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Challenges Faced While Designing Body in White

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Abstract: ***Construction of Body in White (BiW) revolves around plenty of challenges. Ranging from BiW fixtures to curbing weight of Body in White sheet metal design. This paper discusses about all the design aspects in BiW manufacturing in automobile and confronting challenges that occurs. At present, lots of existing theories are being applied and efforts to improve the same are being made. This paper provides a path on how components can be developed and make necessary improvements. CAE (Computer Aided Engineering) tools have been used for FEA (Finite Element Analysis) and also an example of stress analysis of automotive chassis is given. An outcome depending on behaviour of loads acting on frame is drawn. The importance of hollow tubes, tubes of different- cross sections to counter weight and ease the designing of BiW frame have been proposed. This paper also provides insight on safety parameters with current construction of tubular frame chassis. Other solutions such as hybrid tubes, foam padding and plastic trim have been pointed out in this paper.***
Keywords: CAE, FEA, manufacturing, loads, tubes, cycle-time, cross-section.

I. INTRODUCTION

Body in White is the nomenclature given to car's body in automobile manufacturing. It is basically a frame that is either monocoque or welded. All the remaining components such as engine, doors are attached to this structure. Then, Body in White forms as a shell to which all the hanging parts such as engine, suspension, doors are mounted. This BiW is further categorized in two forms: 1. Frame based structure; 2. Monocoque structure. Research show that BiW made up of aluminium is more preferred over steel. As using it makes 30% of weight reduction and also light- weight. However, composites inclusive of polymers are very much in use. For instance, steel- polymer- steel or aluminium- polymer- aluminium sandwiches. Salvoy- a firm has produced composites including aluminium and different materials in 2019.

Body in White is a stage just before final preparation of manufacturing. Simulations of crash test are developed. Its production, aerodynamic principles are constructed from a clay model to a BiW ready product. Some of these designs are widely offered to racers, where they can replace these parts to those with aftermarket [1]. Some of the challenges faced while designing BiW are:

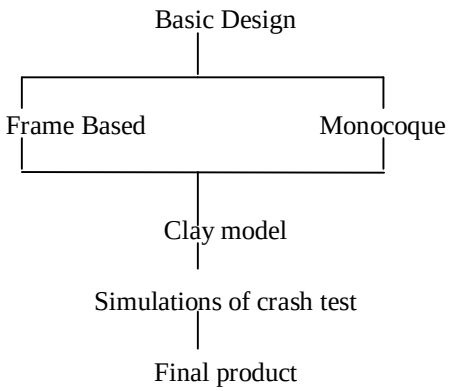


Fig. 1 Design process of Body in White

A. Composition

As compared to conventional materials like steel, approaches from other researchers which not have been used or need to use are highlighted.

1) Structural epoxy adhesives are thought of replacing welding process to some extent. Spot welds are only brought into picture while polymerization [2].
2) Body in White predominantly comprises of sheet metal that maybe steel or aluminium alloy. Most commonly aluminum alloys are used to manufacture BiW for automobile. Steels are used for heavy trucks and commercial purposes [3].

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3) [4] Propose that use of composite material like Carbon Fiber Reinforced Polymers (CFRP) reduces the weight by making it light-weight without altering other factors. It can have great impact in automotive field.
4) [5] Propose two methods of optimizing the design: one by using flexural rigidity and other by using optimization variable.
5) Despite developments in polymer and other composite material alleviation is only towards metallic products. Full austenization of basic aluminum alloy can be used for sheet metal by holding temperature in homogenous ɣ-zone. As it results in lower strength but also a certain amount of ductility providing better toughness. Also, varying cooling rate after forming process is contrary to upper critical one will produce bainite which is final microstructure. This increase will indirectly increase the crashworthiness due to better energy absorption.

B. Manufacturing Process

Once the material is finalized, the design of Body in White is carry forwarded to next stage that is manufacturing process. A couple of approaches have been proposed in this paper. [6] comment that improvements in Resin Transfer Molding (RTM) technology will prove a boon in reducing cycle time in CFRP up to 3 min as well as in high-pressure injection and compression. As application of Selective Laser Melting (SLM) in aerospace has resulted in the ease of manufacturing process by reducing the complex geometries, it will also be beneficial in automotive industry. According to [7] combined all major approaches applicable to rigid mechanical assemblies. However, the conventional statistical tolerance fails to justify the actual manufacturing process. [8] says the rigid tolerance simulation does not include any kind of deformation of parts that occurs due to clamping, welding, clinching, riveting or other operations. Finite Element Modeling simulation can outweigh this flaw by simulating the compliant part; with condition that model must be modified in each case and also the length of simulation run time scales with model size and complexity. Hybrid welding can be used to join steel or aluminium as they are only used in sectors other than automobile [9]. Continuous adhesive bonding or combination of adhesive bonding and welding or riveting can also be used. [10] has suggested that hydroforming is used for both steel and aluminum alloys in manufacturing closed section components with varying cross-sections across the length. If a composite polymer like Carbon Fiber Reinforced Epoxy (CFRE) is used, a different method of design body structure would be necessary. As they have varied characteristics in material behavior and design than those of metals and also require other processing techniques. Body structural components like front or rear rails, A-pillar, B-pillar and roof cross members are used. Most of them are closed sections but some are open sections too. The thickness of the beam sections should lie within 0.9-2.2 mm. Majority are straight beams and do not have uniform cross-section. Closed hollow box sections for steel are manufactured by stamping. Two hat sections are spot welded with their flanges respectively. For aluminum, extrusion is used as a manufacturing process. Polymer foam core should be implemented that have much higher weight saving than steel-polymer-steel or aluminum-polymer-aluminum sandwich panels.

C. Productivity

Now that the manufacturing is completed emphasis is given on producing the product in right-time. Efforts are made to ensure that the process from designing the model to assemble the components within time frame. By destructive testing this target can be achieved. Major welding flaws, deformation errors which occur when Spot welding, joining, riveting are spectated. Goal is to remove defects and immaculate the BiW structure which are not visible in normal working conditions [11]. When Finite Element Method, mathematical algorithms are clubbed with AI it will be an added advantage to reduce effort for adjustments in metal sheet fixture. Robots will use positional deviations according to varying external loads.

This can also be quoted as Intelligent Mechanization [12]. [13] argue that using conventional techniques of production of BiW with steel and aluminium alloys in not possible so a new method of hybrid joining; Rivet Resistance Spot Welding (RRSW) is implemented. As compared to Self- Piercing Riveting (SPR) it has more strength. [14] said that and event- triggered feed- forward control method which works on prediction will be least in vogue to understand the real- time inline dimension control of overall Body in White assembly procedure.

This would probably decrease the frequency of fixture adjustment. [15] showed how knowledge based search algorithm can reduce the time in production of BiW. This algorithm is used in software prototype. [16] debates that rather than using conventional cycle, Weibull distribution should be used to develop Net Ideal Cycle Time (NICT) from this type of distribution. This results in increase of 3.1% in estimating NICT and is more trusting plan.

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1) Summary

a) Destructive testing should be implemented to inspect defects [11].
b) Intelligent mechanization should be used [12].
c) Rivet Resistance Spot Welding (RRSW) should be used for joining steel and aluminium as an alternative to conventional joining method [13].
d) Knowledge based search algorithm can reduce the total time of production [14].
e) Event triggered feed forward control method will be beneficial to monitor real time dimension control of assembly in order to lower the dependency of fixture adjustment [15].
f) Similarly, Weibull distribution method should also be used [16].

D. Cost

As the Body in White structure comprises of 50- 70% of total car, the overall cost estimation is brought- down drastically. Along with high safety, light-weight and other luxurious facilities, cost- effectiveness is also equally important. With increased demand for 'eco- friendly' cars and customer needs, ever-lasting, anti- corrosion technology has developed. This has led to increase the cost of BiW. However, measures are taken to counter the same.[17-18] address on Technical Cost Modelling which may help in analysing costs for volume production and lifecycle cost assessment. Another model proposed by him was up to 45% reduction in costs and use of carbon fibre material and other composites.[19] address to inculcate alternative materials and not only focus on steel and aluminium. They propose a cost- benefit structure to analyse the use of existing materials and help to evaluate monetary in long-run and environmental costs.[20] said that laser welding should be used which has higher productivity than other processes which indirectly reduces cost. 'Green Sand Mould' method combined with AI manufacturing processes is highly recommended. This makes a big trench in cost than State of Art [2].

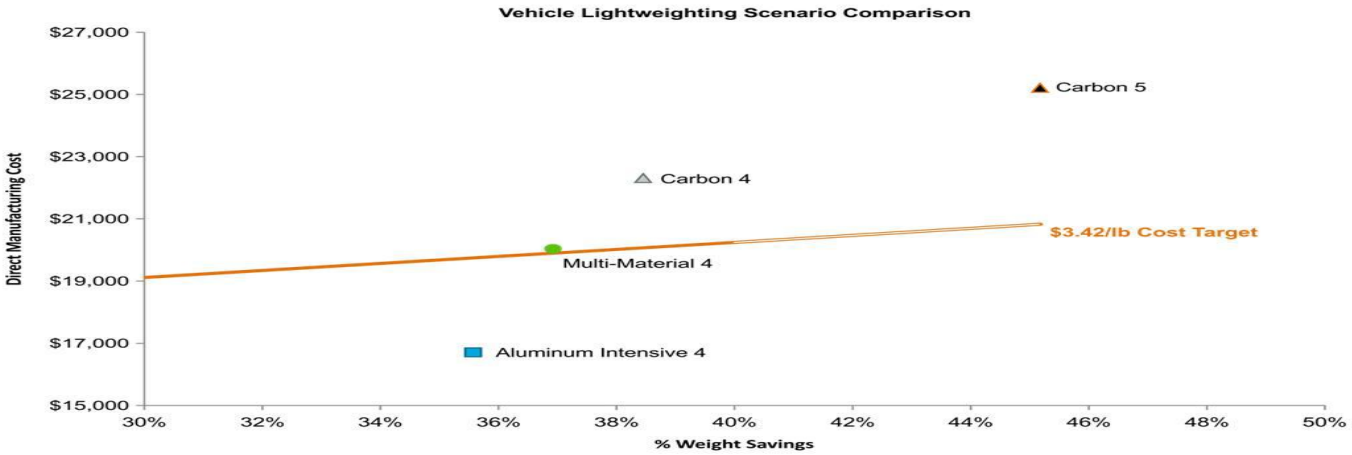


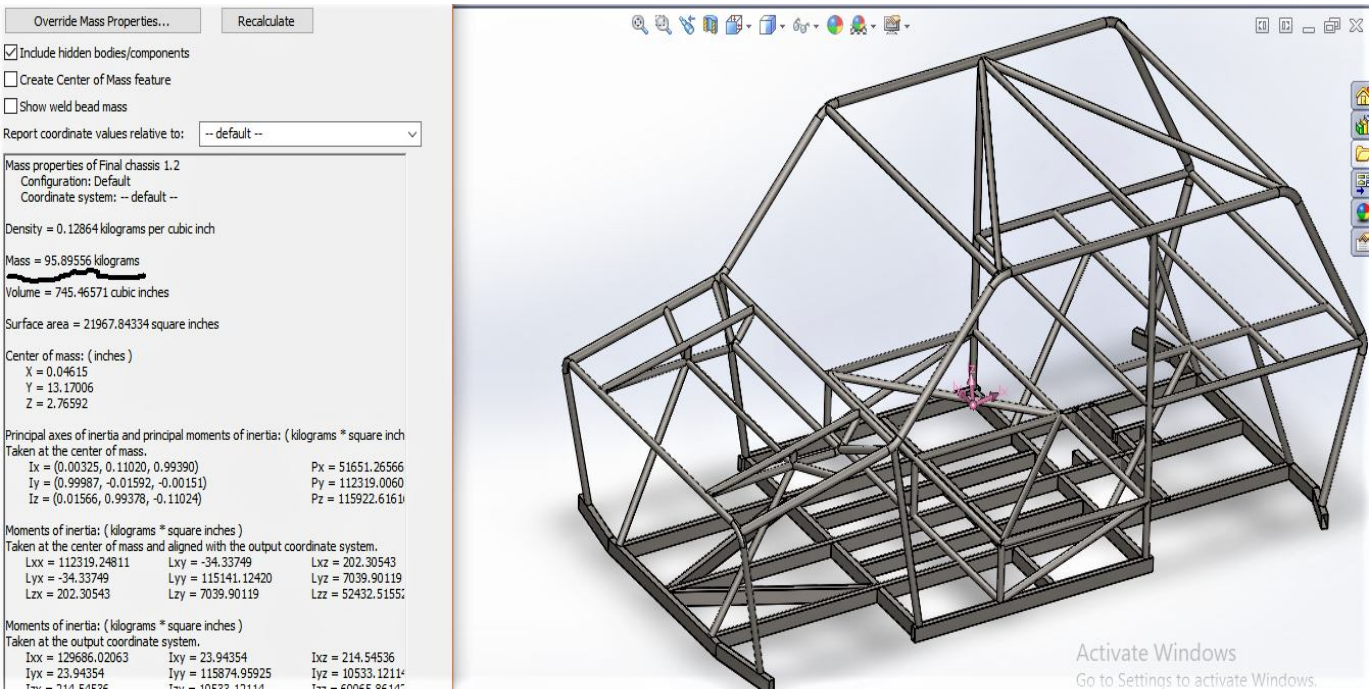
Fig. 2 Graph of Scenario Savings vs. Target.

E. Crashworthiness

While some units are easily replaceable there should be some way to improve the safety parameters of Body in White structure. FEM modal analysis is carried out to check the impacts of loads on frame. With help of these methods necessary improvements are suggested. [21] had experimented crash analysis with replacement theory by replacing conventional steel and aluminum alloys with Magnesium. The experiment conveyed that the structure weight was reduced by 40% and had astonishing results. [22] use an optimization method based on equivalent static loads method ESL, a nonlinear dynamic topology. [23] have followed a number of approaches that depict the importance of usage of composite materials, foams, hollow tubes to improve the mass of vehicles body. Surrogate model method can be implemented to transform the complex collision optimization problem with high nonlinearity to an easier approximate model optimization. [24] have focused on model identification methods that use optimization algorithms to create reliable multi-body systems. [25] sensitivity analysis helps in mass reduction by monitoring critical panels of Body in White structure. [26] have proposed the MSOT Multi- dimensional factor auto body model, S-Screening auto body component, O-Optimization of plate thickness, T- Testing and validation technique to overcome the flaws which analyse crashworthiness of Body in White. [27] say that using Scaling Finite Element method is highly debatable because of its computational costs and also time consuming. Hence, he showcased to use deterministic edge detection technique which is fast and accurate.

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1) *Experimental Analysis:* An example illustrating using monocoque chassis is given below. Three materials namely steel, aluminium and Magnesium are used to show the behaviour of BiW structure in terms of mass reduction, cross-section and rigidity. Solid works 2020 and Ansys V14.5 have been used as tools.



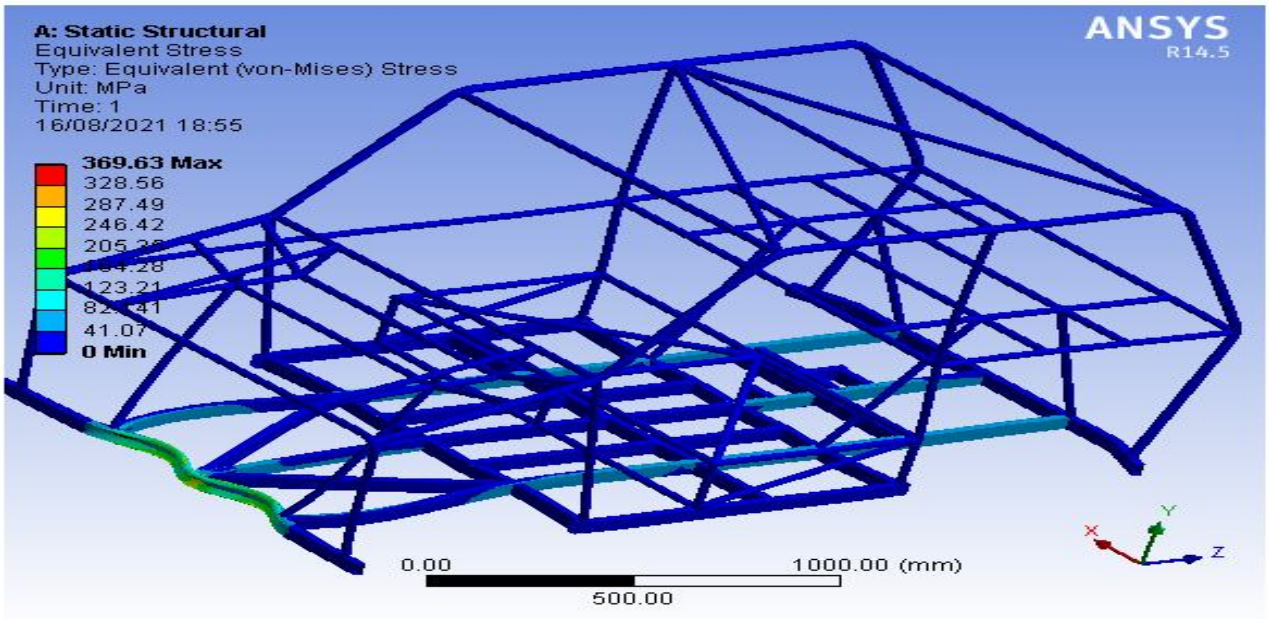


Fig. 3 CAD model of monocoque chassis with AISI 4130 composition and its stress results

Here, AISI 4130 Chromoly Steel is used as material. Standard mass of 550kg for four wheeled passenger car is assumed and only Front load impact is considered. It can be observed that when this material is used weight of 95.89kg is obtained with factor of safety 1.17 upon force of 31270N which is 30 times more of the weight.

Now, without altering the force, mass, displacement and applying conditions, the 2nd scenario is observed by changing the material.

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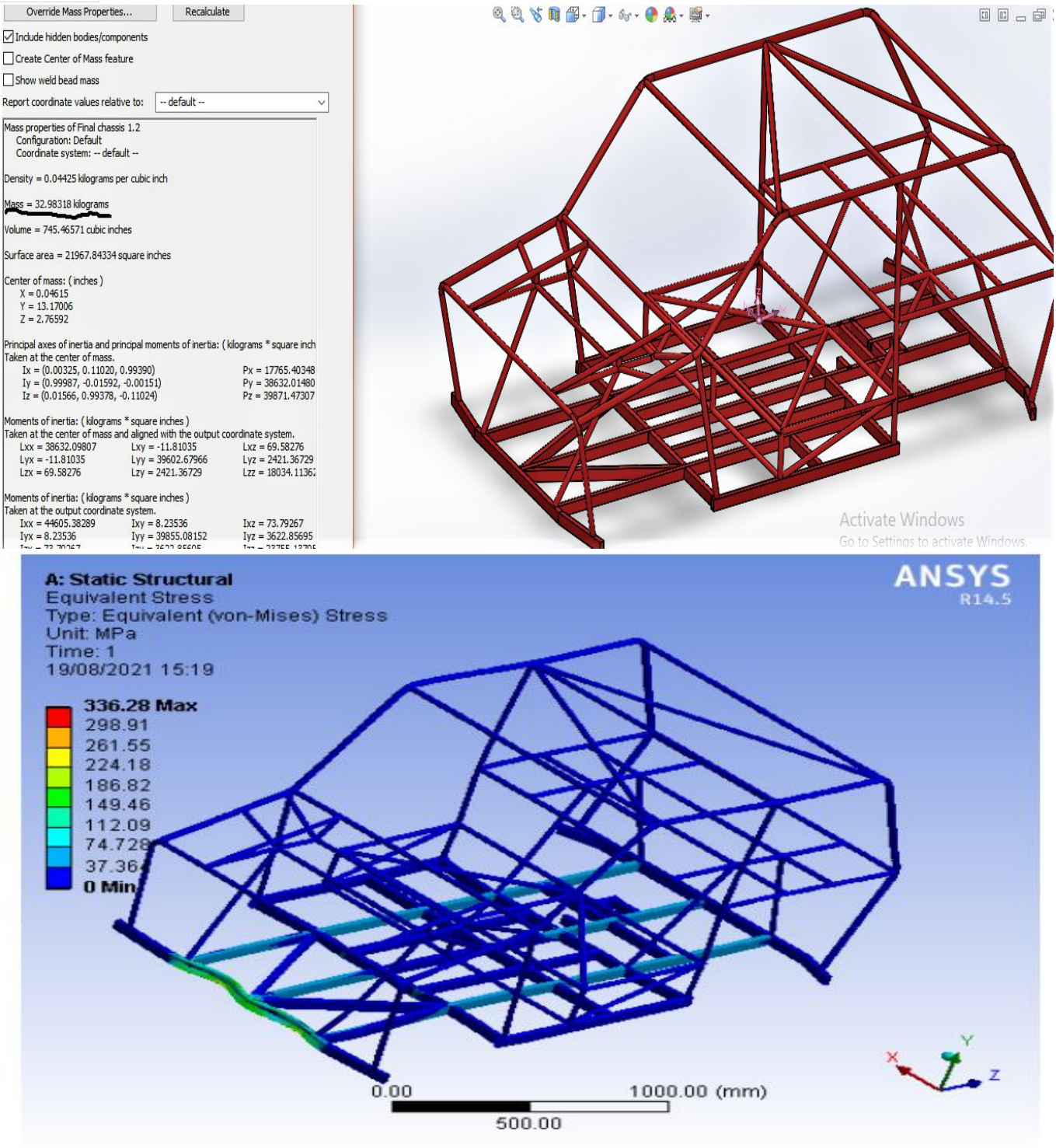
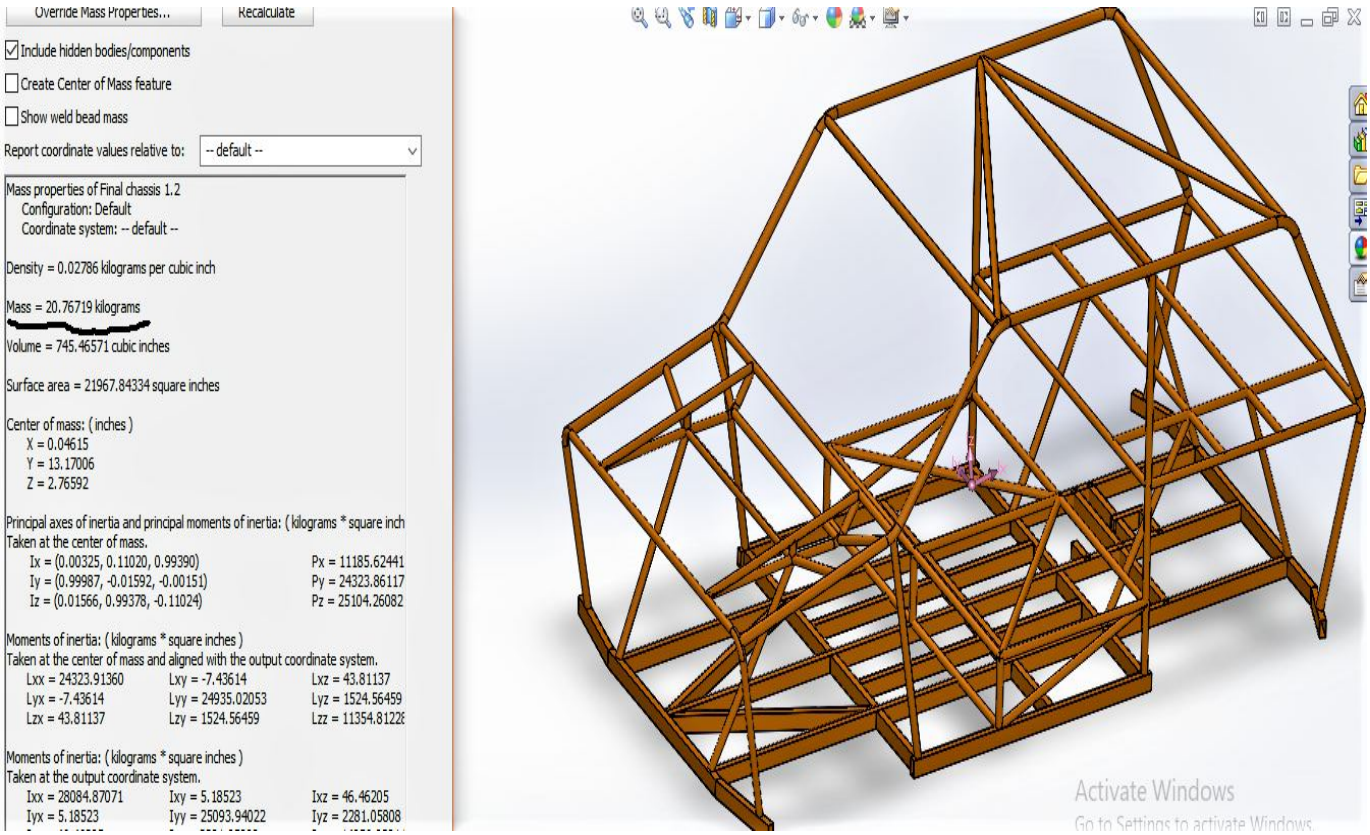


Fig. 4 CAD model of monocoque chassis with Aluminium6061 composition and its stress results

It can be seen that despite reduction in mass to 32.98kg which is 60%, the stress remains the same. This means it is less rigid as compared to steel, so is the manufacturing of Body in White using aluminium as material a bit complex.

In the 3rd scenario, the material is again changed to Magnesium AZ31.

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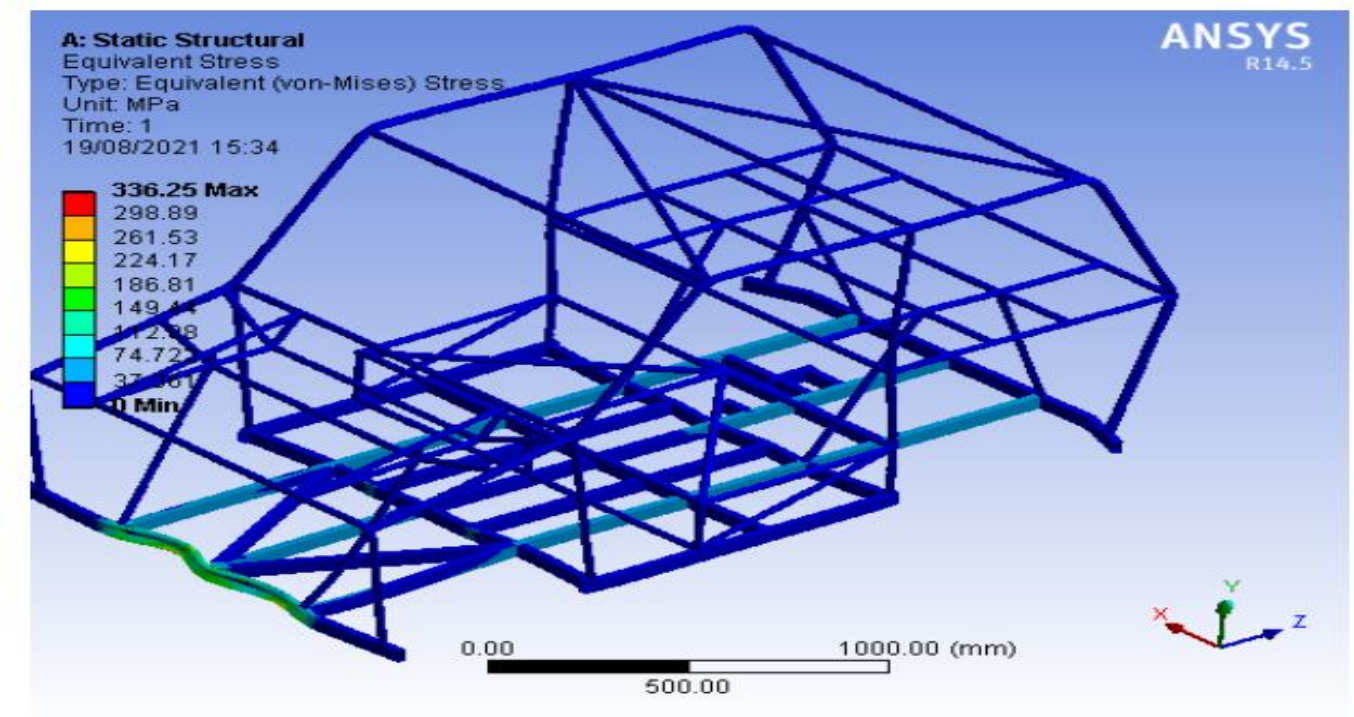


Fig. 5 CAD model of monocoque chassis with magnesium AZ31 composition and its stress results

Now, the mass is drastically reduced to 20.76kg but the manufacturing of structure is quite difficult and time consuming.

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II. RESULTS & DISCUSSIONS

A. According to [21], Magnesium alloy is also used which result in although there is 70% reduction in mass but not trustworthy in terms of rigidity and stiffness.

B. Sensitivity Analysis can also be applied to this example with some extra developments in design [25].

C. As said by [23], hollow tubes are used with varying cross-section which are easier to design and consume less time. This method is called Surrogate Model method. Also, it has an application of non-linear topology as per [22].

III. CONCLUSIONS

A. Overall, use of composite materials has been extensively implemented which assures high stiffness with low weight. Various manufacturing processes have been improved to keep the on-going in long-run.

B. Different techniques like Weibull distribution, knowledge based search algorithm and intelligent mechanization are used to reduce the cycle time of production of Body in White.

C. Cost-efficient designs with respect to increase in productivity and optimization of time effectively are deployed. These strategies are used in various forms to satisfy the increased demand globally.

D. Right- time manufacturing is ensured by careful study from design to validation. Simulation models are integrated widely so that the BiW passes all the safety parameters along with high torsional rigidity.

E. All the parameters explained in this paper are performed on a specific chassis model to showcase the behavior of composite materials and to propose an easy way of designing a simple Body in White structure by employing geometrical shapes.

IV. FUTURE CHALLENGES

A. There needs to be more advancements in usage of Magnesium alloys as it can change the design approach to a great extent.

B. Some improvements in manufacturing process of aluminium, by varying the cooling process for bainite, can result in increase in stiffness as well as rigidity. Advancements in this area are necessary.

C. Research on re-cycling of steels without carbon emissions should be explored.

D. Using composite materials which are environment friendly should be in spotlight.

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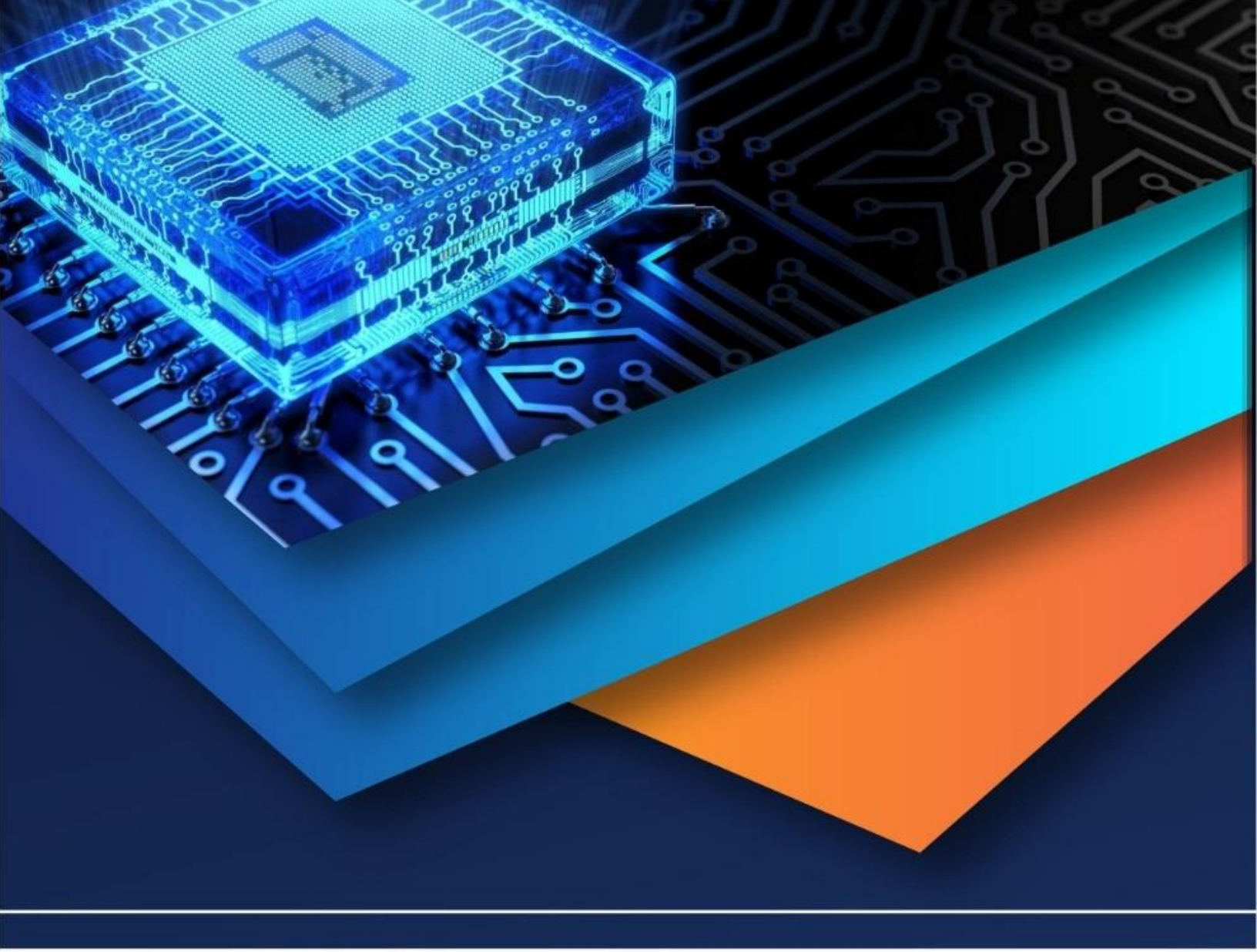
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