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A review on Body in White materials

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***Abstract*- Automotive weight reduction is very important and highly demand in the present scenario, because leads to increasing energy saving and reduction in emissions. The conventional material steel is replaced with high grade steels, aluminum, Magnesium and composites gradually for the Body in White structure. Light weighting of Body in white, the mechanical properties and crash worthiness are retained. For the mechanical joining process of multi material system new technologies are presented. For the joining process of body in white various finite element analysis are provided with improving technology. Various manufacturing issues and cost aspects are discussed.**

***Keywords*- Automotive materials; body in white; lightweight; mechanical joining;**

1.0 INTRODUCTION

In the present years the vehicle light weighting main trend to in order to increase the fuel efficiency, also improving vehicle performance and reduction in emissions. In order to light weighting possible only in vehicle's body in white structure (BIW) which is main back bone of vehicle. The light weighting of BIW is achieved by change in structure or material modification. The modification is costly process which requires the changes in forming process, welding and assembly system. In order to light weighting of BIW the traditional material mild steel is replaced with aluminum alloy, high strength steel, Magnesium and composite material [1], [2]. High strength steel have high potential to weight reduction with higher strength and ductility. Comparing to steel the aluminum usage is more in BIW structures which has a large variety and availability and also absorbs crash energy higher than steel.

Joining of materials done using riveting which is increases the weight of the body. During multilateral joining process many issues raised because of material phase change which leads lower the strength of structure. In order to reduce the weight many new innovative joining process invented like clinching, laser beam welding etc. Before making the real structure of body in white, structures are analyzed using CAE models in finite element analysis software in order to check the NVH, safety, mechanical performances[3], [4].These analysis helps to make the changes if there any changes required before moving further.

2.0 LITERATURE REVIEW

Mayyas et al.[5] Studied about tools for material selection of body in white using Quality Function Deployment (QFD) and Analytical Hierarchy Process (AHP). The AHP is mainly a mathematical formulas. QHP is customer oriented method.in this study steel grades like DP, HSLA, martensitic steel, aluminum sheets(5xxx,6xxxx), magnesium and titanium sheets, HDPE and CFRP are analyzed. The weight reduction in vehicle total weight leads to improve the fuel economy. Very less density materials are gives more complexity during manufacturing process to maintain the geometry. In QFD mainly focus on the customer needs like performance, fuel economy, safety, NVH, maintenance and life which are depends on technically density, strength, elongation, vibration, various resistance etc. In AHP provides the mathematical relation to the customer need and engineering aspects. In this materials we know that some materials are attractive towards the mechanical properties which will fail in the customer needs. Finally the tools are very helpful for the design of BIW for both aspects. QFD is very good tool for the selection of material in automotive parts without neglecting the customer and engineering requirement. Also AHP is decision making tool based on the selection of materials. In this study steel grades are better ranked for the selection of BIW panel. Further we can study this on the base of cost and manufacturing.

Mustafa Kemal[6] studied about applications of magnesium (Mg) and its alloys in automotive industry. In this study magnesium material is contribute towards the fuel economy, environmental causes, advantages and limitations in the automotive industry. Mg alloys helps in the improvement of creep and corrosion properties at higher temperature. Also Mg alloys reduces the weight around 22%-70% in automotive components. Alloy materials are Al, Mn, Zn, Thorium (Th) are increases the strength to weight ratio of Mg. The specific strength of Mg is higher is compared to Al and Fe. Mg-Al-Si alloys improves creep resistance but difficult to casting. Alloy AZ91 is used for die casting but having maximum operating temperature is 125°C. Mg-Th shows high creep resistance at 350°C. Mg-Al-Sr shows heat resistant lightweight properties used for engine blocks but Strontium (Sr) has less effect on corrosion resistance. Coatings are done to Mg-alloys to increase the corrosion resistance. Coating also improves the lubricity and frictional resistance. Some of the coating methods are hazardous and not environmental friendly. Pure magnesium easily alloying with other materials because of low mechanical strength. Formability of Mg is very poor at room temperature. The Mg alloys are high reactivity and water coolants are not used, there will be possibility of fire risk. The Mg alloys are used in various applications in automotive components like gear box, engine block, interior parts, suspension arms, cast components etc. the corrosion, creep properties, need to improve in order use more Mg alloys in vehicles to reduce the weight.

Erica et al. [7] studied about strategic materials selection in the automobile body. Here polymer composite shows significant effect on economic potential in BIW design. Also know that fiber composite component assembly are implemented on vehicle models. It represent in process based cost modelling (PBCM) for (a) fiber-reinforced composite component production, (b) component assembly, and (c) design implications of glass vs. carbon reinforcement. PBCM is for analyzing economy of alterative manufacturing process without affecting the economic burden of trial and error investigation. Total manufacturing cost of assembly and each manufacturing component cost calculated. The design calculations are made for CFRP unibody, GFRP unibody and compared with Steel unibody. Structural reaction injection molding process is used, consists of 4 process a) pre-form making, (b) pre-form trimming, (c) reaction injection molding, and (d) final part trimming and inspection. Cost is estimated based on cycle time on each process, machine cost. The composite material component manufacturing cost is high compared to steel components because of low production volume. Results shows that the polymer composite industries need developments in process and design and production perspective to maintain good economy.

Jürgen Hirsch [8] studied about development in aluminum automotive applications. Aluminum is light weighted material which leads meet economic and environmental requirements. Al alloys 5xxx and 6xxx are used to increase the strength and formability. Aluminum is mainly for the design of BIW using Extrusion and stamped sheet monocoque. Al-Mg-Mn alloys are shows optimum formability and strength which is due to their specific high strain hardening. Most of the components are produced by casting to achieve strength and durability. Super light car (SLC) concept is use minimal weight to BIW design, taking account of affordable cost and optimum performance. In SLC heat forming technique introduced to producing complex aluminum tubular shapes. In this concept laser brazing technique used to join the AL and steel. Al alloys are fit in many requirements like to increase the performance, to resist the corrosion. The SLC shows aluminum used for the car body having merits of 30% not losing performance. Manufacturing process extrusion and casting are applied where the strong integration required.

De Cooman [9] studied about the cold rolled and inter critically annealed low alloy steel(TRIP-Transformation-Induced Plasticity) sheet material and their mechanical properties for the manufacturing of car's body in white which provide improvement in safety. The TRIP steel has a high energy absorption potential and having tensile strength around <1000 MPa.it report high strength steel can combine the properties over a larger strength ductility steel. The low alloy TRIP steel contains alloying element about 3.5 wt. %. Whereas conventional trip steel contains abbot 4.5 wt. %. Carbon and Mn contents takes vital role in weld ability and hardenability respectively in the trip steel. Low alloy trip steel contains 3 phases' ferrite, bainite and austenite along traces amount of carbides. From the TEM images shown that carbide is free in the bainitic ferrite phase. The cold rolled TRIP steel are processed by use of thermal cycle including five stages the TRIP steel reach high strain rates in the Split Hopkinson bar method. Presence of retained austenite in the low alloy trip steel which cannot made as bulk phase. From the stress strain curve Carbide free bainite shows continuous yielding and high work hardening. Crash resistance test performed for the trip steel which results that it can absorb more energy than other steels. CMnSiAl and CMnAl TRIP steel are compared on the basis of strain rates and CMnAl TRIP has more elongation in both ferrite and bainite phases. TRIP steel has major contribution in the thickness reduction in automotive industry without affecting to the draw ability and formability. Cold rolled trip steel are Zn coated have high tensile strength, used for the A and B pillars of BIW manufacturing.

Paolo et al. [10] studied about development of carbon/epoxy structural components for the high performance vehicle. Focused on the failure modes of designing fiber/resin materials. Materials also shows to withstand environmental aging, described using ASTM D2247 and ASTM G26. The flexural test shows that the tape laminates failures suddenly than the woven laminates because the laminate cracking. The interlaminar shear (ILS) strength of the material is found for different unidirectional tapes of the material using ASTM D2344.In ILS test laminate cracking not affect the strength because of matrix is dominated. Quasi-isotropic nature of material lead design of both structural and nonstructural components. For the body panel and chassis component the material need to far exceed in the safety requirements and enormous to achieve the crashworthiness. In the body panel to get high surface finish and not to show the marks of the fabric, it undergoes many process of paints which helps in mold adhesion, moisture resistance.to validate the resin system 4 tests are conducted. From the result know that design for strength and stiffness using multidirectional tape materials than the unidirectional material. Epoxy is good adhesive between body panel and steel chassis which is best at vibration damping, strength and stiffness. Fine surface finish helps in longer durability from environmental resistance.

Merklein et al. [11] studied about thermal behavior of ultra-high strength boron manganese steel (22MnB5) in the hot stamping condition. This material is light weight and shows reduced formability. Apart from normal formability process, here partial press hardening technology is used to manufacture the parts along with a thermal properties are determined using a heat able quenching tool. Partial press hardening process is for the where region shows higher ductility is relive higher forces, ex. Crash situation. In hot stamping steel passes in 2 micro structural transformation. After phase transformation followed by quenching process which shows martensitic phase transformation, where the strength of material is up to 1600Mpa and having complex geometric shape. Heat transfer coefficient (α) is determined for different tool temperature 20°C, 100°C and 300°C using a universal mechanical testing machine type SchenckTrebel RM400. HTC is responsible for the thermal behavior and cooling of blanking in whole forming operation. As the tool temperature increases the HTC increases along with increasing contact pressure, but drastically decrease in the cooling rate. Impact of contact surface also induces the heat transfer coefficient. In the deep drawing test gap distance takes role in vary the heat transfer coefficient determined using newton's law of cooling. As the gap distance becomes the more the HTC is decreases along with the tool temperature. The process are significantly depends on the tool temperature. The HTC values high for the contact pressure whereas low for the gap distances. The stamped part application used for the safety and crash related components of the BIW. Furthermore need to investigate the surface finish and topology of the material to explain the thermal behavior.

Masaaki et al. [12] studied about development of aluminum body for the most fuel efficient vehicle. Replaced steel material with aluminum for the BIW.in order to face the cost and technical performance, designed a hybrid aluminum body structure which resulted in half of weight over steel body having high safety and performance and stiffness.
Aluminum space frame structure uses extrusion mold and performance wise good and uses more fastening parts and fittings for mounting other panels which leads to more cost. Aluminum hybrid structure is combination of monocoque and space frame structure and combined by casting, press molding and extrusion molding. Hybrid body structure has 15% less parts and 24% less welding points compared to monocoque body. To improve the energy absorption rate and to minimize the head on collision damage, side frame divided into front and rear of cast parts. To bend extruded materials push through bending method is used compared to stretch bending method to avoid the involvement of bending dies. Thixotropic forming method is used. By using hybrid structure, weight reduction, high collision safety, coast savings of vehicle obtained.

Feraboli et al.[13] Studied about development of CFRP structures for topless high performance vehicle. Cars are reengineered as convertibles, it lose 50% or more body's torsional rigidity. Carbon/epoxy composite frame is introduced to compensate the absence of roof structure. Here design of frame, manufacturing decisions are discussed using integrated product development (IPD) strategy. The CFRP structural elements are sandwich form comprised into fabric piles and aramid honeycomb of 5mm thickness. In the rear sub frame design majority to increase the torsional rigidity and resist the cyclic loads. CFRP frame are used upon the steel frame which not only reduce weight and allow for versatile design. Mechanical characteristics (torsion rigidity, bending, and flexural loading) of specimens are found. Once the experimental tests are over, component are subjected to full scale vehicle modeling by hyper mesh and Nastran. From the analysis 50% torsional rigidity improvement observed by replacing the steel frame with CFRP in a rear sub frame structure. Furthermore required to test on safety requirements and crashworthiness on CFRP material.

Hoffman et al. [14] studied about the cold rolled steels for the automotive application. Majority of BIW are offered by advanced multiphase steels, because of their formability and high strength level. They are mainly focus the strength and crash resistance. The high strength multiphase steels are developed by hot dip galvanizing process to get good formability properties. The annealed grades like Dual phase (DP) & TRIP steels with tensile strength of 1000MPa with sufficient ductility used for the vehicle structure.to improve the strength/durability balance a new range of steels researched was high Manganese steel with induced plasticity(X-IP).Cold rolled multiphase steels are DP steel, TRIP and complex phase (CP) steels shows a different microstructure. DP steels consists of ferritic matrix phase having lesser yield strength values at equal tensile strength values when compared to CP steels containing martensite or bainite in a matrix of ferrite phase. Whereas TRIP steels contain ferrite matrix with retained austenite having strength range 500-1000MPa and with minimum total elongation value. X-IP steels are single phase austenite microstructure shows extraordinary tensile ductility compared to other high strength multiphase steel.

The microstructure and grain sizes takes major role in the material to get a high yield strength. Work hardening rate depends on microstructure and dislocation density due to straining. Comparing carbon steel and DP steel, both shows microstructure with hard phase particles sharing more or less same geometric features. But the combination of tensile strength and work hardening rate shown by straining value (n).Influence of aluminum or Al-alloy to DP steels shows best hardening behavior because of high amount of retained austenite and high concentration of carbon which leads to advantage for crash resistance. From TTT behavior the influence of Al-Alloy on steel knows. True stress and true strain curve drawn for the X-IP steel which shows the high strain hardening rate with increasing strain. Also from SEM got to know that deformed tensile specimen shows high density of deformation twin. From this, new grades of high performance steels produced by Thyssenkrupp is concentrating on strength and crash resistance. Furthermore development of alloying microstructure and thermal treatment verification has to done.

Prawoto et al.[15]studied about the vehicle weight reduction through heat treatment. In this process for BIW and suspension system, steel is maintained as base material. Heat treatment like Annealed microstructure, quenched microstructure, tempered microstructure, Austemper microstructure were used. Even combination of heat treatment were examined.

Stephan et al. [16] studied about mechanical joining process for body in white production. For the light weight BIW production multi material mix is used. Proportion of high strength steel and aluminum alloy materials used. For joining the materials mechanical joining process are suitable and new technology developed that is clinching, which is economical method also. This method join the material by punching and clinching at one step. Clinching is joining process by forming, permanent joints are formed without additional material and without heat introduction. In this process die geometry contains sharp punching edge and hemisphere geometry at punch side, used to get lowest punching force over maximum surface[17]. Two punches are used, outer punch for stamping and inner punch for clinching. This process depends on the material thickness and strength of material. Finite element analysis provides details of process step takes place and also helps in monitoring the joining sequence. FEA analysis the tool loads during the process and avoids the broken dies by changing the punch diameter which results in reduction on critical tensile stress at a die bottom. This FEA and simulation reduces the cost and time for development of process[16].

Fridlyander et al. [18] studied about use of aluminum alloys in automobile structure. Sheet of AV alloy (60661) with fine grained recrystallized structure which is suitable for automotive panels and easy to manufacture. In this paper mechanical properties of sheets after aging are presented. The use of aluminum fails in two factors which are 1) cost is high compared to steel and 2) difficulty in manufacturing of structure. But these factors are negligible when the vehicle mass is reduced to improve the fuel efficiency. Cost problem solved by a large scale production also by recycling of scarp aluminum to further more use. The complete body of car by aluminum alloy leads to usage in design of car having hybrid engine with electric traction motor. Scania and Daimler used welded frame from pressed aluminum for the bus body and car cabin respectively. The bus body resulted in 600kg weight reduction helps increase the seating capacity and in car cabin corrosion resistance is improved which is preserved for 20years or more. The main reason for usage of Al in the car bodies are having small grain size range 2 to 50µm , high corrosion resistance, have good formability, high strength, dispersion hardening and high quality surface properties. There will be a possibility of recycling of 80-90% of worn aluminum parts also. Heat treated alloys provides controlled recrystallized structure and easy to manufacture for the external paneling of cars.

Paradiso et al.[19]discussed about the friction stir welding for the dissimilar joining of metals. Magnesium and aluminum were considered for the joining process.4mm thickness plates were welded in butt joint configuration. During welding process the material flow are different in both the alloys. Microstructure and micro hardness of the joints are examined. BIW is hybridized by using composite material of the reinforced with GF and PA family which is developed by CaproCAST process (advanced sheet thermoforming and 3D-injection method)[20].

Hoffmann et al.[21] Studied about the steels for the automotive application. ThyssenKrupp developing a different steels with tensile strength in the range of 1000MPa and excellent formability which are multiphase, super ductile and density reduced steels. New forming technologies were developed at the increased temperature for the processing of complex parts. ThyssenKrupp identified future of steel and technology concepts using technology monitoring and implemented simultaneous engineering process along with the automotive manufacture for the production and testing of steels. Multiphase and Manganese steels were introduced to manufacture the automotive parts. Multi-phase steels exhibit superior strength/ductility balance and outstanding work hardening behavior compared to the conventional steel with Al and Mg alloys. During forming, hot stamping increase the strength of steel and introducing a manganese boron steel to achieve the strength of 1500MPa during press quenching. In Semi hot stamping, steel retains its least strength after the cooling at room temperature. High strength parts with complicated shape are formed by super plastic forming. ThyssenKrupp pre development projects leads to investigate the new product ideas and converted to standard projects using product development process.

Celalettin et al.[22]Studied about advanced joining techniques for automobile industries. Many new techniques are developed for the automobile and aerospace manufacturing in order to reduce the cost and improve the performance. Aluminum and steel were considered for the joining of different materials, which are the major for the manufacturing of body structure components. The multi material selection is purely based on cost and production process. The main aim is weight reduction without affecting to safety and performance of the vehicle. Comparing to steel, aluminum alloys were more used for the body components. Aluminum easily available in variety of forms (sheet, casting, extrusion) and also absorb crash energy doubled the steel[23]. Joining of dissimilar material is due their superior functional capabilities. The joining of steel and aluminum faces lot problem due to melting temperature of both metals are different, poor, Wetting of aluminum, different physical and chemical properties of the metals etc. in order to overcome the convectional fusion welding do not yield good mechanical joints[24]. From the research works new joining techniques are found which are self-pierce riveting (SPR), clinching, friction stir welding, friction stir spot welding and laser welding Self-pierce riveting (SPR),[22] clinching: This method will to weld the steel and aluminum even though they have different melting temperature and high thermal conductivity. In SPR process the sheets are mechanically interlocked with tubular rivet. In SPR no pre holed drill required. In this riveting leg is spreading in the lower sheet and upper sheet driving the rivet for sheet joining[25]. In clinching, sheets are joined with a punch and die by hemming. These two process are based on no metallurgical bonding by controlled plastic deformation. Other researchers are examined these methods by different grades of steels and aluminum alloys. The rivet welding process is improved methods of conventional SPR, joining done by applying electric current to joints. This method shown improve of the steel rivet in microstructure[26]. Friction Stir Welding (FSW) and Friction Stir Spot Welding (FSSW) Methods: FSW is joining of sold states, here no melting of temperature takes place. A rotating tool is penetrated on soften working material, due to the frictional heat generation metal joining takes place. FSSW process similar to FSW only the movement of welding tool is different[22]. During the joining of the dissimilar materials, the thickness, rotational speed and depth of cut of tool also considered. In the electrically assisted FSW process with electrical current filed moving with FSW tool[27]. The mechanical welding force, temperature distribution and microstructure are compared with conventional FSW. Laser welding: It complements the fabrication and processing of joins in the joining process. Heterogeneous joints can be formed by welding of DP600 steel and A6082. The shear strength of the joints around 190Kpa. In the two pas laser welding, defect free lap joints obtained[28]. Apart from different joining process need to look into product quality without additional process.

Pooja et al.[29]studied about a new technology for structure weight reduction using vehicle concept modeling. In order to lightening of vehicle body is necessary is reduce crash performance and NVH. Developed a CAE model of BIW without any detailed CAD data. A CAE model is developed by beam elements with a combination of beam and shell elements[30]. Model represents the structural dynamic body characteristics in terms of mass and performance. The analytical method is validated by using LMS measurement system to demonstrate dynamic conditions of free vibration. The concept model is tuned for the fundamental resonant frequencies using optimization tool in Nastran. From the developed model concluded that weight reduction in the body structure will optimize the NVH performance.

Mingtu et al.[31]studied about Design, Evaluation Methods and Parameters of Automotive Lightweight. In this paper discussed about significance, concept, characterization parameters and experiment methods used for the lightweight automobile design. Lightweight coefficient equation explained here for the physical and technical significance parameters. A life cycle analysis done for the selection, economy and application of the materials. Designing of lightweight automotive includes reduction in weight of body in white without affecting the properties and performance. Super high strength steel (SHSS) is considered for the execution of lightweight material, due to poor formability hot forming process is considered for the body. Even tailor welding and hydroforming process reduce the number of parts and welded points and improves the performance of parts.

Mohan et al.[32]studied about minimal part breakup BIW design approach for the multi material and minimum parts will reduce the mass of the vehicle. Using the multi material concept for the test rig at initial phase is very expensive[33]. In order to minimize the cost FEA analysis is preferred. The analysis is to determine the bending and torsion stiffness of aluminum and magnesium. For the BIW upper body parts Magnesium analyzed to further to reduce the mass. Torsion stiffness of steel/magnesium was found better than steel/aluminum[32].

Nikola et al.[34] Studied about optimization of BIW structures for the crash and static loads using performance based topology. Topology optimization methods used for the design of lightweight structures and provides optimum distribution of material for the user defined design. Two main objectives are conceded during the design i.e. maximum stiffness during regular conditions and maximum energy absorption during crash occurs. By the linear weighting of BIW, the concurrent optimization of crash and static loads are demonstrated.
Hybrid cellular automata (HCA) method is for topology optimization approach, which distributes the uniform internal energy throughout the structure using a FEM software LS-TaSC (DYNA). For the crash analysis of BIW, used different velocities at initially and 9 linear elastic static load cases for front, rear and seat. From the analysis removal of elements from mesh leads to instability, in order to keep the stability minimum density was set for 0.005. From the HCA method, yields of stiffness and crash energy absorption for all load cases was good. For the higher number load cases and large size analysis further need more advanced tool to perform the analysis. The proposed method used in industrial vehicle design process.

Daniel et al. [35] studied about sustainability of aluminum material for car bodies. In this paper discussed about aluminum material for the car bodies which consists of 20% total weight of the car. Aluminum material's difficulties and advantages investigated along with aspects like cost, safety and manufacturing techniques used for the car bodies. Discussed about Space frame technique for the joining process which provides maximum rigidity and stiffness. Steel joining process is compared with aluminum material joining process. Recyclability of aluminum material from the production scarp and their advantages and disadvantages are discussed. Regarding safety failure and its reform and repair approach are discussed. Ecological aspects like energy consumption for the manufacturing and emission from the vehicle for the steel and aluminum are compared. Replacement of steel with aluminum in body application is uncertain. However aluminum has reduced the weight and increased the rigidity. Furthermore development required in the manufacturing process, as well as in the fuel consumption.

Réjane et al. [36]Studied about mechanical properties & shear clinching technology for aluminum and ultra-high strength steel for the car body structures. Multi material design approached for the BIW production in order to get safety and comport requirements. Due to formability Conventional clinching is limited for multilateral design. In order to overcome formability shear clinching process used. Mechanical behavior are compared under single and multiple shear clinching process. Joining of hot formed UHSS and aluminum is possible in single stage shear clinching[16].
Specimens AA6016 T4 and 22MnB5 are prepared for according to DIN standards for the shear clinching. During the experiment damage of joints occurs which is determined according to DIN EN ISO 12996. Depending on the load type failure modes, neck failure, and unbutton expected[37]. From the experiment cylindrical pre-hole geometry can carry less load compared to tapered pre-hole geometry. Both the hole geometries fail under fatigue test at low level load conditions. Furthermore investigation is required for the fatigue test at different load for the hole geometrics and need to improve the reliability and reproducibility of shear clinching technology[36].

Yuxwan et al. [38] Studied about use of high strength steel (HSS) for the lightweight and crashworthy of car body. Replaced mild steel with HSS sheet in order to reduce the depth and also from FEM simulation verified depth reducing equation for the body parts crashing to the rigid wall. From the sheet thinning analysis, reduction in depth with same absorbing capacity of impact energy lead to reduction in body weight. From the body impact analysis weight reduction achieved by without impairment of each part's impact energy absorbing capacity. From simulation impact energy absorption before and after material selection is almost close each other for the body parts. From these result body weight is reduced without affecting the crashworthiness. Donders et al.[4]proposed a reduced beam and joint modelling in FE models to improve NVH behavior in vehicle BIW.

Schubert et al. [39] studied about laser joining process for the light weight structures in automobile applications. This process offers good manufacturing of joints of light metals like Al, Mg and Ti. Laser beam welding for the aluminum in automobile parts, which reduces the weight by replacing the rivet joints. The holes in the seam which are reduces the mechanical properties at the joints, which are eliminated by adopting suitable weld geometry and weld qualities. For the dissimilar material thermal joining is very difficult because of intermetallic phases. The diffusion process is controlled by high power laser beams with high joining speed is passed for the Al-Steel combination. From the experiment using a filler wire which increased Welding speed up to 40%. For the Al-Mg filler is not used because the melting points of both metals similar. Further research required to find out metallurgical characteristics of weld.

Rajasekaran et al.[40] Studied about bulk head optimization to improve the performance of BIW structure. Automotive industries brining a new BIW designs with to improve the performance with less increased weight. During the BIW design experiment new technique identified and optimized internal reinforcement. For the BIW performance bending and torsion stiffness load cases were considered. Torsional stiffness of BIW found using CAE and compared with physical test which is 96% similar to result of the CAE result[41]. For the joints of A, B and C pillars bulk head design were designed. For the design experiment optimal latin hypercube method is used with binary digits which indicates whether bulk head required or not in the BIW. Bulk head location design optimized using finite element analysis. From this experiment overall BIW stiffness increased by 3.9% with 1.2% of weight increment. Furthermore to decrease the mass of BIW using 3G optimization[40].

Christensen et al.[42]discussed about the structural topology for Hybrid electric vehicle. Two different modelling techniques taken to compare the boundary condition for the inertia and the sensitivity of BIW against the load and battery box stiffness. Model techniques shows the BIW structural force path development and distribution of mass. The implicit topology optimize method does not fully consider the inertia effects, strain rate effects and material characteristics

Bairwa et al.[43]studied about heat treatments for formability in aluminum lithium alloy. The alloy chosen for the BIW, having high strength to weight ratio. Heat treatment is given to the alloy to improve the aging, strength, dent resistance and high formability. Tensile properties found out for different solutionizing temperatures along with aging properties also. Out of different temperatures best 3 temperatures are identified from the mechanical properties and formability. From high formability investigated that lead into processes like sketch forming and deep drawing. From the deep drawing properties of body structure is simulated in PAMSTAMP2G software. During the experiment 3 aging temperature, 3 ageing times and 3 solutionizing temperature. Tensile test and R value test were conducted as per ASTM standards. Tensile results were not up to the mark in the different heat treatment temperatures. From the result higher values 3 different conditions lead into high formability with high strain hardening value and R value. The results were consistent at ageing temperature 170°C. From the simulation forming performances was similar to steel material.

Zhu et al.[44]studied about robust optimization for Meta model lightweight design of front body structure. For design purpose geometrical size and tolerance, sheet gauge and material properties were important. Without these leads to loss of feasibility and reliability. For the reliability analysis basic Monte Caro simulation method used. Polynomial response surface, radial basis function (RBF), kriging (KG), and artificial neural network (ANN) are include in the Meta model[45]. Support vector regression (SVR) Meta model are more used than other Meta model for the optimization of structure. Double loop strategy used for robust optimization with GA solver where the reduced weights obtained using robust optimization and deterministic are 7.8003 kgf and 9.0385 kgf respectively.

Miller et al.[46] Studied about development in aluminum alloys for automotive industries. In this study properties of aluminum were studied which will replace the heavier metals for the automotive structures to minimize the weight. For the aluminum 5000 and 6000 alloys surface quality and formability improvement were discussed. Aluminum for the various automobile parts were discussed. Use aluminum for the BIW structure result in 50% weight reduction. Comparison between extruded space frame and monocoque structure were made. Development Inner and outer panels of the vehicle using 5xxx and 6xxx alloys shown good mechanical properties and formability.

Pfestorf [47] studied about manufacturing of HSS and aluminum for mixed material BIW. For the mixed material combination of aluminum and steel developed a new technology which is a cold joining process is combined with adhesive bonding process. For the structure joining first all the hot processes were done like spot welding, laser welding and brazing. For the aluminum cold forming technologies are applied. Class A surface required after painting with adhesion bonding for the mixed materials. In forming of high strength steel sheet spring back effect increases with increase in yield strength with decrease in elongation. Hydrogen embrittlement on BIW during Painting process leads increase in the tensile strength of the advance high strength steel[48]. Dry film lubricant considered for the forming process, it does not concern about material properties[49]. A new tool is designed to eliminate the spring back and analyzed using simulation. Resistance spot welding process improve the fatigue strength of TRIP steel with adhesive bonding. For corrosion resistance of aluminum and steel components are joined using self-pierce riveting with adhesive bonding. Steel components are hot dipped galvanized. Oxidation layer of adhesive bonding on aluminum needed passivation which can be done by coil passivation[47].

Andure et al.[50] Reviewed about lightweight material for automobiles. For reducing exhaust emissions of vehicle can be possible by weight reduction and aerodynamic drag. The material aluminum foam properties and mechanical properties mainly dependent on pore structure. Cross section size, and pore diameter and Nominal ligament length were affected by foam pore size. Compressive deformation behavior of aluminum leads absorption of crush energy for the optimum crashworthiness. Crash energy absorption behavior is compared for the dense solid and foam aluminum material and foam is better than dense solid at peak stress[51]. The aluminum foam sandwich panels have vibration damping frequency range 100 -500Hz is highest compared to steel and iron sheet. Natural fibers composites properties were discussed for the automotive application. Presently used for the vehicle interiors which lead 20% weight reduction. Steels properties were discussed with their different types of grades. Magnesium material is having lowest density compared to other materials. Mg has better NVH characteristics than aluminum and only drawback is poor corrosion resistance. From this review lightweight materials can be chosen according to properties wise for the automotive applications.

3.0 CONCLUSION

For the greater demand of reduced emissions and better fuel efficiency light weighting of body in white materials change to aluminum alloys ,high strength steels instead of mild steel and cast iron. These materials have excellent mechanical properties, cast ability, stiffness, resistance corrosion, high crashworthiness and NVH properties. Using Aluminum material leads to recycling of scarp parts about 80%. Variety of technologies like clinching, friction stir welding, and laser welding are used for the joining of the body structures. Even these process capable of joining of dissimilar multilateral system. Even new technologies are analyzed using finite element software for the performance check. These joining process are performance wise good, further development required for reduction of cost during manufacturing. Fiber reinforced composites are used for the BIW structures which cost twice compared to metallic materials. These composites shows excellent properties similar to metallic materials. Furthermore development required in the design, production process wise for the use of polymer composites in the BIW structure.

REFERENCES

[1] A. Jambor and M. Beyer, "New cars — new materials," *Mater. Des.*, vol. 18, pp. 203–209, 1997.

[2] S. S. Cheon, D. G. Lee, and K. S. Jeong, "Composite side-door impact beams for passenger cars," *Compos. Struct.*, vol. 38, no. 1–4, pp. 229–239, 1997.

[3] S. Donders *et al.*, "A reduced beam and joint concept modeling approach to optimize global vehicle body dynamics," *Finite Elem. Anal. Des.*, vol. 45, no. 6–7, pp. 439–455, 2009.

[4] D. Mundo, R. Hadjit, S. Donders, M. Brughmans, P. Mas, and W. Desmet, "Simplified modelling of joints and beam-like structures for BIW optimization in a concept phase of the vehicle design process," *Finite Elem. Anal. Des.*, vol. 45, no. 6–7, pp. 456–462, 2009.

[5] A. Mayyas *et al.*, "Using Quality Function Deployment and Analytical Hierarchy Process for material selection of Body-In-White," *Mater. Des.*, vol. 32, no. 5, pp. 2771–2782, 2011.

[6] M. K. Kulekci, “Magnesium and its alloys applications in automotive industry,” *Int. J. Adv. Manuf. Technol.*, vol. 39, no. 9–10, pp. 851–865, 2008.

[7] E. R. H. Fuchs, F. R. Field, R. Roth, and R. E. Kirchain, “Strategic materials selection in the automobile body: Economic opportunities for polymer composite design,” *Compos. Sci. Technol.*, vol. 68, no. 9, pp. 1989–2002, 2008.

[8] J. Hirsch, “Recent development in aluminium for automotive applications,” *Trans. Nonferrous Met. Soc. China (English Ed.*, vol. 24, no. 7, pp. 1995–2002, 2014.

[9] B. C. De Cooman, “Structure-properties relationship in TRIP steels containing carbide-free bainite,” *Curr. Opin. Solid State Mater. Sci.*, vol. 8, no. 3–4, pp. 285–303, 2004.

[10] P. Feraboli and A. Masini, “Development of carbon/epoxy structural components for a high performance vehicle,” *Compos. Part B Eng.*, vol. 35, no. 4, pp. 323–330, 2004.

[11] M. Merklein, J. Lechler, and T. Stoehr, “Investigations on the thermal behavior of ultra high strength boron manganese steels within hot stamping,” *Int. J. Mater. Form.*, vol. 2, no. SUPPL. 1, pp. 259–262, 2009.

[12] M. Saito, S. Iwatsuki, K. Yasunaga, and K. Andoh, “Development of aluminum body for the most fuel efficient vehicle,” *JSAE Rev.*, vol. 21, no. 4, pp. 511–516, 2000.

[13] P. Feraboli, A. Masini, L. Taraborrelli, and A. Pivetti, “Integrated development of CFRP structures for a topless high performance vehicle,” *Compos. Struct.*, vol. 78, no. 4, pp. 495–506, 2007.

[14] H. Hofmann, D. Mattissen, and T. W. Schaumann, “Advanced cold rolled steels for automotive applications,” *Materwiss. Werksttech.*, vol. 37, no. 9, pp. 716–723, 2006.

[15] Y. Prawoto, J. R. P. Djuansjah, K. B. Tawi, and M. M. Fanone, “Tailoring microstructures: A technical note on an eco-friendly approach to weight reduction through heat treatment,” *Mater. Des.*, vol. 50, pp. 635–645, 2013.

[16] S. Busse, M. Merklein, K. Roll, M. Ruther, and M. Zürn, “Development of a mechanical joining process for automotive body-in-white production,” *Int. J. Mater. Form.*, vol. 3, no. SUPPL. 1, pp. 1059–1062, 2010.

[17] R. Neugebauer, R. Mauermann, S. Dietrich, and C. Kraus, “A new technology for the joining by forming of magnesium alloys,” *Prod. Eng.*, vol. 1, no. 1, pp. 65–70, 2007.

[18] I. N. Fridlyander, V. G. Sister, O. E. Grushko, V. V. Berstenev, L. M. Sheveleva, and L. A. Ivanova, “Aluminum alloys: Promising materials in the automotive industry,” *Met. Sci. Heat Treat.*, vol. 44, no. 9–10, pp. 365–370, 2002.

[19] V. Paradiso, F. Rubino, P. Carlone, and G. S. Palazzo, “Magnesium and Aluminium alloys Dissimilar Joining by Friction Stir Welding,” *Procedia Eng.*, vol. 183, pp. 239–244, 2017.

[20] E. Cischino *et al.*, “An Advanced Technological Lightweighted Solution for a Body in White,” *Transp. Res. Procedia*, vol. 14, pp. 1021–1030, 2016.

[21] H. Hofmann, T. Heller, and S. Sikora, “Design of Modern Steels for Automotive Application,” *Mater. Sci. Forum*, vol. 638–642, pp. 3111–3116, 2010.

[22] C. Yuce, F. Karpat, N. Yavuz, and O. Dogan, “a Review on Advanced Joining Techniques of Multi Material Part Manufacturing for Automotive Industry,” *Proc. Eighteenth TheIIER Int. Conf.*, no. 5, pp. 63–68, 2015.

[23] Ducker, “Aluminum in 2012 North American Light Vehicles: Executive Summary,” 2011.

[24] F. W. Bach, A. Beniyash, K. Lau, and R. Versemann, “Joining of Steel-Aluminium Hybrid Structures with Electron Beam on Atmosphere,” *Adv. Mater. Res.*, vol. 6–8, pp. 143–150, 2005.

[25] W. Voelkner, “Present and future developments of metal forming: selected examples,” *J. Mater. Process. Technol.*, vol. 106, no. 1–3, pp. 236–242, 2000.

[26] M. Lou, Y. Li, Y. Wang, B. Wang, and X. Lai, “Influence of resistance heating on self-piercing riveted dissimilar joints of AA6061-T6 and galvanized DP590,” *J. Mater. Process. Technol.*, vol. 214, no. 10, pp. 2119–2126, 2014.

[27] X. Liu, S. Lan, and J. Ni, “Electrically assisted friction stir welding for joining Al 6061 to TRIP 780 steel,” *J. Mater. Process. Technol.*, vol. 219, pp. 112–123, 2015.

[28] A. Kouadri-David, “Study of metallurgic and mechanical properties of laser welded heterogeneous joints between DP600 galvanised steel and aluminium 6082,” *Mater. Des.*, vol. 54, pp. 184–195, 2014.

[29] P. Doke, M. Fard, and R. Jazar, “Vehicle concept modeling: A new technology for structures weight reduction,” *Procedia Eng.*, vol. 49, pp. 287–293, 2012.

[30] M. A. Fard, T. Ishihara, and H. Inooka, “Identification of the head-neck complex in response to trunk horizontal vibration,” *Biol. Cybern.*, vol. 90, no. 6, pp. 418–426, 2004.

[31] M. Ma and H. Lu, "Proceedings of the FISITA 2012 World Automotive Congress," vol. 200, pp. 965–976, 2013.

[32] A. N. E. W. Minimal, P. Breakup, W. D. Approach, M. Map, and S. Assessment, "Jurnal Teknologi A NEW MINIMAL PART BREAKUP BODY-IN- WHITE DESIGN APPROACH AND OPTIMIZED," vol. 7, pp. 17–22, 2016.

[33] J. Lu, A. N. E. W. Minimal, P. Breakup, W. D. Approach, M. Map, and S. Assessment, "s tr ot for Pr ly - N tio Pr iew On ly for Di s tr ibu tio n," vol. 7, pp. 1–2, 2012.

[34] N. Aulig, E. Nutwell, S. Menzel, and D. Detwiler, "Preference-based Topology Optimization of Body-in-white Structures for Crash and Static Loads," *14th Int. LS-DYNA Users Conf.*, pp. 1–11, 2016.

[35] D. Carle and G. Blount, "The suitability of aluminium as an alternative material for car bodies," *Mater. Des.*, vol. 20, pp. 267–272, 1999.

[36] R. Hörhold, M. Müller, M. Merklein, and G. Meschut, "Mechanical properties of an innovative shear-clinching technology for ultra-high-strength steel and aluminium in lightweight car body structures," *Weld. World*, vol. 60, no. 3, pp. 613–620, 2016.

[37] C. J. Lee, J. Y. Kim, S. K. Lee, D. C. Ko, and B. M. Kim, "Parametric study on mechanical clinching process for joining aluminum alloy and high-strength steel sheets," *J. Mech. Sci. Technol.*, vol. 24, no. 1, pp. 123–126, 2010.

[38] Y. Li, Z. Lin, A. Jiang, and G. Chen, "Use of high strength steel sheet for lightweight and crashworthy car body," *Mater. Des.*, vol. 24, no. 3, pp. 177–182, 2003.

[39] E. Schubert, M. Klassen, I. Zerner, C. Walz, and G. Sepold, "Light-weight structures produced by laser beam joining for future applications in automobile and aerospace industry," *J. Mater. Process. Technol.*, vol. 115, no. 1, pp. 2–8, 2001.

[40] R. Mohan, H. Venkatesan, and S. Mahadevan, "New methodology for light weight solutions to improve BIW structural performance using bulk head optimization," *J. Mech. Sci. Technol.*, vol. 30, no. 8, pp. 3533–3537, 2016.

[41] S. S. Dinde, "Evaluate and Improve Torsional Stiffness of BIW Using FEA and Validate Results with Test," no. 2, pp. 2093–2100, 2015.

[42] J. Christensen, C. Bastien, M. Blundell, A. Gittens, and O. Tomlin, "Lightweight hybrid electrical vehicle structural topology optimisation investigation focusing on crashworthiness," *Int. J. Veh. Struct. Syst.*, vol. 3, no. 2, pp. 113–122, 2011.

[43] M. L. Bairwa, S. G. Desai, and P. P. Date, "Identification of Heat Treatments for Better Formability in an Aluminum-Lithium Alloy Sheet," *J. Mater. Eng. Perform.*, vol. 14, no. 5, pp. 623–633, 2005.

[44] P. Zhu, Y. Zhang, and G.-L. Chen, "Metamodel-based lightweight design of an automotive front-body structure using robust optimization," *Proc. Inst. Mech. Eng. Part D J. Automob. Eng.*, vol. 223, pp. 1133–1147, 2009.

[45] V. C. P. Chen, K.-L. Tsui, R. R. Barton, and M. Meckesheimer, "A review on design, modeling and applications of computer experiments," *IIE Trans.*, vol. 38, no. 4, pp. 273–291, 2006.

[46] W. S. Miller *et al.*, "Recent development in aluminium alloys for the automotive industry," *Mater. Sci. Eng. A*, vol. 280, no. 1, pp. 37–49, 2000.

[47] M. Pfestorf, "Manufacturing of High Strength Steel and Aluminum for a Mixed Material Body in White," *Adv. Mater. Res.*, vol. 6–8, pp. 109–126, 2005.

[48] G. Lovicu *et al.*, "Hydrogen embrittlement of automotive advanced high-strength steels," *Metall. Mater. Trans. A Phys. Metall. Mater. Sci.*, vol. 43, no. 11, pp. 4075–4087, 2012.

[49] M. Meiler, M. Pfestorf, M. Geiger, and M. Merklein, "The use of dry film lubricants in aluminum sheet metal forming," *Wear*, vol. 255, no. 7–12, pp. 1455–1462, 2003.

[50] D. L. P. Andure M.W., Jirapure S.C., "Advance Automobile Material for Light Weight Future – A Review," *Int. Conf. Benchmarks Eng. Sci. Technol. ICBEST 2012 Proc. Publ. by Int. J. Comput. Appl.*, pp. 15–22, 2012.

[51] a. Fuganti, L. Lorenzi, a. Grønsund, and M. Langseth, "Aluminum Foam for Automotive Applications," *Adv. Eng. Mater.*, vol. 2, no. 4, pp. 200–204, 2000.