Bibliographic review of the research on the field of car crash worthiness from a Body-In-White perspective

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1. Introduction

1.1. What is the Body-In-White of a car?

The Body-In-White is made up of all the structural parts of the car where one dimension is much less than the other two, that means sheet parts. When we refer to structural parts of a car we are talking about all parts that have the main function of maintaining the integrity of the car shape in the case of external loading's, without compromising the comfort up to a certain degree.

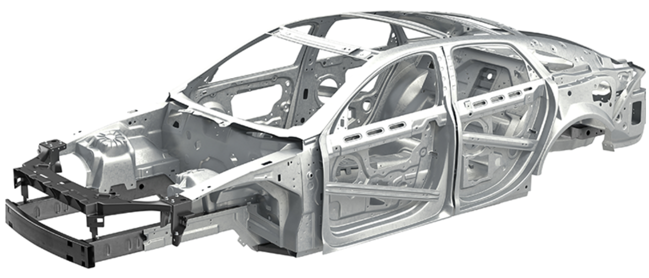

Figure 1: Example of a car Body-In-White

1.2. Manufacturing process of complex parts

The huge amount of requirements to full-fill prior to a car be released in the market turns the manufacturing process of a BiW into a challenge. The geometry of the BiW is almost entirely restricted to the geometry of the skin of the car the same way that, the skin of the car is restricted from an aesthetic and aerodynamic point of view. Following some of the most important steps to obtain a single part of a BiW are explained briefly.

1.2.1. Nesting

Once the coils of raw materials are received they have to be cut into blanks. The selection of the most suitable shape distribution for cutting the coils is a key decision. At this point the target is to optimize the amount of material used. This process is called nesting and the parts obtained for further forming are called blanks.

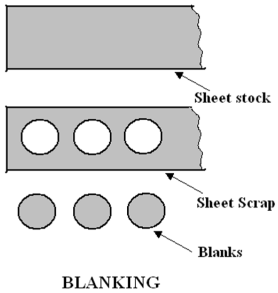

Figure 2: Concept of nesting

1.2.2. Forming

The process of forming can be divided into cold forming and hot forming. Both processes require the use of a press, however both processes are meant to obtain parts with very different material mechanical properties. Cold forming is the process of obtaining a semi final shape without carrying out any heat treatment in the blank, so that the blank is at room temperature and the final part undergoes hardening by plastic deformation. Hot forming implies a change in the phase of the material. The steel blanks are heated above 900 degrees in order to convert all the material to austenitic phase and once this phase has been completely reached, a quenching is made in order to obtain martensitic structure.

1.2.3. Laser cutting

This technique serves for obtaining a suitable tolerance all around the hot formed blank, as well as to make certain holes that are not able to be made in the press tooling.

1.2.4. Joining

The joining process can be briefly divided into mechanical and welding joining. All the main parts constituting the BiW are joined mainly by spotwelding, eventhough there are many types of welding. The mechanical joints are those where welding is not suitable, the use of mechanical joints allows the joined part to be replaced for a new one in case of a crash.

2. Bibliographic review

The research related to the field of crash worthiness is very extensive, likewise the present bibliographic research it is going to be approached from an structural point of view. The common point of all the articles presented is the aim of improving many aspects regarding Body-In-White production, simulation and testing.The necessity of decreasing the pollution in the world, together with the rise of the price of the traditional fuels leads the automotive industry to be focused in reducing the weight of the car. However, there must be a compromise between car weight reduction and the necessity of obtaining a car structure with the suitable mechanical properties.

From the BiW perspective, the weight reduction ca be achieved by changing the forming process of some parts from cold to hot stamping, by doing this it is possible to reduce the sheets thickness between 0.2 and 0.4mm, however the final hot formed parts are not good at absorbing energy. In the event of a crash, it is crucial that the structure is able to absorb a big amount of energy, likewise, it is necessary to study what can be modified during the manufacturing process, in order to control the optimize the final mechanical properties.

Li Bao et al, [1] discuss about several existing manufacturing techniques meant to achieve a final component with tailored properties. The advantage of having tailored properties is the possibility of absorbing energy as well as minimizing the intrusion in the vehicle, depending on the mechanical properties given to the final component.

These described techniques are mainly divided into 2 big groups: intrinsic and not intrinsic. Intrinsic strategy targets the tool configuration in order to control key variables: material setup of the tool, surface finish, cooling rate in tooling channels and tooling contact conditions. In general this research summarized different existing ways to control the change of phase from Austhenitic to Martensitic thus, controling the ductility of the material at key areas.

Nowadays the most broadly used material for BiW parts is steel, and even though aluminum it's also used for some parts with simpler geometries like bumpers or other type of extruded profiles, when it comes to more complex parts that are meant to absorb a big amount of energy, aluminum turns out to be restricted to relatively expensive cars.

In apart from steel and aluminum, other type of material typea that are being a common target of research are the composites, and concretely carbon fibre reinforced polymer (CFRP) and glass fibre reinforced polymerp (GFRP).

The B-Pillar is a very important structural part that plays a crucial role in the event of a lateral crash, being the most important part in maintaining the structural integrity of a BiW when the crash occurs.

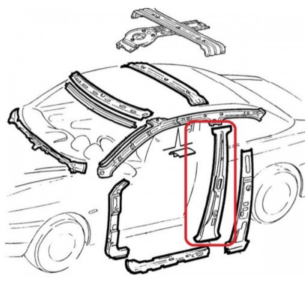

Figure 3: Exploded view of a bpillar geometry example (inside red region)

M.I.Ibrahim et al [2] carried out a 3-point bending numerical study of two B-Pillar manufactured with CFRP and with GFRP. In terms of cost, the composite material is expensive, and the manufacturing process complex, however as it is outlined in the study, weight saving up to 60 per cent are obtained with a CFRP 1.4mm thickness bpillar with local reinforcement, compared to the steel one. Even though no comparison is made to the behaviour of the steel bpillar, out of this study it is possible to extract the specific internal energy absorption which can be later compared with a steel part for a better understanding.

Regarding the optimization of energy absorption another interesting study it is given a remark. Q. Estrada et al, [3] carried out a numerical modified 3-point bending study of squared aluminum profiles under different boundary conditions. The aim of the study it was to demonstrate that the lateral impact energy may not be only dissipated by plastic deformation but also by dissipation due to friction in the square ends by contact with another sheet.

It is shown that friction due to contact on the external square profile ends increases significantly the capability of the assembly to dissipate energy up to 175 per cent in respect to the same assembly without considering the friction at the ends.

Furthermore, the actual trend of the car industry is the electrification of vehicles. The fact of moving from an ICE (Internal Combustion Engine) to an EVB (Electric Vehicle Battery) is a big challenge in many aspects. In terms of safety, the battery box (containing all the lithium cells) has to be protected against the event of a crash. Likewise, it is important that the battery box is detachable from the car, and that implies using mechanical joints.

The use of Bolts as mechanical joints in EVBs gives rise to the necessity of further study of the behaviour of this components when a crash occurs. Florian Schauwecker et al, [4], studied numerically the behaviour of Bolts under tension and shear taking into account fracture. The fracture mechanism is simulated through the material failure model incorporated in the explicit solver LS-DYNA, GISSMO (General Incremental Stress Strain Material Model), which uses the material triaxiality (measure of loading type) as well as the lode Angle (measure of stress state point within the deviatoric plane) in order to compute the accumulated damage, prior to the material fracture and thus element/s deletion. In their study their concluded that the use of GISSMO predicts properly the fracture mechanism in numerically modeled bolts, as long as 3D elements together with a fine enough mesh are used to model the Bolts domain.

On the other side, all parts constituting the BiW are assembled in a complex joining process where the use of robots is necessary to achieve a suitable serial production timings. The main welding process used for joining the BiW parts is the spot welding, this type of welding consist in high electrical intensity crossing 2/3 sheets (maximum) in order to create a homogeneous material in the area of application. The spot welding area as well as its surrounding change its properties after an intensity being applied. A drawback of this process is that the material sheet surrounding the spot weld it is weakened. Likewise, the gradient of mechanical properties in the area of heat application turns into a challenge in terms of material modelling.

Takahiro AITO et al, [5] carried out a numerical study of the fracture occurring in a joint spot welded. They realized this study by developing a software called "NSafe-MAT" that is able to predict the failure mode at the spot weld as well as in the HAZ (Heat Affected Zone), the HAZ is the area surrounding the sport weld where the intensity has been directly applied. They found a good correlation with experiments and concluded that, their software together with the commercial explicit software LS-DYNA is suitable to properly predict the real behaviour of parts joined by spotwelding.

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