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3D printed jigs and fixtures Application in manufacturing of suspension arm for ATV

Rohit Paliwal[1], Rahul Saini[2], Rohit Kumar Mishra[3], Samrat Tiwari[4], A.K. Madan[5]

Department of Mechanical Engineering, Delhi Technological University, Delhi, India[1,2,3,4,5]

Abstract: Tools, like jigs and fixtures are an integral part of manufacturing technology that help maintain quality as well as production efficiency. Jigs and fixtures are generally used to hold, align and assemble various components and sub-assemblies throughout the manufacturing process. Their importance is practically invisible while the production is running smoothly but becomes much more evident when problems occur. To steer clear of production defects or halts, manufacturing tools must be constantly evolved and developed through rapid prototyping, manufacturing and deployment. In this innovation report, we have presented how we designed and used 3D printed jigs and fixtures to improve the manufacturing of probably the most important part of the ATV (All-Terrain Vehicle), i.e. the suspension arms.

Keywords: manufacturing technology, production efficiency, manufacturing process, sub-assemblies, rapid prototyping, 3D printed, jigs and fixtures, ATV.

1. INTRODUCTION

The modern printing process used to make more accurate and realistic 3D structure using Computer aided Design model (CAD model) or any 3D-model [1][2]. This 3D file is converted to STL(standard tessellation language) file format which is in triangular mesh format of the object and this is sliced into multiple 2D-layers to bound them together and makes the printing operation smoother[3][5]. Engineers introduced the technology of 3D printing for structural models development with simple and efficient performance but ease of manufacturing using this technology is responsible for its rapid widening of 3D printing materials and applications in the last decades [4]. 3D printing technology now a days is being highly used in health science, medicines and dentistry, radiology/imaging, maxillofacial surgery and anatomy [6][7].

JIGS and FIXTURES

A device that is used to hold, support, work-piece detection and also used for guiding purposes to the cutting tool in various machining operations, is said as jig. A jig in product's manufacturing ensures interchangeability, higher degree of accuracy and precision, and better product repetitive quality in manufacturing of product. Jigs are also introduced in any manufacturing process to change tool's movement and location [8][9]. Jigs are the custom-made type tools which means that they are prepared according to the shape and size of final product (which we are going to manufacture). This shape and size of jig can be estimated by means of prototype of product. Boring and drilling are most common types of jigs. These jigs are identical but its type, shape, size and bushing position varies [10][11].

The sturdy and rigid mechanical devices which ensures reliable quality, interchangeability, precise and fast machining, and reduced lead-time are said to be fixtures. Fixtures are work-holding device which are not responsible for guiding, positioning and location of cutting tool. These limitations can be overcome by adjustments and changes on the working machine [12][13].

The advantages of fixtures and jigs includes setup reduction, durability, improved productivity and reduced decision making in any operation which is selected from standard operation [14].

Jigs and fixtures are used in pump-assembly operations, ingots cutting in a steel-plant, automobile-parts mass-production etc. Jigs are especially used in mass tapping, reaming and drilling. Fixtures are especially used in mass-griding , milling and turning operations [15][16].

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Types of 3D Printing

The technologies which are used for printing in 3D and Additive manufacturing, uses Computer aided design to make model in 3D versions and then is converted into a Standard Triangle Language (STL) format file [17][18]. Light, extrusion and Inkjet -based 3D printing are the most commonly and widely used technologies in 3D printing [19].

Inkjet based 3D printing

Powder bed settling type of printing is termed as Inkjet Based printing. Thermal printing and also Piezoelectric inkjet 3D printing are mainly the types of Inkjet printings.
A thin-film resistor is used as a heating element for the printing. A high electric current passes through this resistor by giving an electric pulse which then vaporizes the ink into bubbles which is placed adjacent into it. The size of the vapour bubble increases in the ink-reservoir and the pressure is generated [20][21] which results in the discharges of the ink-droplets from the nozzle.
In piezo-electric printing, a sudden change in the reservoir filled with ink occurs by applying an external voltage to the piezo-electric transducer. So the ink-droplets are discharged from the nozzle by a pressure wave which is caused by this volumetric change.
Accurate and precise sizes of droplets are generated which are uniform in Piezoelectric inkjet printing and because of no heat exposure and ink stress as compared to thermal printing it is suitable for wider range of materials. And on the other hand, thermal printing has a higher speed of printing and the parts are of lower cost.[22][23]

Extrusion based 3D printing

This printing is directed by the automated robotic-system to settle the ink at a particular level which is is the form of continuous filament [24][25]. And this is caused by the movement of 2 head axes X and Y. The most widely used extrusion-based 3D printing is based on melting the material which is known as FDM i.e Fused deposition modelling. The process is quite simple and of low cost, the thermoplastic filamentary materials is necessary to use which cannot adjust the encapsulated cells and bio active agents in the materials that is melted which causes hinderance in its biomedical application.[26][27].
There are two techniques (without melting the material) of printing which is based on deposition mechanisms that are pneumatic and mechanical also known as screw and piston based.
Because of the ability to adjust the air pressure, pneumatic printing uses the wide range of viscosities [28]. Better control dimensionally over the material flow is achievable in mechanical based printing and inks having higher viscosities can be printed, because of larger deposition forces. However, the cell membranes gets damaged in the dividing process because of the configuration of the screw and the large driving forces [29][30].

Light based 3D printing

In this type of printing nozzle is not used hence it is a nozzle free technology, By using an exposed source of light, to give the required amount of energy to bring out photo polymerization and solidify a photosensitive polymer ink and layer by layer printing gets accomplished[31]. SLA is a technology known as Stereolithography and is widely and commonly light based printing technology. Digital light processing and two photon polymerization are also its type. The light source and the imaging system creates the difference between all these technology and the system which are similar are control and stepping system [32][33].
Because of the movement of the laser beam over a wide surface area and space it could print the large size models but the area which will be exposed in DLP is limited which makes it printing limited to small size objects with high resolution (□1μm)[34][35].

2. LITERATURE REVIEW

Benjamin Dillenburger Et al. [36] in his research on geopolymers 3D printing proposed the mix design strategy which allows the geopolymer implementation in varies from powder bed 3D printing. He compared casting nad 3D printed powder bed in his valuable research and found casting mix design Varies from 3D printed mix design. He claimed- 3D-printing of the product with mix-design of material will be more intricate in powder bed.

Jeidson Marques et al [37] in his research on three-Dimensional printing usage in forensic sciences highlights the 3D printing applications and need that should be developed and incorporated 3D printing technology in the Indian forensics department. He discussed various merits, demerits and limitations of 3D printing in forensics. The major drawback he pointed out is scarcity empirical data on the 3D printing accuracy. He also pointed out the advantages of

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3D printed model which are better visualization, interpretation & understanding. In his research, he suggests to include 3D printing technology in Indian forensics.

Sebastian Leimbrink et al [38] in his research work in 3D printing welding jig: Design and testing determined the efficiency of 3D printed welding jigs and compared these 3D printed welding jigs with the conventional system. He claimed the 3D printed jig provide precision along with cost reduction.

Wei Keat Ng, Wen Shyang Chow [39] in his research work on plastics in 3D printing claimed various application areas of 3D printing which includes pharmaceutical, biomedical, electronic, face shield, robotic and others fields. He discussed various future challenges and perspective in 3D printing. They also discussed strategies for improvement in 3D technologies. He claims products along with customization, complex geometry design, and rapid prototyping features can be produced with 3D printing technology.

Hirohide Shiratori et al [40] did his research work on 3D printed carbon fiber to check compressive strength variation with curved sections. They proposed test method for evaluating 3D printed carbon-fiber(continuous) curved section's strength. They designed a test jig which is a thin L-shaped specimen to conduct test and evaluated curved section strength experimentally. They compared curved section's maximum compressive stress . They claimed from their research that as the radius become smaller the maximum compressive stress of curved section decreases. This curved section's strength deterioration can result in curved section's fiber twisting, and this fiber twisting causes defects like fiber breakage.

Bakarich et al. [41] in his research on 3-Dimensional printing explained the preparation of hydrogel composites with are reinforced with fibers with 3-Dimensional printing using UV-curable adhesive and precursor (alginate/acrylamide gel) in a unit-step process. The AM technology adaptation improved toughness of matrix and also showed improved surface morphology .This research work concluded dependency the flexural strength, fracture toughness and shear capacity of reinforcing fibers.

Zen chen [42] in his research work on 3D printing impacts on supply chain estimated that this technology of 3 Dimensional printing would change the convectional style manufacturing and going to rise of new competition rules. They also concluded that 3D printing will going to set a new definition to complex products which will help in customization of products on consumers demand and will eliminate tradition allabor. They also stated that 3D printing will give new heights to mass production and technology.

Tekinalp et al. [43] in his research work shifted his attention to various difficulties which are linked with 3D-printed fibre reinforced composites. They also determined load taking capacity of composite-parts which were madeup with ABS (Acrylonitrile Butadiene Styrene) resin Feedstock and Carbon fiber. There were a increase in stiffness and strength of samples which were fabricated by compression-moulding (CM) and Fused deposition modeling (FDM).

Song et al. [44] in his research on stretchability and thermal conductivity determination of nanosheets of graphene concluded that mechanical properties of 3-Dimensionally printed Polylactic acid (PLA) are better than Polylactic acid (PLA) prepared with injection moulding method because it showed orthotropic, elastoplastic behaviour in both the cases of tension as well as compression along with robust asymmetry. Mechanical properties of PLA matrix which was reinforced by natural-fibre was also improved due to Post tensioning of these natural fibre reinforcement which were embedded in Polylactic-acid matrix.

Basavraj Gadagi and Ramesh Lekurwale [45] in their research on 3 Dimensional metal printing concluded that the process of 3 dimensional printing reduces time gap between production and design processes. It also lowers trial and error counts, alleviate defects. Hence, these characteristics of 3D printing label it as cost-effective for printing metallic products in large counts. They also highlighted the fact that strength of machined parts manufactured with conventional processes is different from 3D printed machined part strength. This difference is dependent on various factors like machine working environment, raw material quality and power supply making machines run.

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3. TECHNICAL SPECIFICATION OF MACHINE AND MATERIAL

For printing jigs and fixtures we used the Ender 3 Pro 3D printer. The filament we used is PLA (Poly Lactic Acid)

Table 1 Technical Specification of Ender 3 Pro

Maching Model	Ender 3 Pro
Modeling Technoloy	Fused Deposition Modeling
Printing Size	220mm* 220mm* 250 mm
Printing Speed	≤180mm/s, 30-60 mm/s normal.
Printing Precision	±0.1mm
Nozzle Diameter	0.4mm
Hotbed Temperature	≤100°C
File transfer	SD-card offline or Online
File Format	STL, AMF, OBJ
Slicing Software	Cura, , Simplify3D, Repetier Host
Power-Supply	AC100-120V/6.8A 200-240V/3.4A/ 50/60Hz
Filament	1.75mm PLA, TPU, ABS, carbon fibe, Gradient-color, Wood etc.
Net weight	6.98 Kg
Machine Size	440mm* 440mm* 465 mm
Gross Weight	9 Kg
Pacakaging Size	595mm* 495mm* 165 mm

Table 2 Mechanical properties of PLA[46]

Property	PLA
Chemical Formula	(C3H4O2)n
Yield Strength	27.69±0.77 MPa
Tensile strength	30.22±0.89 MPa
Flexural strength	64.48±2.49 MPa
Tensile Modulus	1572.42±27.16 MPa
Flexural modulus	2423.73±56.42 MPa
Specific Gravity	1.24
Melting Temperature	165.64°C

Why 3D Printed jigs and fixtures as compared to traditional CNC machining?

Traditionally, DelTech BAJA engineers manufactured tooling in metal as and when needed by the team by outsourcing it to a CNC house. Depending on forces exerted by the component to be manufactured, it may not always be necessary to manufacture these tools completely in metal. Poly Lactic Acid, or polylactide (PLA) based filaments come into play here, these filaments are extremely cheap, print at relatively low bed pre-heating temperatures of 210 degrees Celsius and are hence easy to print on any entry level 3D Printer (Creality Ender 3 pro in this case). 3D printing allows engineers like us to create products that are highly optimized depending on the end use, often manufacturing geometries that can't be manufactured on a CNC machine, i.e., internal filling (or infill) percentage and patterns like grids, tri-hexagons, gyroid, etc. Manufacturing these jigs and fixtures through advanced manufacturing technologies like additive manufacturing helps us eliminate skilled labor steps involved in machining from a solid billet.

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4. RESULTS:

A step by step approach to manufacturing of ATV suspension arms

STEP 1: Preliminary Design and Simulations (LOTUS)

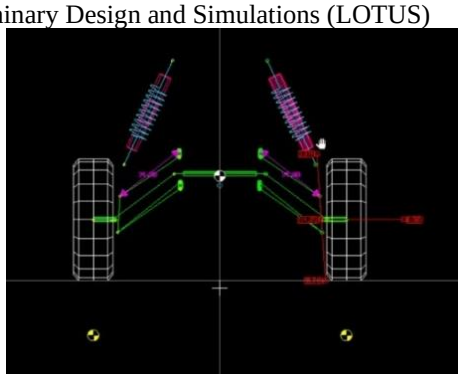

Fig 1

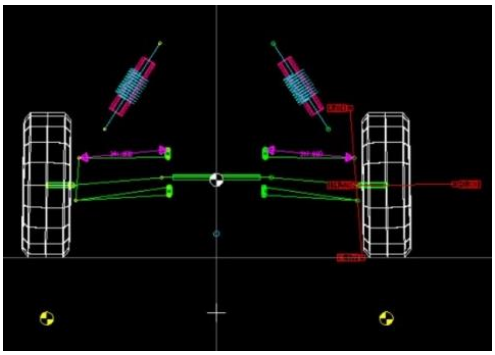

Fig 2

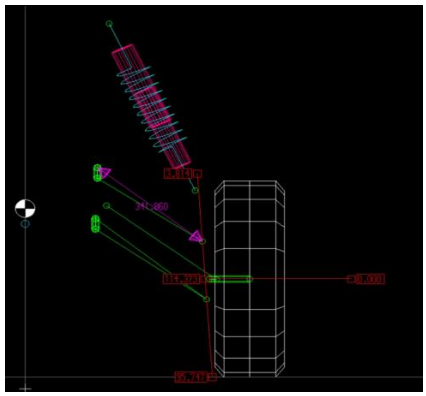

Fig 3

Fig 1,2&3, wheel and suspension motion analysis in LOTUS

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STEP 2: Designing fixtures on suspension arm base frame (SOLIDWORKS)

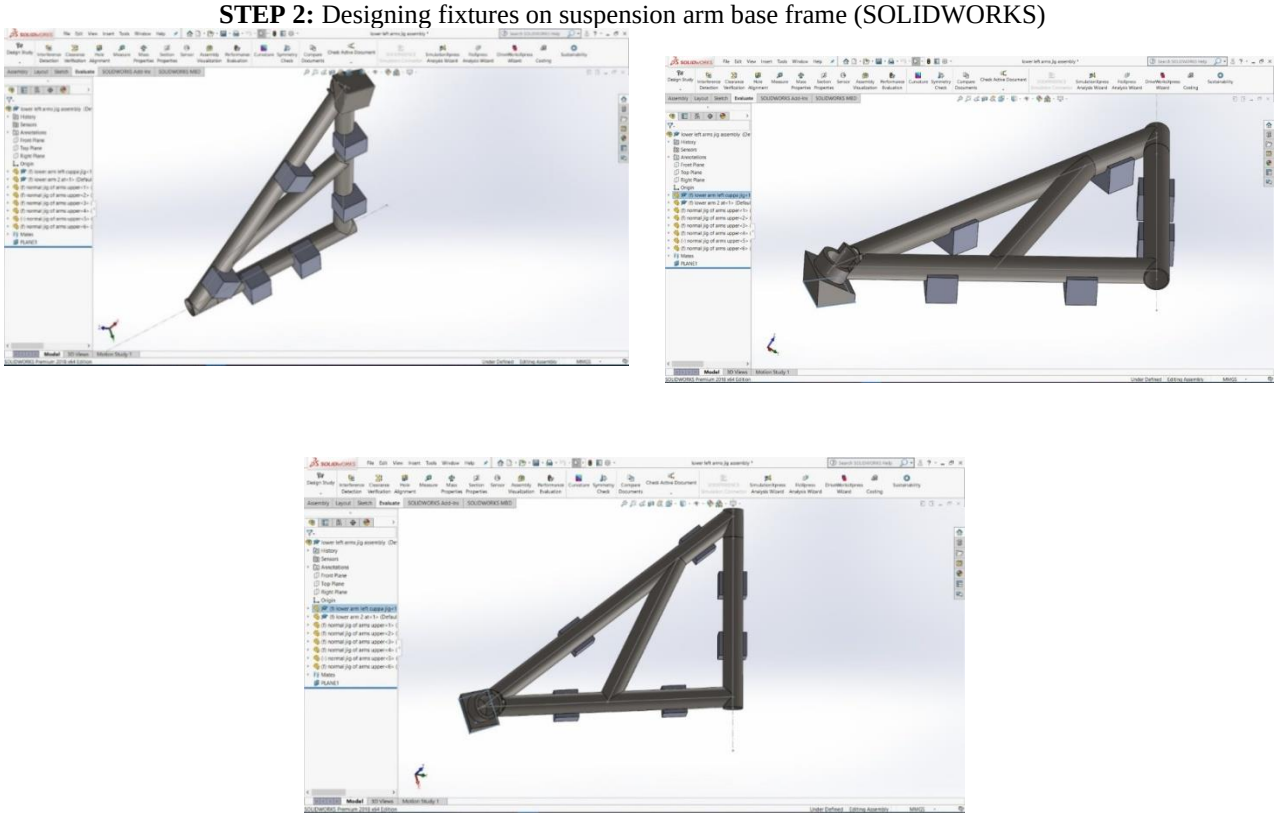

Fig 4, 5, & 6 Solid work design of jigs

STEP 2: Designing fixtures on suspension arm base frame (SOLIDWORKS)

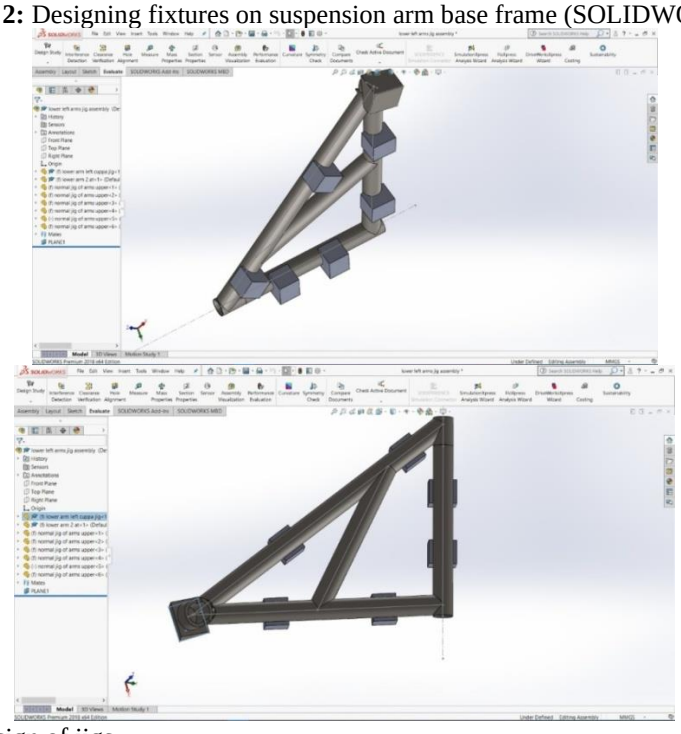

Fig 4, 5, & 6 Solid work design of jigs

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STEP 3: Load Simulation and Analysis on fixture (ANSYS)

structural analysis was performed on Ansys 19.2.material PLA plastic, Mesh size 3mm, Avg. aspect ratio =3.45 , Avg. skewness =0.45 ,48967 elements, 97211 nodes was chosen for the better stress distribution throughout the surface. base of jig is fixed and the force is applied from the top surface.total deformation and equivalent stress was calculated.

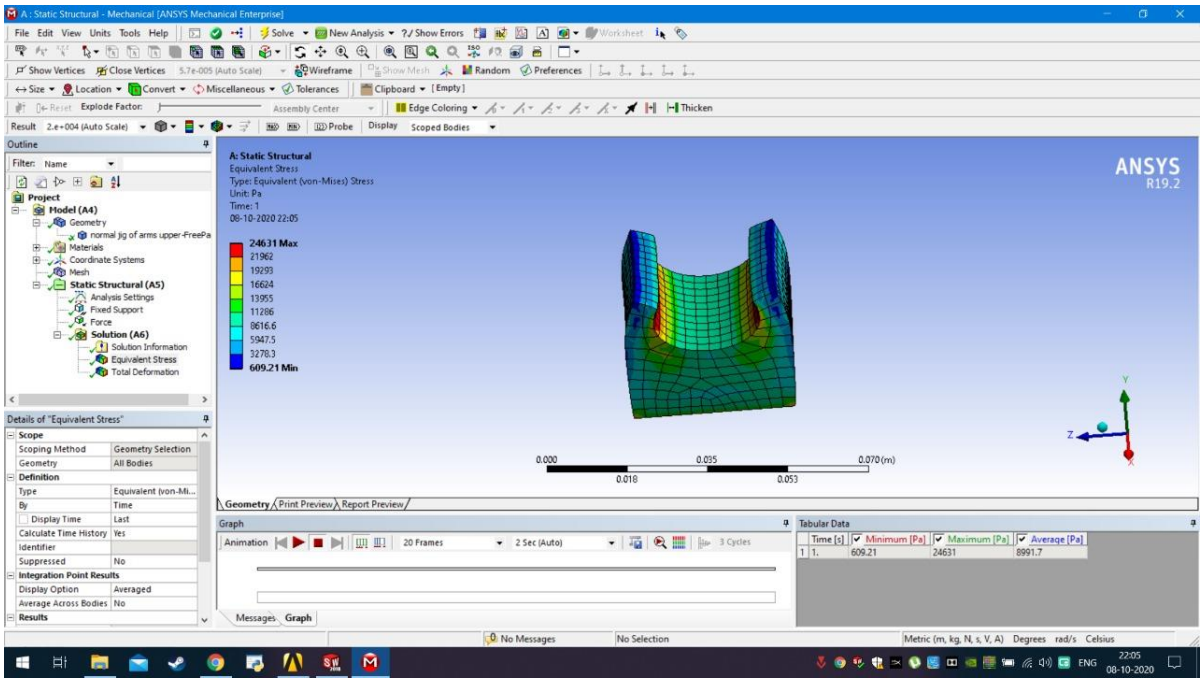

Fig 7 Load analysis in ANSYS

STEP 4: Fitting first batch of jigs and fixtures on 3D printer bed using CURA

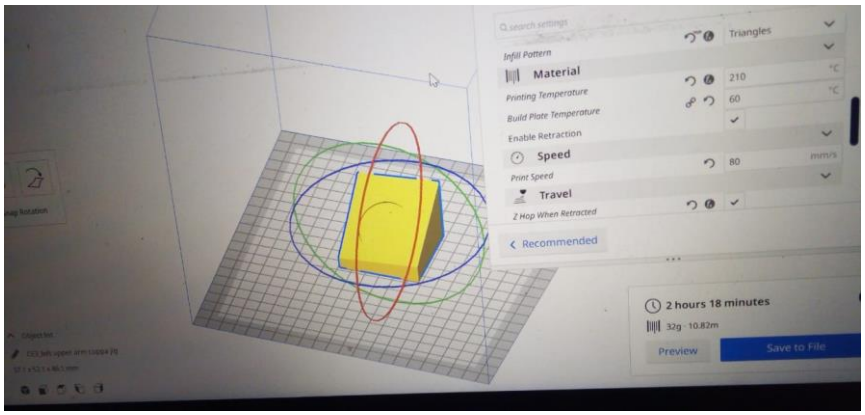

Fig 8 Bed fitting and initial settings for 3d printing

STEP 5: Fitting second batch of jigs and fixtures on 3D printer bed using CURA

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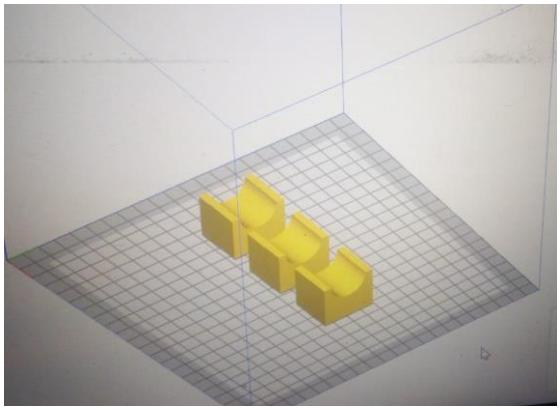

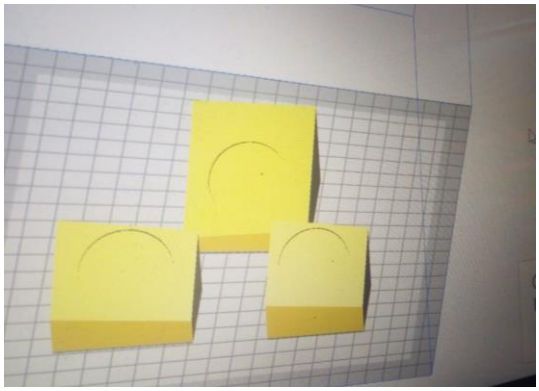

Fig 9 & 10 Print setting in batches for saving time

STEP 6: Preheating the 3D Printer (ENDER 3 PRO)

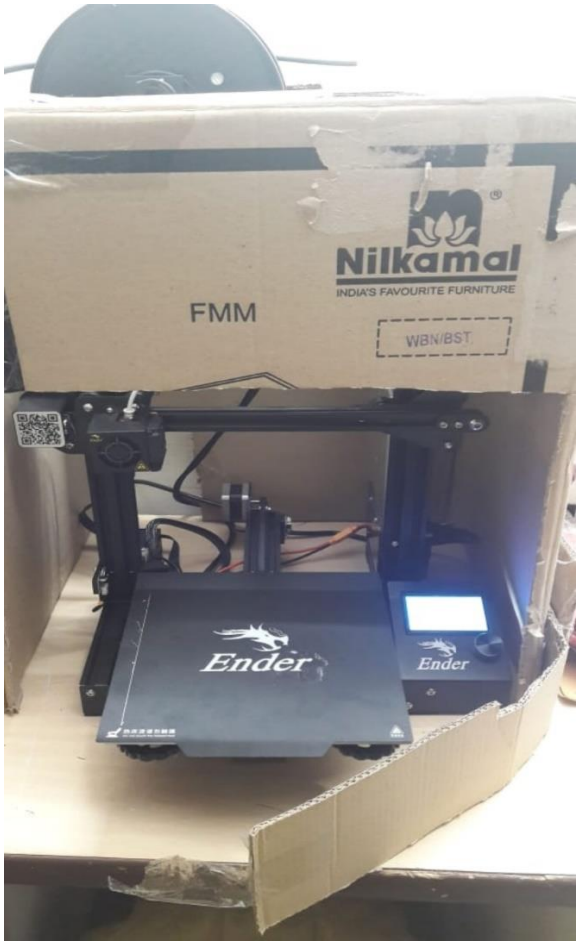

Fig 11 3D Printer bed and trap heating after initial filament and nozzle check

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STEP 7: Checking print for defects, return to STEP 1 if found faulty

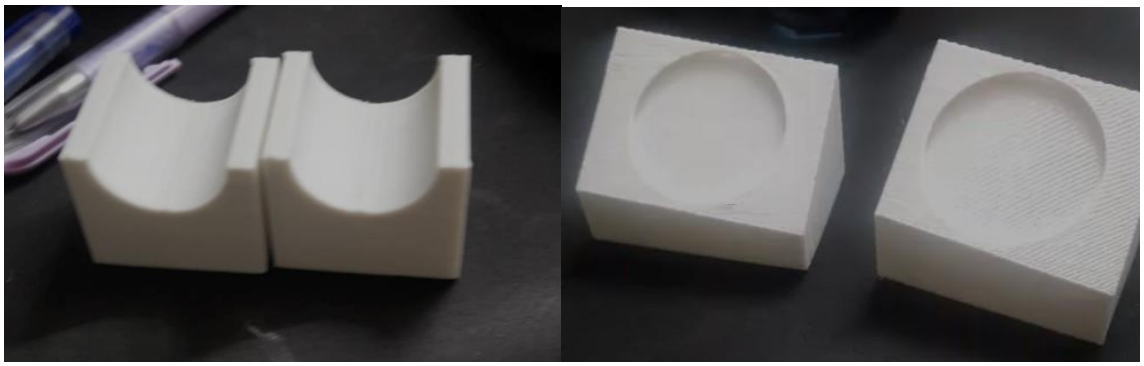

Fig 12 Checking print for defects

STEP 8: Fixing on reference diagram and start the assembly process

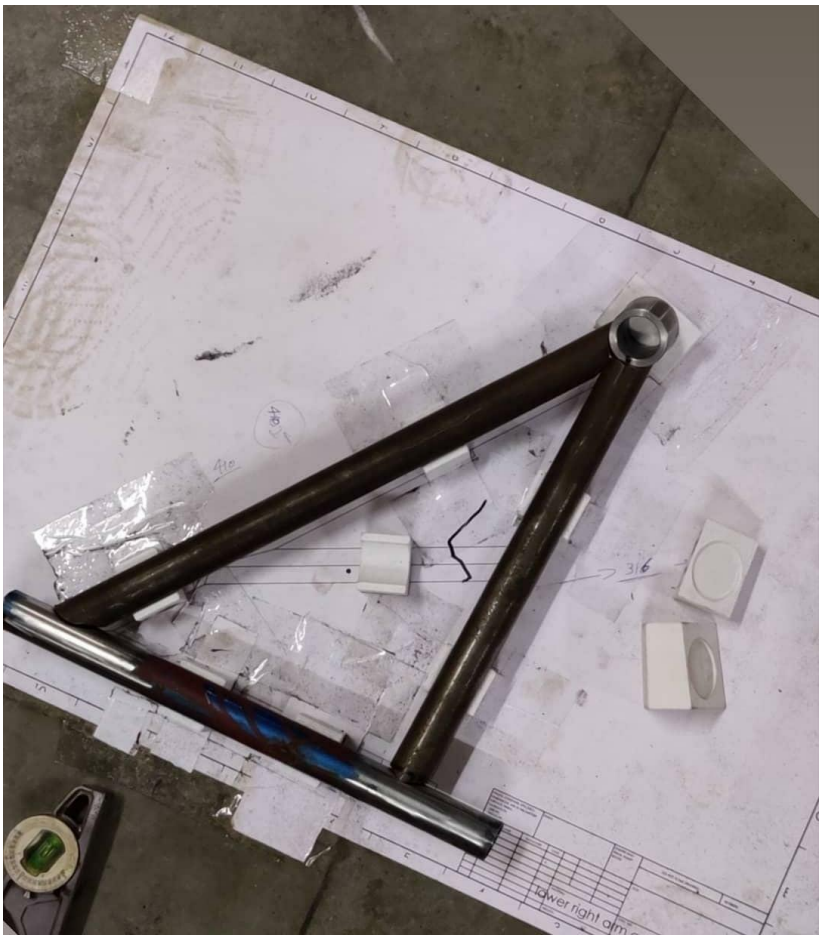

Fig 13 Manufacturing setup for primary suspension arm and spare manufacturing

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STEP 9: Assembling and Testing

Fig 14 Final output integrated with the designated machine for testing

5. CONCLUSION

3D printed Jigs and fixtures gave positive results in project as the vehicle manufactured using 3d printed jigs and fixtures completed endurance test of four-hour. The ATV manufactured has already achieved success in braking, rollover, steering, obstacle management, accelaration and hill climb scenarios as well. 3D printed jigs and fixtures for suspension arms gave positive results to our vehicle and hence a dependable idea to implement.

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