development of Process Design Method for the Finish Forging Process	FEA	Variation of feed, rotation angle, octagon size	FORGE 3D	Octagon process	Radius distribution, relation between angle of rotation and dimensional deviation
[Maarefdoust, 2012]	Simulation of finite volume of hot forging process of industrial gear	FEA	Variation in coefficient of friction, temperature	SuperForge	Gear	Effective stress, effective plastic strain, force stroke curve, contact pressure, temperature distribution, maximum stress vs coefficient of friction, effect of temperature on force
[Slagter, 2001]	Forging Simulation Tool Based on Breakthrough Technology	FEA	Process and design parameters	MSC.Superforge	pulley, crankshaft	Tooling cost savings, production line downtime savings, material cost savings
[Sambhunath and M.T.Sijo, 2013]	Process parameters designing and simulation for the non isothermal forging of Ti-6Al-4V alloy	FEA	Process and design parameters and flow stress models	ANSYS	Cylinderical billet	Flow stress vs temperature, flow stress vs strain rate, stress sensitivity vs temperature, deformation plot, stress distribution,

[Gohil, 2012]	The Simulation and Analysis of the Closed Die Hot Forging Process	FEA	Process and design parameters	-	General upsetting	Stress, strain, temperature, force, flow stress and maximum stress vs deformation, strain vs deformation, load stroke curve, temperature vs deformation
[Chen, Ku and Chen, 2012]	Study of Forging Process in 7075 Aluminum Alloy Professional Bicycle Pedal using Taguchi Method	FEA	Workpiece temperature, mold temperature, forging speed, friction factor	DEFORM 3D	Professional bicycle pedal	Effective strain distribution, effective stress distribution, load variation, damage distribution, maximum principle strain distribution
[Maarefdoust and M.Kadkhodayan, 2010]	Simulation and analysis of hot forging process for industrial locking gear elevators	FEA	Billet temperature, preform, geometry of die,	Superforge	Industrial locking gear elevator	Effective plastic strain vs temperature, effective plastic strain distribution, effective stress vs die corner radius, flash thickness vs press force, force cycle curve
[Arbak et al., 2007]	Forging Simulation at Izeltas	FEA	Modification of temperature, lubrication conditions	Quantor's Qform, MSC's Superforge, SFTC's DEFORM, Transvalor's Forge 3	Steering mechanism joint, ring wrench	Stress and temperature distributions, strain rate
[Meng et al., 2011]	Pseudo Inverse its comparison with Adaptive Incremental Approach	Pseudo Inverse Approach, Adaptive Incremental Approach	Process and design parameters	ABAQUS	Wheel	Equivalent plastic strain and stress, comparison of computation time of softwares
[Joseph, Cleary and Prakash, 2006]	SPH modelling of metal forging	FEA, Smooth particle hydrodynamics	Change in hardness parameter, size of workpiece	-	General	No mesh distorsion or remeshing, removal of defects, plastic strain distribution
[Moradi and Nayebsadeghi, 2011]	3D simulation of the forging process of a gas turbine blade of nickel-based superalloy	FEA	Process and design parameters	-	Gas turbine blade	Temperature distribution, equivalent strain distribution, load displacement curve, flow stress
[Gontarz, Z.Pater and K.Drozdowski,2013]	Hammer forging process of lever drop forging from az31 magnesium alloy	FEA	Process and design parameters	DEFORM 3D	Lever	Material flow kinematics, strain and damage criterion distributions, forging energy
[Sharma and K.Hans Raj, 2008]	Finite element modelling and simulation of hot upsetting process to minimize central bulge in manufacturing	FEA	Preform and process design	-	Basic upsetting	Maximum equivalent strain rate, forging load, radius of curvature, bulge error

[Han and Lin Hua, 2009]	Comparison between cold rotary forging and conventional forging	FEA	Process and design parameters	ABAQUS	Cylindrical workpiece	Load curves, metal flow analysis, plastic deformation zone distribution, axial and radial strain distribution, force and power
[Numthong and S.Butdee, 2012]	The Knowledge Based System for Forging Process Design based on Case-Based Reasoning and Finite Element Method	FEA, Case-Based Reasoning	Process and design parameters	DEFORM 3D, Manusoft	Rear axial shaft	Effective stress and strain distributions, temperature distribution
[Skubisz, Sinczak and Chyla, 2008]	Reduction of die loading by divided flow pattern in the finisher die web area	FEA	Process and design parameters	Qform 3D	Flanged component	Metal flow velocity, tool stress analysis, effective stress, contact surface
[Hussain et al., 2002]	Simulation of clutch-hub forging process using CAMPform	FEA	Process and design parameters	CAMPform	Clutch-hub	Velocity distribution plots, damage factor, load requirements, complete filling of die, material flow, effective strain distribution,
[Laberg`ere, 2011]	Benchmark of a forging process with a hammer: comparison between fem simulation results and real part shapes using 3D digitising scanner	FEA	Process and design parameters	ABAQUS	Cylindrical part	Equivalent von mises stress vs equivalent plastic strain, damage,

II. DISCUSSIONS

The various fields of research are the different perspectives to manufacture a good quality part. The field of optimization of process includes almost every aspect of research. It includes the optimum die design, preform design and the process parameters, which result in manufacturing of a defect free part with minimum forging load. An overview of the techniques of research shows that almost every researcher has used FEA for the analysis of forging operation. It is because of the advantages over other methods of analysis like slab method, slip line field method, upper bound method; which do not consider the temperature gradients which are present in the deforming material during hot forming operation. The use of FEA can also be attributed to the fact that it provides detailed information using soft computing and save a lot of time, effort and the resources of production. It allows the simulation of various things like the tool and workpiece temperatures, the heat transfer during deformation, strain-rate-dependent material properties, strain hardening characteristics and capabilities for microstructure analysis.

III. CONCLUSIONS

The majority of study has been conducted on the elimination of forging defects using finite element analysis. The method is very helpful for defect prediction, process optimization, die analysis, forging loads, etc. Every researcher has endorsed the FEA's findings. Researchers have employed a variety of methods in addition to FEA, including genetic algorithms, reduced basis technique, adaptive remeshing technique, slab method analysis, and case-based reasoning. The outcomes include shorter cycle times, fewer shop floor trials, fault elimination, the creation of forgings with improved properties, longer die lives, etc. Only a small number of researchers have studied how to govern the computerised forging environment. This is a worthwhile area of study that can be investigated. To strengthen the virtual environment for simulation and enhance the forging process, further research can be done on constitutive equations in numerical modelling, various friction models, varied material behaviour, and various solving techniques. Little has been done in the area of metal flow.. It has not been related to any of the other parameters like stress and strain in the component or the design of the die. A mathematical model related to metal flow can be very useful while die designing of the forging dies. FEA is a very strong base for research in the field of forging because it gives minimal effort for a flawed die design or an imperfect process plan.

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