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Improvement in Life of Forging Die by Using Ansys Software

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Abstract: Forging is a process where a shape of a component is manufactured by heating the raw material in a furnace and hammering it on the die. Though it's a hot forging process, there will die wear and plastic deformation. Due to these deformations often replacement of die is required, which causes an increase in the production cost, and there is a loss of productive plan. It also changes the dimensions of the required component.

The purpose of this study is to increase the die life. To increase die life, if we increase the number of operations on die we can reduce the drop force. If there is reduce of drop force on die parallels, there will be an increase in die life. This process can be done by two ways. One is an analytical solution, and other is experimental setup. The cost of experimental setup is too high compared to the analytical solution. So, this project is done by using CAE software.

In this project, die is modeled by using previously existing model. 3d model of the die is modified by increasing the operation on the die.3d model of the modified die was subjected to contact analysis, fatigue analysis. This Project also extends to transient analysis of die for transient loading. NX-CAD software is used for modeling and ANSYS software is used for analysis of Die.

I. INTRODUCTION

Forging is the term for shaping metal by using localized compressive forces. Cold forging is done at room temperature or near room temperature. Hot forging is done at a high temperature, which makes metal easier to shape and less likely to fracture. Warm forging is done at an intermediate temperature between room temperature and hot forging temperatures. Forged parts ranges in weight from less than a kg to 170 metric tons. Forged parts usually require further processing to achieve a finished part

Forging is a manufacturing technique in which metal is plastically deformed from a simple shape like billet, bar, ingot into the desired shape in one or more stages. Deformation takes place using applying compressive forces between the dies in machine tools like hammers, presses, horizontal forging machines, etc. Forging process has many advantages when compared to other manufacturing techniques.

Virtually all metals have alloys that are forgeable, giving the designer the full spectrum of mechanical and physical properties of ferrous and non-ferrous alloys. The most common forging alloys include:

A. Carbon, micro alloy and alloy steel forgings account for the greatest volume of forgings for a very vast range of applications.
B. Stainless steels are broadly used where resistance to heat and corrosion are required.
C. Aluminum forgings are used in applications where the weight of the component is an issue.
D. Copper, brass and bronze forgings offer excellent corrosion resistance with high thermal and electrical conductivity.
E. Iron, nickel and cobalt high-temperature alloy forgings are preeminent for applications of cyclical and sustained loads at high temperatures.

II. LITERATURE REVIEW

A. Forging Process Analysis and Perform Design by Harshil Parikh, Bhavin Mehta, and Jay Gunasekera.

The purpose of this paper is to optimize the forging process and reduce the required force to forge the final product. A complex 3-dimensional part was provided by Queen City Forging Company, Cincinnati, Ohio. Simulation results predicted that the complex 3D part could be forged in one step, using at least a 900-ton capacity press or higher.

Since Queen City Forging Company has an 800-ton press, the task was to design and perform two die sets to manufacture the part using the existing press. Solid Edge was used to model the dies while MSC. Super Forge was used to simulate the forging process. Several different performs were designed and analysed to obtain the final product in two stages with a maximum load of fewer than 750 tons.

B. Preliminary research for the development of a hot forging dies life prediction model by Thomas Grobaski.

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The goal of this research is to provide an initial step in developing a complete forging die life model. The study involved analysing the initial effects of (1) friction, (2) work-piece temperature, (3) die temperature, and (4) forging press stroke speed on effective die stresses, die surface temperatures, die/work-piece contact pressures, die/work-piece sliding velocities, and die surface temperatures are examined. To obtain the results, the forging process was modelled (Solid Edge 3D Solid Modeling Software), simulated (MSC. Super forge Software), and statistically setup and examined using the two-level full factorial design of experiments (Analyzed with Minitab & MS. Excel). The product reviewed was a 10inch diameter differential ring gear forged at the American Axle Manufacturing, North Tonawanda, New York forging plant. The ring gear is used in the rear differentials for Ford and GM trucks.

C. Finite element stress analysis of forging dies to improve their fatigue life by K. Dehghani, A. Jafari.

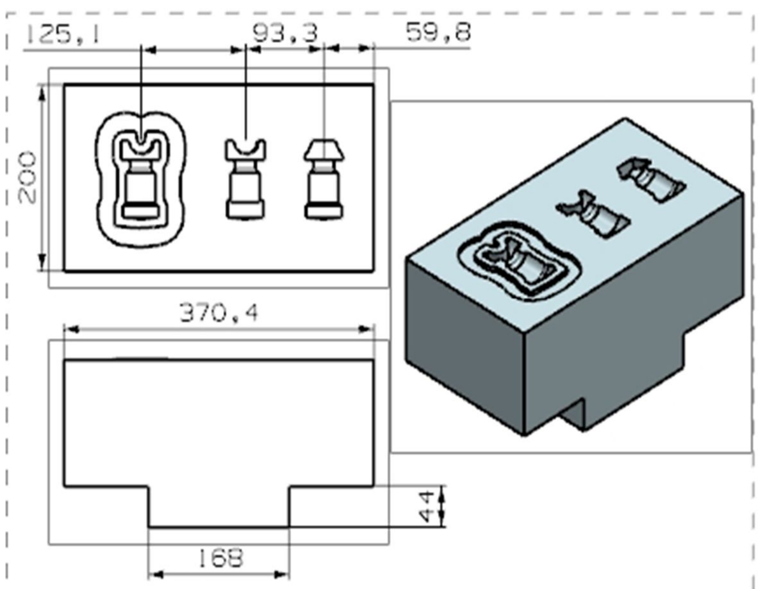
This paper explains the forging dies, and in a particular case a bolt die, are stress analysed by the FEM. Two possible modes of die failure, due to the axial and hoop stresses, were investigated. The critical zones of extremely concentrated stresses have been identified. Several approaches were studied to overcome the tensile stresses that result in a premature failure of a forging die. The results of the finite element simulations show that producing the compressive or negative stresses, as produced by the techniques applied, can completely remove, or at least significantly reduce the detrimental tensile stresses generated during forging. This can readily develop the fatigue life of dies. Numerical stress analysis is performed on critical elements lying in the transition zone of dies. Finally, advanced numerical methods, especially the FEM, were used to determine the optimum mean stress and the optimum alternative stress as well as to analyse the negative compressive stresses generated by the applied techniques. The ABAQUS software is used r the finite element simulation. The maximum mean stress and the optimum alternative stress at the most critical finite element were determined to be 140–150 and 34–38 MPa, respectively.

III. PROBLEM DEFINITION AND METHODOLOGY

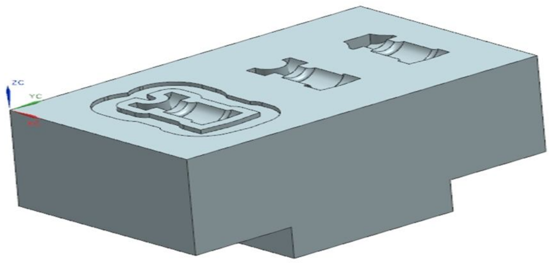
The purpose of this study is to increase the die life. To increase die life, if we increase the number of operations on die we can reduce the drop force. If there is reduce of drop force on die parallelly, there will be an increase in die life. This process can be done in two ways. One is the analytical solution, and other is experimental setup. The cost of experimental setup is too high compared to the analytical solution. So, this project is done by using CAE software. In this project, die is modelled by using previously existing model. 3d model of the die is modified by increasing the operation on the die.3d model of the modified die was subjected to contact analysis, fatigue analysis. This Project also extends to transient analysis of die for temporary loading.

IV. 3-D MODELING OF DIE

3d modeling of the die was done by using NX-CAD. NX-CAD is the world's leading 3D product development solution. This software allows designers and engineers to bring better products to the market faster.

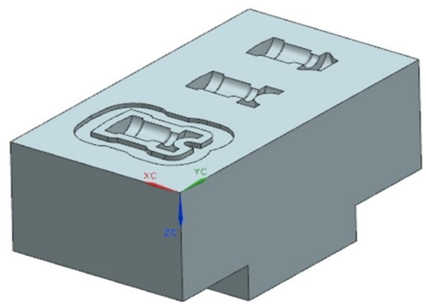


Drafting of modified die



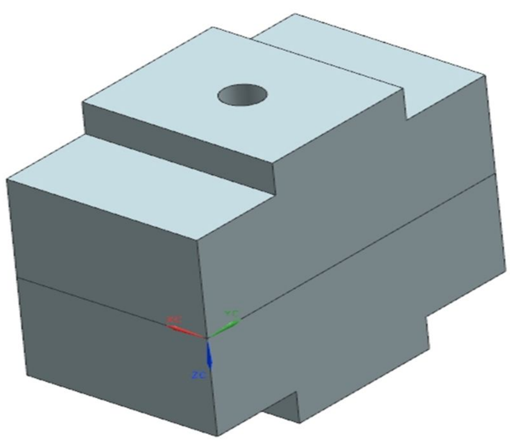
Isometric view of the bottom dies

A. Isometric view of the Top die



Isometric view of the Top die

B. Assembly of top and bottom dies



Assembly of top and bottom dies

V. CONTACT ANALYSIS OF DIE ASSEMBLY

Contact analysis is carried out on the die assembly for three load cases. The three load cases are defined as per the punch height. The objective of this review is to check the contact status for the applied load. The contact stresses and a deflection obtained due to the applied load is also calculated from the analysis. Contact analysis is a nonlinear problem which will take a lot of time to solve, and it requires sufficient system resources. To do the contact analysis, a solid element should be used. The geometry of the die assembly used for the analysis is shown in the below figures. The 3D model is generated in NX-CAD. The model was then converted into Parasolid and imported into Ansys to do contact analysis.

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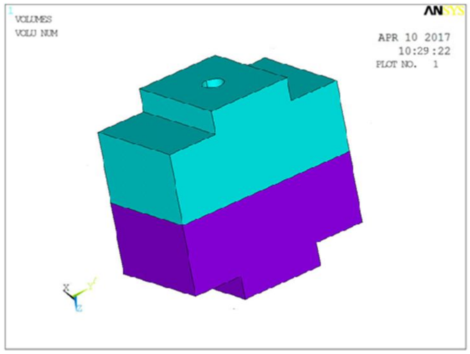

Fig: Shows 3D model of the die assembly

A. Finite element model

A Finite Element model is developed with solid and contact elements. A total of 32975 elements are created for the analysis. The meshed model is shown in the below figure.

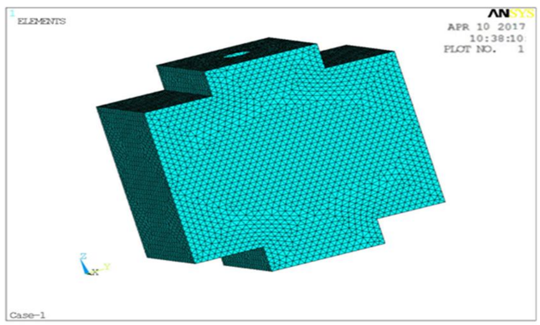

Fig: meshed model of the die assembly

Results: From the analysis, the deflections, Contact status and contact stresses are plotted and are shown below. The maximum total deviation of 0.27 mm is observed as shown below.

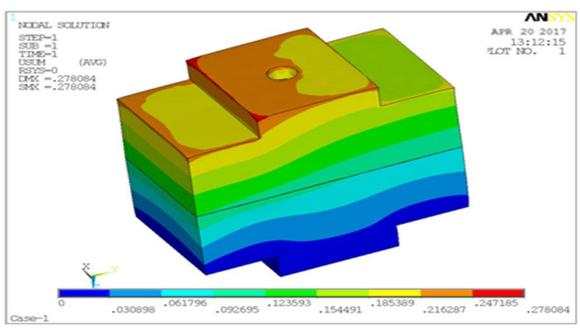

Fig: Total deflection of die assembly for case-1

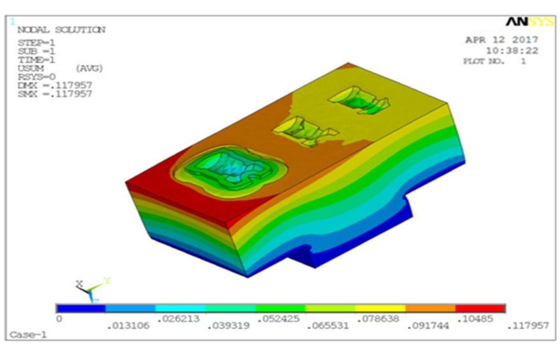

Fig: Total deflection of lower part of die assembly for case-1

From the analysis, the maximum VonMises stresses of 738 N/mm2 is observed as shown below. But it is only a point stress which can be ignored. The average stress found is 330 N/mm2 shown in green color in the below figure.

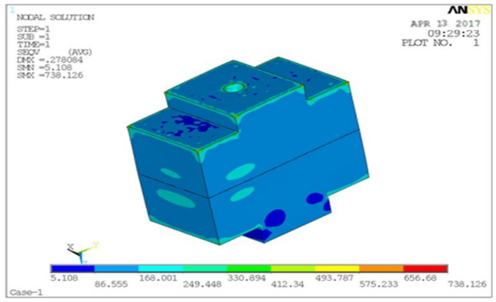

Fig: Von Mises stress plot of die assembly for case-1

From the analysis, the maximum Vanishes stresses of 628 N/mm2 is observed as shown below. But it is only a point stress which can be ignored. The average stress observed is 351 N/mm2 shown in green color in the below figure.

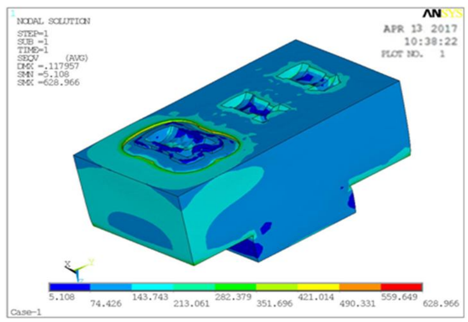

Fig: Von Mises Stress plot of lower part of die assembly for case-1

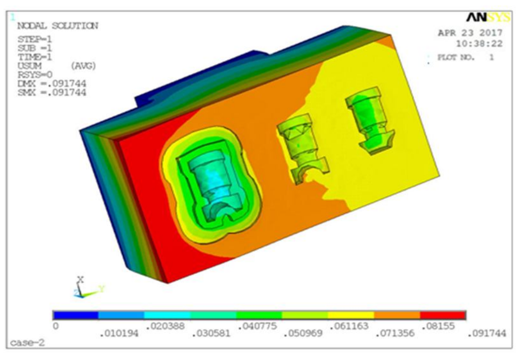

Fig: Total deflection of lower part of die assembly for case-2

From the analysis, the maximum Vanishes stresses of 574 N/mm2 is observed as shown below. But then it is only a point stress which can be ignored. The average stress observed is 320 N/mm2 shown in green color in the below figure.

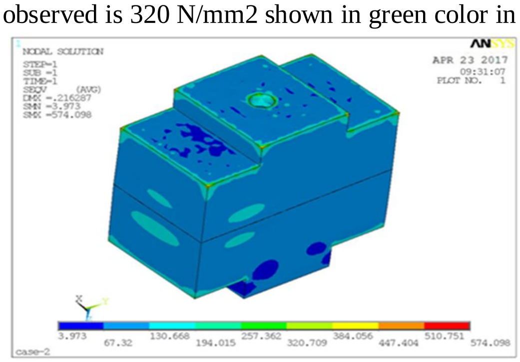

Fig: Von Mises Stress plot of die assembly for case-2

VI. FATIGUE ANALYSIS OF DIE ASSEMBLY

Fatigue, or metal fatigue, is the failure of a component as a result of cyclic stress. The failure occurs in three stages: crack initiation, crack propagation, and catastrophic overload failure. The duration of each of these three steps depends on many aspects including fundamental raw material characteristics, magnitude and orientation of applied stresses, etc.

As the digger arm is subject to cyclic stress due to its operation, it is important to calculate the fatigue life of the digger arm due to cyclic stress. The maximum principal stress obtained from the static analysis is given as input to the Goodman diagram tool to estimate the fatigue life of the digger arm.

Case-1 load is shown below.

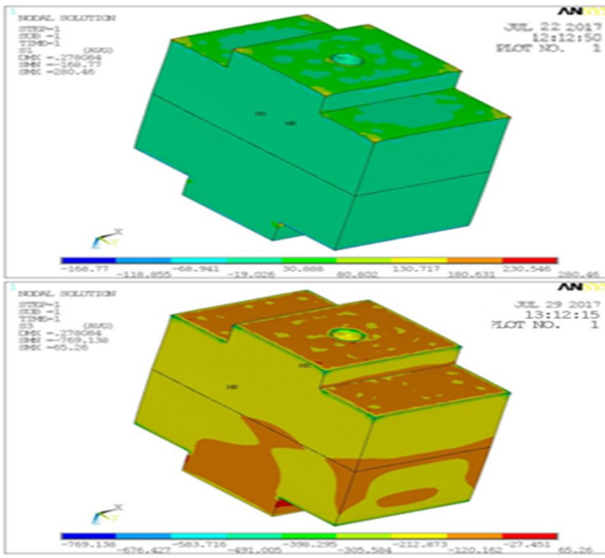

Fig: Maximum and minimum principal stress for case-1 loading

A. Case-3

The maximum and minimum principle stress obtained from the contact analysis of case-3 is given as input in the Goodman diagram tool as shown below. The material properties like ultimate strength and endurance limit values are also given as input as shown in the below figure. The values given for the load case-3 is shown below.

The maximum and minimum principle stress obtained from the contact analysis for the Case-3 load is shown below.

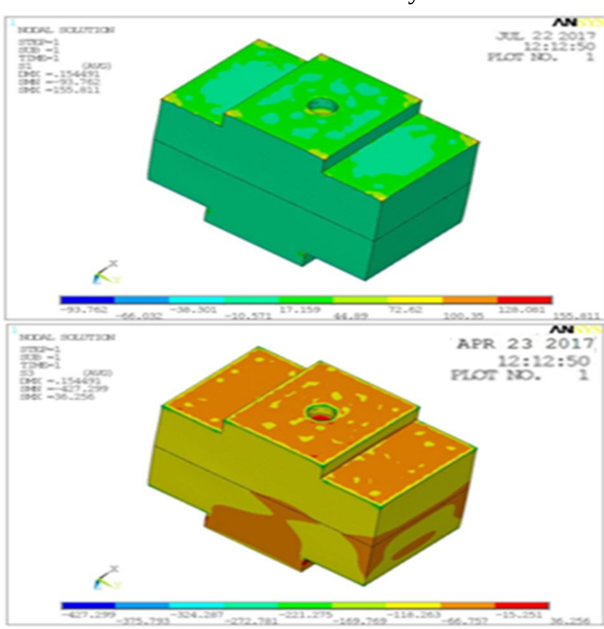

Fig: Maximum and Minimum principle stress for case-3 loading

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VII. TRANSIENT ANALYSIS OF DIE

Transient analysis is a technique to determine the response of a structure to arbitrary time-varying loads such as an explosion. The transient dynamic analysis is used in the design of Structures subjected to shock loads, such as automobile doors and bumpers, suspension systems and building frames, Structures subjected to time-varying loads, such as earth moving equipment, bridges, and other machine components. Household and office equipment subjected to "bumps and bruises," such as cellular phones, laptop computers, and vacuum cleaners.

A. Results

1) Displacements and Stresses at sub step-1 of load step-1:

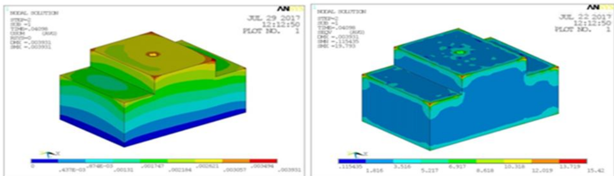

Fig shows total displacement, and von misses observed on die at sub step-1 of load step-1

2) Displacements and Stresses at sub step-5 of load step-1:

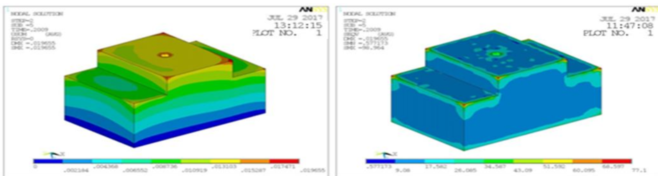

Fig shows total displacement, and von misses observed on die at sub step-5 of load step-1

VIII. TRANSIENT ANALYSIS OF MODIFIED DIE

Transient analysis is a technique to determine the response of a structure to arbitrary time-varying loads such as an explosion. The transient dynamic analysis is used in the design of Structures subjected to shock loads, such as automobile doors and bumpers, building frames, and suspension systems. Structures subjected to time-varying loads, such as bridges, earth moving equipment, and other machine components. Household and office equipment subjected to "bumps and bruises," such as cellular phones, laptop computers, and vacuum cleaners.

A. Results

Displacements and Stresses at sub step-1 of load step-1

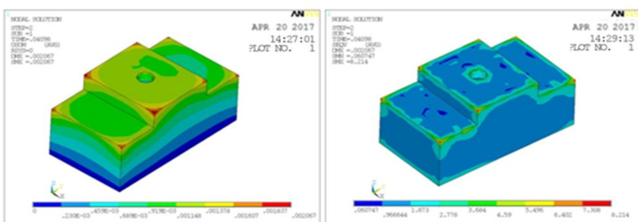

Fig shows total displacement, and von misses observed on modified die at sub step-1

B. Graphs

Graph-1: Graph shows the variation of amplitude versus time period at the top surface of modified die

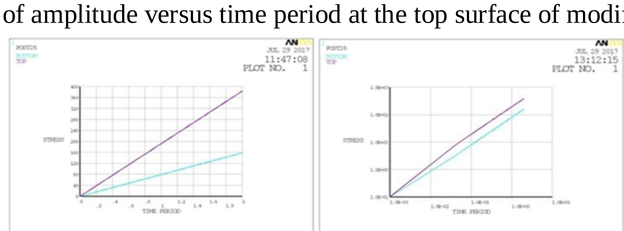

Fig shows Graph between the variations of amplitude versus time period at the top surface of modified die

IX. RESULTS

3d model of Die is subjected to contact analysis, fatigue analysis for three load cases. The original die and modified die are subjected to transient analysis.

A. Results of contact analysis of die

1) Case-1

From the analysis, the results are tabulated as shown.

S.no	Item	Case-1
1	Total Deflection (mm)	0.27
2	Von Mises Stress (N/mm2)	330
3	Contact status	Sticking
4	Contact Penetration (mm)	0.027
5	Contact Stress (N/mm2)	398
6	Contact Pressure (N/mm2)	398

Table: Summary of the results for case-1 load

From the above analysis results, it is seen that the maximum contact stress observed is 398 N/mm2 which is less than the yield strength of the material, i.e. 656 N/mm2. Therefore it is concluded that the die assembly is safe for the above case-1 loads.

2) Case-2

From the analysis, the results are tabulated as shown.

S.no	Item	Case-1
1	Total Deflection (mm)	0.21
2	Von Mises Stress (N/mm2)	320
3	Contact status	Sticking
4	Contact Penetration (mm)	0.021
5	Contact Stress (N/mm2)	309
6	Contact Pressure (N/mm2)	309

Table: Summary of the results for case-2 load

From the above analysis results, it is seen that the maximum contact stress observed is 309 N/mm2 which is less than the yield strength of the material, i.e. 656 N/mm2. Therefore it is concluded that the die assembly is safe for the above case-2 loads.

3) Case-:

From the analysis, the summary of the results is tabulated as shown.

S.no	Item	Case-1
1	Total Deflection (mm)	0.15
2	Von Mises Stress (N/mm2)	229
3	Contact status	Sticking
4	Contact Penetration (mm)	0.015
5	Contact Stress (N/mm2)	221
6	Contact Pressure (N/mm2)	221

Table: Summary of the results for case-1 load

From the above analysis results, it is seen that the maximum contact stress observed is 229 N/mm2 which is less than the yield strength of the material, i.e. 656 N/mm2. Therefore it is concluded that the die assembly is safe for the above case-3 loads.

B. Results of fatigue analysis of die

1) *Case-1:* From the Goodman diagram, it is observed that the Goodman point falls within the limits of Goodman line. From this, it can be said that the total life of die assembly is 5451181 or infinite cycles. From this, it is concluded that the die assembly is safe for fatigue loads for load case-1.
2) *Case-2:* From the Goodman diagram, it is observed that the Goodman point falls within the limits of Goodman line. From this, it can be said that the total life of die assembly is 6617059 or infinite cycles. From this, it is concluded that the die assembly is safe for fatigue loads for load case-2.

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3) *Case-3:* From the Goodman diagram, it is observed that the Goodman point falls within the limits of Goodman line. From this, it can be said that the total life of die assembly is 7714038 or infinite cycles. From this, it is concluded that the die assembly is safe for fatigue loads for load case-3.

C. Results of transient analysis

Results of original die:

Load step-2	Displacement	Von misses stress	Factor of safety
sub step-1	0.0039	15.4	42.5
sub step-5	0.0196	77.1	8.5
sub step-10	0.0393	154.2	4.2
sub step-15	0.0589	231.3	2.8
sub step-20	0.0786	308.4	2.1
sub step-25	0.0982	385.5	1.7
sub step-30	0.1179	462.6	1.4
sub step-35	0.1375	539.7	1.2
sub step-40	0.1572	616.8	1.06
sub step-45	0.1768	635.5	1.03
sub step-50	0.1965	646.1	1.01

From above results, die at every sub step of load step-2 has von misses stresses less than the yield strength of the material.

Results of modified die:

Load step-2	Displacement	Von misses stress	Factor of safety
sub step-1	0.0020	8.21	79.9
sub step-5	0.0103	41.0	16
sub step-10	0.0206	82.1	7.9
sub step-15	0.0310	123.2	5.3
sub step-20	0.0413	164.2	3.9
sub step-25	0.0516	205.3	3.1
sub step-30	0.0620	246.4	2.6
sub step-35	0.0723	287.4	2.2
sub step-40	0.0826	328.5	1.9
sub step-45	0.0930	369.6	1.7
sub step-50	0.1033	410.6	1.5

From above results, modified die at every sub step of load step-2 has von misses stresses less than the yield strength of the material.

D. Comparison of results of the original die and modified die

Graph-1: Graph shows Comparison of Factor of safety of Original die and Modified die

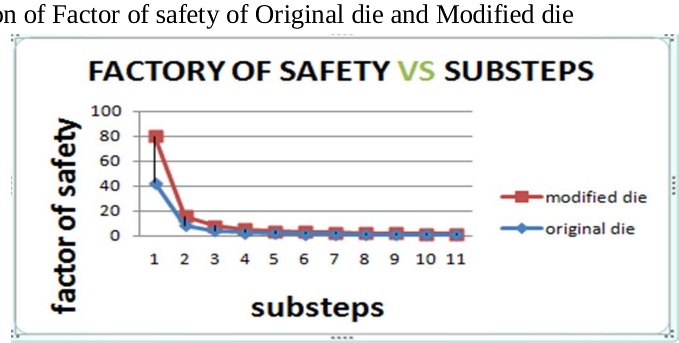

Fig showed graph between factory of safety vs. sub steps of original die and modified die

From above graph, modified die at every sub step of load step-2 has the factor of safety greater than the original die.

X. CONCLUSION

3d model of the die was generated by using the NX-CAD software. 3d model of a die was modified by increasing an operation on the die.3d model of the modified die was subjected to Contact analysis in ANSYS software for three load cases. Modified die assembly had a perfect contact for three load cases and die assembly was safe for all load conditions. Fatigue analysis was done on the die assembly for three load conditions. For all the load cases, Die assembly has infinite cycles and die assembly was safe. Original Die and modified die were subjected to transient analysis to check the behaviour of die for transient loading. Both Original die and Modified die had Von misses stress less than the yield strength of the material at all sub steps of Load step-2.So, both dies were safe for transient loading. In all the sub steps, a factor of safety of modified die was high compared to original die. From these, it was concluded life of the modified die is more compare to original die.

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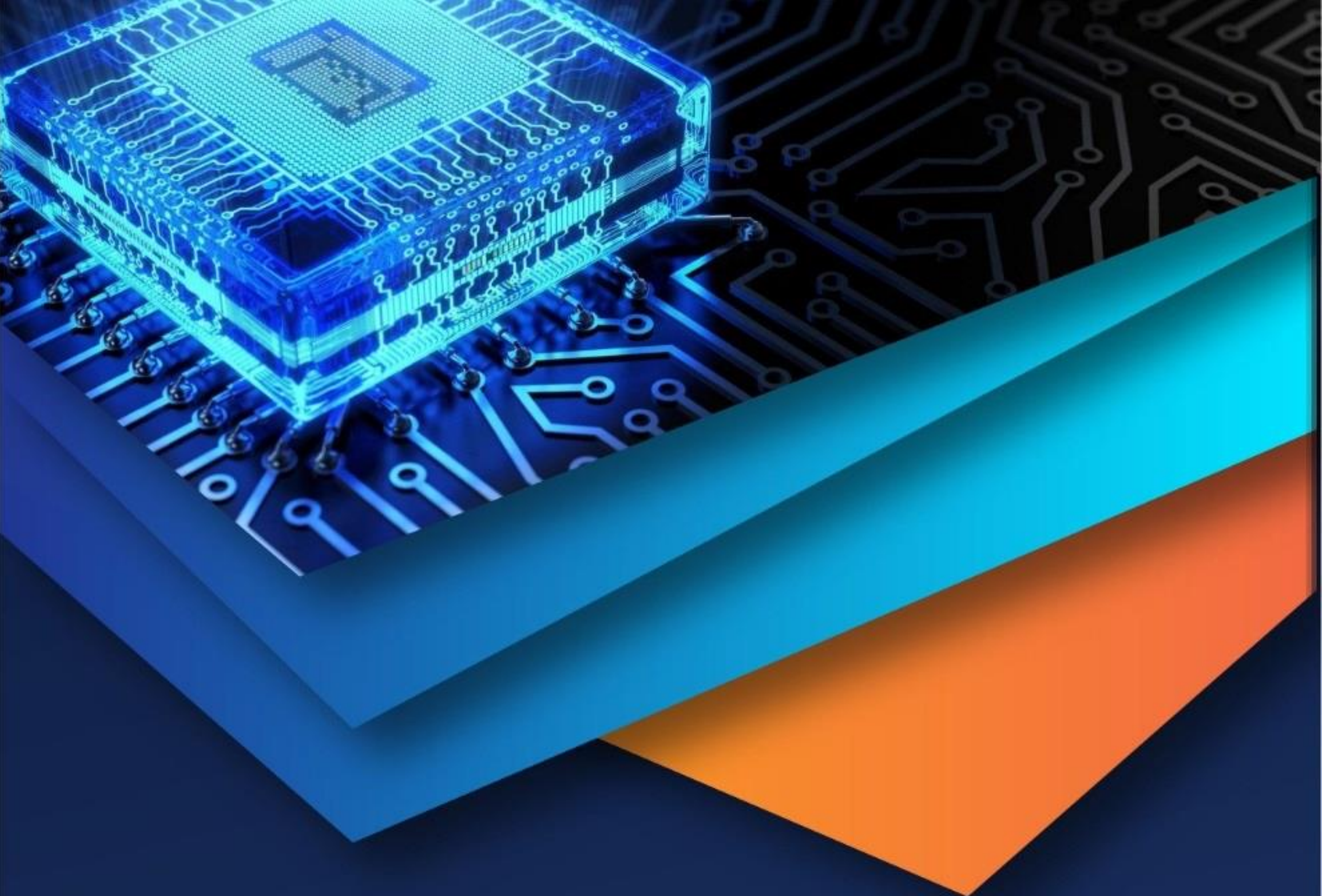

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