OPTIMIZATION OF 3D PRINTED CONNECTING ROD WITH DIFFERENT MATERIALS

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Abstract-Connecting rod interconnects piston to crankshaft and it is responsible for transferring power from piston to the crankshaft and sending it to the transmission. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. A parametric model of Connecting rod is modelled using SOLID WORK software and to that model, analysis is carried out by using SOLID WORK Software. The analysis of connecting rod is done by considering the materials, ABS (ACRYLO NITRILE BUTADIENE STYRENE) which is a common thermoplastic polymer and PLA (POLY LACTIC ACID) which is a type of polyester. PLA provides several advantages over other materials which is easy to 3d print. The best combination of parameters like Von misses Stress and strain, Deformation, Factor of safety are obtained from the analysis. For the 3d printing of connecting rod we are using FDM (Fusion Deposition Modelling) Technique which uses a thermoplastic filament to create a three-dimensional object. Finally, by comparing all the parameters for both materials, the Conclusion can be obtained.

Keywords: 3D Printing Methods, Connecting Rod, Solid Works, ABS, PLA, FDM.

I.INTRODUCTION

3D printing or additive manufacturing (AM) is a process for making a 3D object of any shape from a 3D model or other electronic data sources through additive processes in which successive layers of material are laid down under computer controls. Hideo Kodama of Nayoga Municipal Industrial Research Institute is generally regarded to have printed the first solid object from a digital design. However, the credit for the first 3D printer generally goes to Charles Hull, who in 1984 designed it while working for the company he founded, 3D Systems Corp. Charles a Hull was a pioneer of the solid imaging process known as stereolithography and the STL (stereolithographic) file format which is still the most widely used format used today in 3D printing. He is also regarded to have started commercial rapid prototyping that was concurrent with his development of 3D printing. He initially used photopolymers heated by ultraviolet light to achieve the melting and solidification effect. Since 1984, when the first 3D printer was designed and realized by Charles W. Hull from 3D Systems Corp., the technology has evolved and these machines have become more and more useful, while their price points lowered, thus becoming more affordable.

Nowadays, rapid prototyping has a wide range of applications in various fields of human activity: research, engineering, medical industry, military, construction, architecture, fashion, education, the computer industry and many others. In 1990, the plastic extrusion technology most widely associated with the term "3D printing" was invented by Stratasys by name fused deposition modelling (FDM). After the start of the 21st century, there has been a large growth in the sales of 3D printing machines and their price has been dropped gradually.

INTODUCTION OF CONNECTING ROD

A connecting rod is a rigid member which connects a piston to a crank or crankshaft in a reciprocating engine. Together with the crank, it forms a simple mechanism that converts reciprocating motion into rotating motion.

A connecting rod is the part of a piston engine which connects the piston to the crankshaft. Together with the crank, the connecting rod converts the reciprocating motion of the piston into the rotation of the crankshaft. The connecting rod is required to transmit the compressive and tensile forces from the piston. In its most common form, in an internal combustion engine, it allows pivoting on the piston end and rotation on the shaft end. A Connecting Rod can be of two types H-beam or I-beam or a combination of both. They are used respectively depending on their field of application or use. An I-beam is both light weight 15 and strong, but the type of material used limits it's capacity to handle load. Whereas a H-beam can handle much more stress without bending. So, they are used in high power engines. The function of connecting rod is to transmit the thrust of the piston to the crank shaft, and as the result the reciprocating motion of the piston is translated into rotational motion of the crank shaft. Connecting rod has three main zones: the piston pin end, the centre shank and the big end. The piston pin end is the small end, the crank end is the big end, and the centre shank is of I cross section. The connecting rods are subjected to a complex state of loading therefore, durability of this component is of critical importance. Due to these factors, the connecting rod has been the topic of research for the different aspects such as the production technology, materials, stress analysis etc.

2.LITERATURE REVIEW

1. Dr. B.K. Roy carried out the research on Design Analysis and Optimization of Various Parameters of Connecting Rod using CAE Software's. Various designs of connecting rod have been analysed in this report and finally an optimal design has been selected for Finite Element Analysis. Using ANSYS-12.0 Workbench and CATIA V5R19, Various results are found out and compared with the existing results. It has been found out that the study presented here has come up with better results as well as safe design of connecting rod under permissible limits of various parameters and safe stresses.

2.H.B. Ramani has do Analysis of Connecting Rod under Different Loading Condition Using ANSYS Software. In spite of the great power of FEA, the disadvantages of computer solutions must be kept in mind when using this and similar methods, they do not necessarily reveal how the stresses are influenced by important problem variables such as materials properties and geometrical features, and errors in input data can produce wildly incorrect results that may be overlooked by the analyst.

3. In this paper, the wok is carried out to measure the stress, factor of safety in connecting rod in two-wheeler. The connecting rod is the intermediate member between the piston and the Crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. This describes designing and Analysis of connecting rod. Currently existing connecting rod is manufactured by using Carbon steel, Forged steel, etc... A parametric model of Connecting rod is modelled using PRO-E software and to that model, and analysis is carried out by using ANSYS 15.0 Software. Finite element analysis of connecting rod is done by considering the materials, viz... Forged steel, Aluminium alloy, carbon steel, titanium alloy, etc... The best parameters like Von misses Stress, Deformation, Factor of safety, Stiffness and weight reduction for two-wheeler connecting rod are done in calculation and analysed.

4.The connecting rod is the intermediate member between the piston and the Crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. This thesis describes designing and Analysis of connecting rod. Currently existing connecting rod is manufactured by using Carbon steel. In this drawing is drafted from the calculations. A parametric model of Connecting rod is modelled using CATIA V5 R19 software and to that model, analysis is carried out by using ANSYS 13.0 Software. Finite element analysis of connecting rod is done by considering the materials, viz...

Forged steel. The best combination 21 of parameters like Von misses Stress and strain, Deformation, Factor of safety and weight reduction for two-wheeler piston were done in ANSYS software. Forged steel has more factor of safety, reduce the weight, increase the stiffness and reduce the stress and stiffer than other material like carbon steel. With Fatigue analysis we can determine the lifetime of the connecting rod.

5.The connecting rod is the intermediate member between the piston and the Crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. This thesis describes designing and Analysis of connecting rod. Currently existing connecting rod is manufactured by using Forged steel. In this drawing is drafted from the calculations. A parametric model of Connecting rod is modelled using SOLID WORK software and to that model, analysis is carried out by using ANSYS 15.0 Software. Finite element analysis of connecting rod is done by considering the materials, viz... Aluminium Alloy. The best combination of parameters like Von misses Stress and strain, Deformation, Factor of safety and weight reduction for two-wheeler piston were done in ANSYS software. Aluminium Alloy has more factor of safety, reduce the weight, reduce the stress and stiffer than other material like Forged Steel. With Fatigue analysis we can determine the lifetime of the connecting rod.

Methodology

Step 1: Collecting information and data related connecting rod and 3d printing.

Step 2: A fully parametric model of the connecting rod is created in Solid works software.

Step 3: The 3d printing technique and materials required for the printing is selected.

Step 4: Printing of the component is done by using FDM process.

Step 5: Model obtained in Step 2 is analysed using Solid works to obtain von-missies stress strains and deformation.

Step 6: Finally, we compare the results obtained from Analysis and compared different material.

PROBLEM STATEMENT

1.To study Two cases of connecting rod with different material (ABS AND PLA) and its behaviour study by analysis.

Objective

1. To Design the 3D printed connecting rod with different 3D printing materials and to study the behaviour at actual loading conditions.
2. To find the stresses and deformation produced on 3D printed connecting rod.
3. To find the strongest 3D printing material to manufacture a connecting rod.

3.DESIGN, ANALYSIS AND PRINTING OF CONNECTING ROD

Design Calculations of a Connecting rod

A connecting rod is a machine member which is subjected to alternating direct compressive and tensile forces. Since the compressive forces are much higher than the tensile force, therefore the cross-section of the connecting rod is designed as a strut and the Rankine formula is used. A connecting rod subjected to an axial load W may buckle with x-axis as neutral axis in the plane of motion of the connecting rod, {or} y-axis is a neutral axis. The connecting rod is considered like both ends hinged for buckling about x-axis and both ends fixed for buckling about y-axis. A connecting rod should be equally strong in buckling about either axis.

Let, A = cross sectional area of the connecting rod. L = length of the connecting rod.

c =compressive yield stress.

Wcr =crippling or buckling load.

I xx = moment of inertia of the section about x-axis I yy = moment of inertia of the section about y-axis K xx = radius of gyration of the section about x-axis K yy = radius of gyration of the section about y- axis D = Diameter of piston

r = Radius of crank Rankine formula = (Ixx=4Iyy)

B Pressure Calculation for 150 cc Engine

Engine type: Air cooled 4-stroke

Bore × Stroke (mm) = 57*58.6

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Displacement = 149.5cc

Max. Power = 13.8bhp at the rate of 8500 rpm Max. Torque = 13.4Nm at the rate of 6000 rpm Compression Ratio = 9.35/1

Density of Petrol [C8H18] = 737.22 kg/ m3 Temperature = 60F = 288.855K

Mass = Density × Volume = 0.11Kg

Molecular Weight of Petrol= 114.228 g/mole

From Gas Equation, PV= Mrt

R = R*/Mw = 8.3143/114.28 = 72.76

P = (0.11*72.786*288.85) / 149.5E 3 28

P = 15.469 MPa.

MODELLING OF CONNECTING ROD Step 1: - Opened Solid Works Software.

Step 2: - Selected MODEL option.

Step 3: - Gave the software the location to save the file.

Step 4: - Selected the SKETCH option.

Step 5: - Selected the suitable plane for sketching the connecting rod. (YZ Plane).

Step 6: - Selected the CIRCLE option and drew a circle (Circle 1). (Inner dia. Of big end - 23.88).

Step 7: - Again selected the CIRCLE option and drew a circle (Circle 2) for the same centre as that of previous circle (Outer dia. Of big end - 47.72)

Step 8: - Selected the LINE option and drew a line (Centre line) from centre or the circle.

Step 9: - Again selected the CIRCLE option and drew a circle (Circle 3) at the other end of the previously drawn line. (Inner dia. Of small end – 17.94). 31

Step 10: - Drew another circle (Circle 4) on the centre of (Circle 3). (Outer dia. Of small end – 31.94).

Step 11: - Selected the LINE option and drew two parallel lines on both sides of the previously drawn line. (Distance between centre line and parallel lines - 8 each).

Step 12: - Followed the same steps and drew a rectangular slot between the upper circles and lower circles. (Thickness – 8, Height – 40).

Step 13: - Selected the TRIM option and trimmed the unwanted lines.

Step 14: - Clicked on the FINISH SKETCH option. Step 15: - Selected the EXTRUDE option and selected the lower circle and extruded it symmetrically. (Height of big end – 17.6).

Step 16: - Similarly extruded all the components of the connecting rod symmetrically. (Height of small end – 14.4, Height of the section – 16, Height of the slot – 3.2).

Step 17: - United every component with each other. Step 18: - Selected the SHOW AND HIDE option and hide the sketches, datum planes, co-ordinate system, etc.

Step 19: - Saved the Model using SAVE option. 12 Step 20: - Again selected the SAVE option and saved the model in IGES format for further analysis on ANSYS Software.

3D PRINTING TECHNIQUE

Fusion Deposition Modelling

Fused Deposition Modelling (FDM) method was developed by S. Scott Crump in the late 1980s and was designed in 1990 by Stratasys. After the patent on this technology expired, a large open-source development community developed and commercial variants utilizing this type of 3D printer appeared. As a result, the price of FDM technology has dropped by two orders of magnitude since its creation. In this technique, the model is produced by extruding small beads of material which harden to form layers. A thermoplastic filament or wire that is wound into a coil is unwinding to supply material to an extrusion nozzle head. The nozzle head heats the material up to the certain temperature and turns the flow on and off. Typically, the stepper motors are employed to move the extrusion head in the z-direction and adjust the flow according to the requirements. The head can be moved in both horizontal and vertical directions, and control of the mechanism is done by a computer aided.

3D Printer Material

A. Acrylonitrile Butadiene Styrene [ABS]

One of the most widely used material since the inception of 3D printing. This material is very durable, slightly flexible, and lightweight and can be easily extruded, which makes it perfect for 3D printing. It requires less force to extrude than when using PLA, which is another popular 3D filament. This fact makes extrusion easier for small parts. The disadvantage of ABS is that it requires higher temperature. Its glass transition temperature is about 105°C and temperature about 210 - 250°C is usually used for printing with ABS materials. Also, another drawback of this material is quite intense fumes during printing that can be dangerous for pets or people with breathing difficulties. So, 3D printers need to be placed in well-ventilated area. Also, good advice is to avoid breathing in fumes during printing considering the cost of 3D materials ABS is the cheapest, which makes it favourite in printing communities until now.

Technical Specifications:

- Density- 1-1.4 gm/cm3
- Dielectric constant- 3.1 to 3.2
- Dielectric Strength [Breakdown Potential]- 15-16 kV/mm [0.59-0.63 V/mil]
- Elastic modulus- 2 to 2.6 GPa
- Elongation at break- 3.5 to 50%
- Flexural modulus- 2.1 to 7.6 GPa
- Flexural strength- 72 to 97 MPa
- Heat deflection temperature at 1.82 MPa -76 to 110°C
- Heat deflection temperature at 455 KPa- 83 to 110°C
- Strength to weight ratio- 37 to 79 kN-m/kg
- Tensile strength: 37 to 110 MPa
- Thermal expansion- 81 to 95 µm/m-K Material Properties of Acrylonitrile Butadiene Styrene [ABS]
- Temperature - 225°C
- Flow Tweak - 0.93
- Bed Temperature - 90°C
- Bed Preparation - apply glue stick 2 layer & then abs glue 1 layer

B. Poly Lactic Acid [PLA]

Poly lactic acid (PLA) (is derived from corn and is biodegradable) is another well-spread material among 3D printing enthusiasts. It is a biodegradable thermoplastic that is derived from renewable resources. As a result, PLA materials are more environmentally friendly among other plastic materials. The other great feature of PLA is its biocompatibility with a human body. The structure of PLA is harder than the one of ABS and material melts at 180 – 220°C which is lower than ABS. PLA glass transition temperature is between 60 – 65 ° C, so PLA together with ABS could be some good options for any of your projects.

Technical Specifications

- Density - 1.3 g/cm³ (81 lb/ft³)
- Elastic (Young's, Tensile) Modulus - 2.0 to 2.6 GPa (0.29 to 0.38 x 10³ psi)
- Elongation at Break - 6.0 %
- Flexural Modulus - 4.0 GPa (0.58 x 10⁶ psi)
- Flexural Strength - 80 MPa (12 x 10³ psi)
- Glass Transition Temperature - 60 °C (140 °F)
- Heat Deflection Temperature At 455 kPa (66 psi) - 65 °C (150 °F)
- Melting Onset (Solidus) - 160 °C (320 °F)
- Shear Modulus- 2.4 GPa (0.35 x 10⁶ psi)
- Specific Heat Capacity - 1800 J/kg-K
- Strength to Weight Ratio - 38 kN-m/kg
- Tensile Strength: Ultimate (UTS) - 50 MPa (7.3 x 10³ psi)
- Thermal Conductivity - 0.13 W/m-K
- Thermal Diffusivity - 0.056 Material Properties of Poly Lactic Acid [PLA]
- Temperature - 180°C
- Flow Tweak - 0.95
- Bed Temperature - 60°C
- Bed Preparation - apply glue stick 2 layers

Printing

Before printing a 3D model from .STL file, it must be processed by a piece of software called a "slicer" which converts the 3D model into a series of thin layers and produces a G-code file from .STL file containing instructions to a printer. There are several open-source slicer programs exist, including, Slic3r, KIS Slicer, and Cura. The 3D printer follows the G-code instructions to put down successive layers of liquid, powder, or sheet material to build a model from a series of cross-sections of a model. These layers, which correspond to the virtual cross sections from the CAD model, are joined or fused to create the final shape of a model. The main advantage of this technique is its ability to create almost any shape or geometric model. Construction of a model with existing methods can take anywhere from several hours to days, depending on the method used and the size and complexity of the model. Additive systems can 35 typically reduce this time to very few hours; it varies widely depending on the type of machine used and the size and number of models being produced.

ANALYSIS

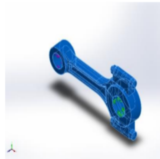
Static analysis

Static analysis deals with the conditions of equilibrium of the bodies acted upon by forces. A static analysis can be either linear or non-linear. All types of non-linearities are allowed such as large deformations, plasticity, creep, stress stiffening, contact elements etc. this chapter focuses on static analysis. A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those carried by time varying loads. A static analysis is used to determine the displacements, stresses, strains and forces in structures or components caused by loads that do not induce significant inertia and damping effects. A static analysis can however include steady inertia loads such as gravity, spinning and time varying loads. In static analysis loading and response conditions are assumed, that is the loads, and the structure responses are assumed to vary slowly with respect to time. The kinds of loading that can be applied in static analysis includes, a) Externally applied forces, moments, and pressures b) Steady state inertial forces such as gravity and spinning c) Imposed non-zero displacements A static analysis result of structural displacements, stresses and strains and forces in structures for components caused by loads will give a clear idea about whether the structure or components will withstand for the applied maximum forces. If the stress values obtained in this analysis crosses the allowable values, it will result in the failure of the structure in the static condition itself. To avoid such a failure, this analysis is necessary.

Results and Discussion

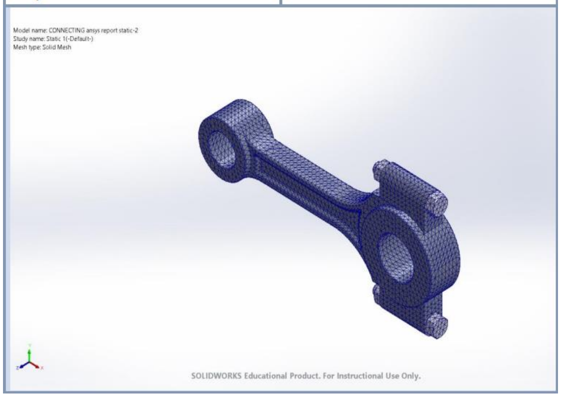
For ABS material:

Material Properties:

Model Reference	Properties	Components
	Name: ABS Model type: Linear Elastic Isotropic Default failure criterion: Unknown Tensile strength: 3e+07 N/m^2 Elastic modulus: 2e+09 N/m^2 Poisson's ratio: 0.394 Mass density: 1,020 kg/m^3 Shear modulus: 3.189e+08 N/m^2	Solid Body 1(Fillet1) (BOLT-1), Solid Body 1(Fillet1) (BOLT-3), Solid Body 1(Fillet8) (CONNECTING ROD -2-1), Solid Body 1(Cut-Revolve1) (NUT-1), Solid Body 1(Cut-Revolve1) (NUT-6), Solid Body 1(Fillet1) (connecting rod u-1)

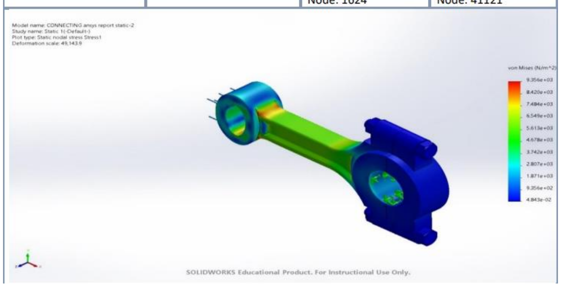
Mesh information:

Total Nodes	61890
Total Elements	38935
Maximum Aspect Ratio	14.341
% of elements with Aspect Ratio < 3	95.2
Percentage of elements with Aspect Ratio > 10	0.0411
Percentage of distorted elements	0
Time to complete mesh (hh; mm;ss):	00:00:04
Computer name:	



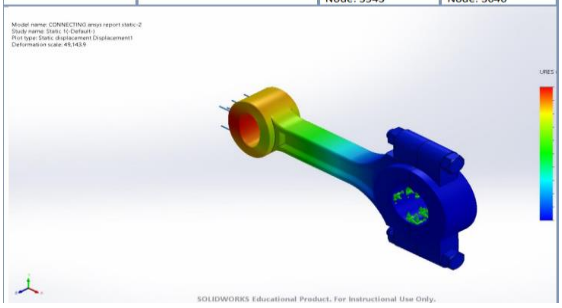
Study Results:

Name	Type	Min	Max
Stress1	VON: von Mises Stress	4.843e-02N/m^2 Node: 1624	9.356e+03N/m^2 Node: 41121



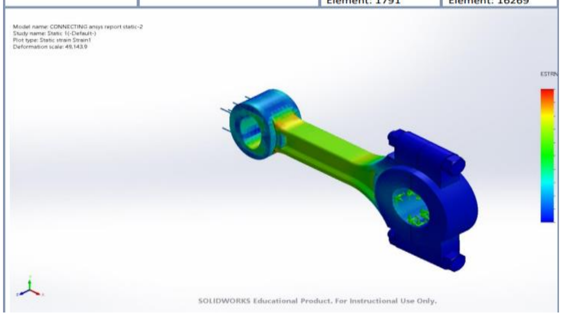
Connecting rod Ansys report static-2-Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 3543	3.196e-04mm Node: 3640



Connecting rod Ansys report static-2-Static 1-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	4.701e-11 Element: 1791	4.208e-06 Element: 16269



Connecting rod Ansys report static-2-Static 1-Strain-Strain1

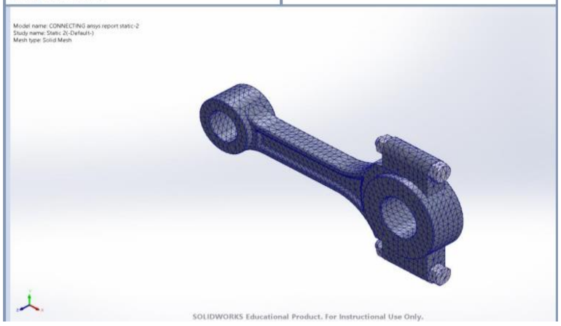
For PLA Material:

Material Properties:

Model Reference	Properties	Components
	Name: **PE Low/Medium Density** Model type: **Linear Elastic Isotropic** Default failure criterion: **Unknown** Tensile strength: **1.327e+07 N/m^2** Elastic modulus: **1.72e+08 N/m^2** Poisson's ratio: **0.439** Mass density: **917 kg/m^3** Shear modulus: **5.94e+07 N/m^2**	**Solid Body 1(Fillet1) (BOLT-1), Solid Body 1(Fillet1) (BOLT-3), Solid Body 1(Fillet8) (CONNECTING ROD -2-1), Solid Body 1(Cut-Revolve1) (NUT-1), Solid Body 1(Cut-Revolve1) (NUT-6), Solid Body 1(Fillet1) (connecting rod u-1)**

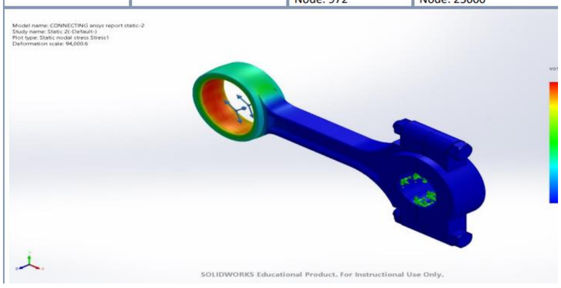
Mesh information:

Total Nodes	37104
Total Elements	22611
Maximum Aspect Ratio	17.682
% of elements with Aspect Ratio < 3	88.8
Percentage of elements with Aspect Ratio > 10	0.0929
Percentage of distorted elements	0
Time to complete mesh(hh;mm;ss):	00:00:04
Computer name:	



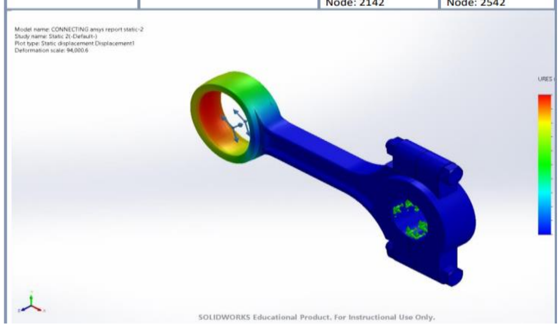
Study Results:

Name	Type	Min	Max
Stress1	VON: von Mises Stress	3.134e-08N/m^2 Node: 972	2.465e+03N/m^2 Node: 25000

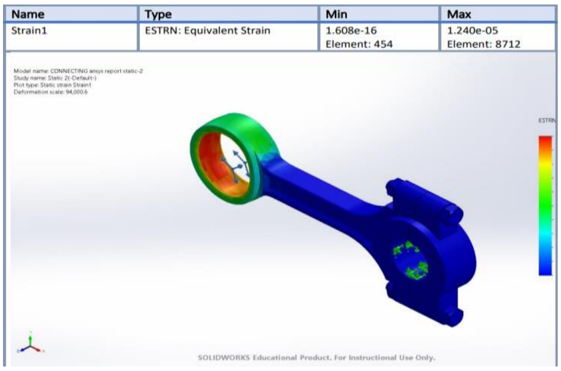


Connecting rod Ansys report static-2-Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 2142	1.671e-04mm Node: 2542



Connecting rod Ansys report static-2-Static 1-Displacement-Displacement1



Connecting rod Ansys report static-2-Static 1-Strain-Strain1

CONCLUSION

It was concluded that Acrylonitrile Butadiene Styrene is the strongest 3D printing material which can carry a load of 47 KN up to Yield stress. FEA results shows that Acrylonitrile Butadiene Styrene is strong when subjected to tensile or compressive loading. These types of 3D printed components can be used when there is customized requirement. This will result into reducing the time of Production, complex designs can be manufactured and avoids the cost of moulding. This concept of Advance manufacturing can be used for different mechanical parts manufacturing like gears and Mould manufacturing for composite materials. These types of manufacturing can be used in Biology where 3D printed body parts can significantly enhance learning. Feeling the texture of a brain is different from seeing it in a book or on screen. Complex structures of protein molecules in DNA can be very easily appreciated with 3d prints.

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