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PRODUCTION PROCESS – BODY IN WHITE

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Abstract: *This article aims to disclose the production process of Body in White. This article illustrates beyond the steps of the production of the body of a car, but also, some definitions about the theme in hand, the machines, the equipment and the raw material used in the process. The development of a productive process goes beyond simple research and concepts, which requires a high level of knowledge, experience, and group work. The Body in White is the beginning for every remaining assembly of a car, your specifications and precisions are of upmost importance.*

Keywords: *Body in White, flowcharts, process, control.*

1. INTRODUCTION

Over a century after the first gasoline automotive being built in the United States of America in 1896, many parts have changed (Coffey & Layden, 1996). Back then, the automobile became a symbol of romantics, of individuality and power. Nowadays, more than 100 years later, one verifies that with the evolution of technology and the changes in habits provided by society, the automobile became a representation of more than just a consumer dream it occupied people's lives as a utility and necessity. That's why one can affirm that no sole invention drastically impacted the lives of millions of people in the 21st century like the automobile.

The automotive sector represents, in Brazil, one of the sectors most affected by the effects of globalization and market opening that began to show their strength at the beginning of the last decade (Deming, 1990). It corresponds, alone, to more than 10% of the country's industrial GDP, which today has the 8th largest vehicle fleet in the world. The old "carts," as they were pejoratively called in the early 1990s, gave way to ultra-high-tech cars, which are nowhere to be found in automobiles manufactured elsewhere in the world. The concept of quality has been receiving several interpretations over the years (Deming, 1990).

However, the one that seems to be the most appropriate read between the lines: the maximum quality is what the client considers important to him/her. The necessities of the client must be attended, maximizing the performance of the produced resources with the minimum possible costs. The quality, considered today as one of the biggest competitive advantages, is the least that is expected from a manufacturer of automobile, that is, either the company has quality or it is out of business.

A project requires diverse requirements to reach success; analysis of material, data research, and debates are indispensible to reach the best result. In search of excellence and satisfaction of the proposed requisites, the authors used FMEA tool, which is a technique used by an engineer/team as a way to guarantee that the potential defects and your associated causes/mechanisms have been considered and located (Ford Motor Company, 1997).

2. BODY IN WHITE

Body in White or BIW refers to the phase of the conception of automobile to the design stage of a production car in which the metallic blank components of the body of the car have been welded (GM Performance Parts, 2012). BIW is named before painting and before adding parts such as doors, hoods and deck covers, as well as mudguards. The engine, chassis, subassemblies, or props (glass, chairs, upholstery, electronics, etc.) are assembled on the frame structure.

The popular etymology for the BIW suggests that the term is derived from the appearance of a body of a car after it is submerged in a white coat – even though the real color of the primer is grey (GM Performance Parts, 2012). It could also refer to when the bodywork of the car was made of wood – all wood products are considered "in white, before finishing.

3. TOOLS

3.1. Planning

3.1.1 5W2H

5W2H, also known as the action plan, is a tool very obvious and very used that no one can pinpoint who created it (Nakagawa, 2014). As a tool, it gained popularity with the dissemination of quality management techniques and, later, those of project management. When something should be implemented, the following questions were asked:

- What has to be done?
- Why should it be implemented?
- Who is responsible for the action?
- Where does it need to be executed?
- When should it be implemented?
- How should it be conducted?
- How much will the implementation cost?

The 5W2H tool can be used alone to put in practice a simple decision in the company, such as the acquisition of a new machine or the execution of a punctual activity (Nakagawa, 2014). In the simplest situations, the completion of the 5W2H in any form in text editor, spreadsheet or even in a text is enough, this can be seen in Fig. A.1.

3.1.2 Flowcharts

Flowcharts are a graphic representation that illustrates the sequence of a work in an analytical form, characterizing the operations, the responsible and/or organized unities involved in the process (Oliveira, 2005). It represents with rationality, logic, clearness and synthetic routines or procedures in which are involved documents, obtained information and processes (Oliveira, 2005).

The flowchart shows how the work is done and penetrates into problems whose solution is directly concerned with the exercise of a rational administration. Highlighting the role circulation and formulae between diverse organized units or between the people, it is used for researching defects at the work distributions and functions in the functional relations, at delegating authority, at attributing responsibility and other managing processes and can be seen in Fig. A.2.

3.1.3 Control Plan

The control plan was introduced in the automobile industry, having its usage widespread through the TS 16949 norm in an automaker of Ford, Chrysler and General Motors (IQA, 1994). Quality management involves development, the adoption of policies and procedures to guarantee the project attends the necessities specified by the clients. Quality is the degree in which the product is in accordance with the project or specification (Gilmore, 1974). One can still affirm that quality means a project will be done without deviation of its requisites (Mulcahy, 2011).

The quality process, aids project management to control costs, involvement of resources in activities, envision a higher client satisfaction, control risks, reworks and chronogram, during the project life cycle (IQA, 1994). For this project, the authors created a specific control plan (Fig. A.3) to better illustrate this tool to the readers.

3.2 FMEA

FMEA (Failure Mode and Effect Analysis) is a methodology that aims evaluate and minimize risks by analyzing possible failures (determining the cause, effect and risk of each failure) and implementing actions to increase reliability (Sakurada, 2001). This qualitative method, studies possible failures of components, systems, projects and processes and their respective effects generated by these failures (Sakurada, 2001). The fail mode is an expression utilized to characterize the process and the mechanism of failure that occurs on these items. Each item can have multiple fail modes. A determined fail mode will become more or less evident according to the function the item is performing. The effect, though, follows the same system. The relationship between fail mode and effect, if well controlled, can help the reliably analysis as well as the adopted maintenance processes, better seen in Fig. A.4.

3.3 Layout

It is the physical arrangement of a company and its components, such as machines and equipment inside the organization, where, through established calculations and definitions according to the product to be manufactured. By structuring the company this way, the work is more efficient and less time is wasted (Chiavenato, 2005).

One of the main reasons to make a new physical arrangement of a company is to reduce wasted time between the movement of materials and the product itself, based on that, “the best movement of material is not to move” (Canene & Williamon, 1998). One must also consider that a new and well-done layout bases to distribute the machines, raw material and furniture to fill the space best way possible in the sectors or in the organization as a whole, considering the best way to implement labor adaptation in their new workstations to guarantee workers' satisfaction (Cury, 2007).

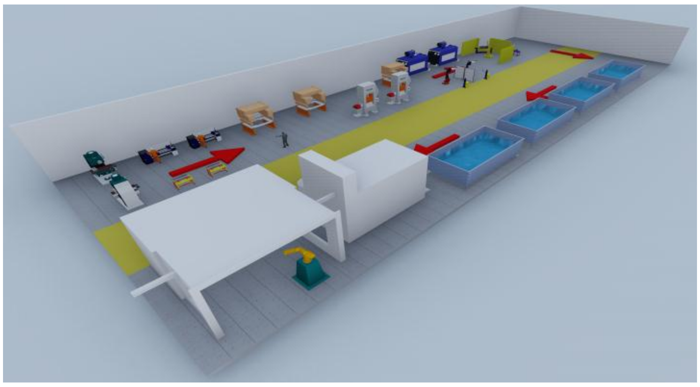

Figure 1. Group designed BIW Layout

4. RAW MATERIAL AND SPECIFC TECHNIQUES

4.1 Dual Phase Steel

This steel's microstructure is predominantly formed by islands of hard phase, martensite, dispersed in a ferritic matrix (Usiminas, 2013). The presence of these constituents and their volumetric fractions influence the mechanical properties of the steel. These structures provide excellent ductility, making possible the high hardening rates. They are specially suggested for the automobile industry, for reinforcement structural parts, propitiating weight reduction through reduction of thickness and contain noticeable impact absorption, given its high ductility resilience (Usiminas, 2013).

4.2 Stamping Steel

It can be supplied with low carbon (no alloying elements) or with ultra-low carbon (with titanium and/or niobium to link the carbon and nitrogen). These steels are provided with guarantees of mechanical properties, limiting in most cases the maximum value of flow limit (FL), resistance (RL) and ensuring a minimum elongation (EL) (Usiminas, 2013). For higher conformability steels, it can be guaranteed that the coefficients of anisotropy (r) and hardening (n). Their use is indicated for stamping processes of medium to extra critic, which the resistance, rigidness and ductility are required.

4.3 Medium/High Resistance Steel

This steel conciliates attributes of elevated mechanical resistance, high conformability and resistance to atmospheric corrosion (Usiminas, 2013). The mechanical resistance is obtained, especially by endurance mechanism by solid solution, because of the presence of magnesium and/or phosphorus. Medium/high resistance steels are mainly used in the automobile industry. Tables 1 and 2 show the steels that compose the BIW body.

Table 1. Description of steels used in the BIW body

AÇO	C	Mn	Si	P	S	LR (MPA)	LE (MPA)	AL (%)	SENTIDO
USI-DP-780 (1)	0,18 (max)	3.3	2	0.09	0.04	780 (min)	380-580	13	Transv.
SAE-12340	0,13(max)	0	0	0.1	0.02	440 (min)	340-440	22	Long.
USI-EP	0,10 (max)	0.45	0	0.03	0.03	370 (max)	260 (max)	35	Transv.

Table 2. Description of the steels used in the BIW frame

	< 220 Mpa (Acier doux)
	220-400 Mpa (HLE)
	400-600 Mpa (THLE)
	600-800 Mpa (TTHLE)
	Emb. à chaud
	Aluminium or composite

5. PRODUCTION PROCESS

The production process is a method, system or activity executed in an adequate sequence to transform and modify a raw material until it has utility. This process, usually, is used by industries (Weiss, 2012). Depending on the product and the production process, the quantity of energy consumed varies.

5.1. Production and assembling

5.1.1 Cutting

Cutting is associated with raw material in smaller sizes (Weiss, 2012). The choice of the type of cutting machines depends on the format and the thickness of the material to be cut. The cutting process is the first step in the construction of any industrial part. It is in this step that which material needed is defined and how much of it needs to be used. Equipment (Weiss, 2012):

Fork-lift: a machine used to carry and unload goods, in this case, the reels;

Overhead crane: classified by elevating a type of overhead crane. The main equipment parts of the elevating machines are: crane, overhead crane, lift and winch. It is used to take a steel reel to a coil winding machine;

Cutting machine: machines, which the reels are put and winded, stretched and then cut in a metallic blank;

Suction conveyor robot: facilitate and speed up the work, providing a better handling performance, reducing risk of casualties and facilitating then production. It has a great retention force, higher positioning accuracy and doesn't damage the raw material;

Conveyor belt: used to move raw material in the production process or finishing process. In the production of bodywork, they are used in most of the process, such as carrying the metallic blanks until the presser.

5.1.2 Stamping

It has the purpose to construct the parts coming from the sectors of cutting, bending and/or fusing of metallic blank (Weiss, 2012). The cutting, bending and/or fusing are done by cold pressing. Metallic blank stamping is used to fabricate thin-walled parts made of metallic blank or tape from various metals and alloys. Stamping operations can be summarized in three basic operations: cutting, bending and embossing or fusing.

In the press sector, steel sheets are transformed into parts for the automobile body (Weiss, 2012). The metal blanks arrive in coils and / or blanks already cut and chemically treated. The blanks are molded in up to five different presses with pressures of up to two thousand and four hundred tons each, which cut, drill and bend the blank sheets until reaching the desired part. A press used, when assembled and in full operation, has the capacity to produce 960 pieces per hour.Equipment (Weiss, 2012):

Overhead crane: classified by elevating a type of overhead crane;

Presser: machine that molds materials through force application. This machine is used to give shape to the steel blanks until the desired product is done;

Schuler Presser: tailor made and destined for several applications in the automobile industry. They are especially developed for the production of external parts of the bodywork, from 100% automated pressing lines to transfer pressers for big panels and compact transfer pressers (Schuler, 2014). They have a capacity starting at 300 tons.

5.1.3 Assembling and Welding

The parts stamped on the presses are welded in hopper and the bodywork take shape (Weiss, 2012). Here, the parts coming from the presses, passing through the assembling process, engraving and welding until they form the car body. In the beginning of this step, several bottom parts are assembled, which are connected to the front of the car. Following, the car rooftop, the rear and the sides are assembled together, forming the bodywork that receives the welding points. Afterwards, the bodywork goes to complete the welds, which after going through the revision process goes to the coating hangar. In several welding points, the workers themselves do the welding, with the robots still completing the heavy load of the weld, and are also used in places that are difficult to be accessed by humans (Weiss, 2012). Equipment (Weiss, 2012):

Conveyor belt: used to move raw material in the production process or finishing process. In the production of bodywork, they are used in most of the process, such as carrying the metallic blanks until the presser;

Mounting brackets: robots support the welded boards for the start of the welding process;

Suction conveyor robot: facilitate and speed up the work, providing a better handling performance, reducing risk of casualties and facilitating the production. It has a great retention force, higher positioning accuracy and doesn't damage the raw material;

In the process of welding, several processes can be used, such as spot welding, laser welding and arc welding (MIG/ MAG). Among these processes the spot welding is the most used because of the greater simplicity (Kavamura, 2007), ease of control and less investment required, resulting in a product with quality.

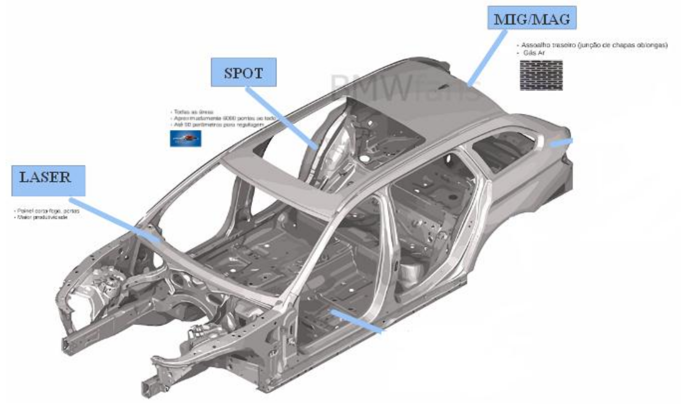

Figure 2. Types of weld done in BIW

Spot welding is a welding process based in a high current flow between two electrodes and two metal parts to be united (Kavamura, 2007). When the current flows, heat is generated in the touching points. The pressure of the electrodes is the same for a short period of time, after the current stops its flow, to keep the metal parts together while the point cools off and solidifies. The electrodes don’t fuse during the flow because of a fluid that goes through them.
The robots that weld the spot execute complicated movements, such as contouring the parts and reach inaccessible points without damaging the parts that are being welded (Kavamura, 2007). Thus, many welding application utilize six degree of freedom robots, three for positioning and three for orientation or posture according to the part. Though the necessary movements to the spot welding robots are complicated, the only spot requiring a great precision is the spot welded spot. Thus, it is possible to use point-to-point control during the robot's trajectory between the weld points. To avoid collision between the robots and the parts that are being welded during this two-point-welding movement, the robot is instructed with a large number of positions, which it must pass in its route until the next welding spot.

The welding tweezers is the equipment that performs the spot welding, it is controlled by a welding timer that, through parameters defined with the robot that sends it the program number to be executed, determines the opening moment of the tweezers, the only function of the tweezers is to close the arms and allow the welding current to pass through. The soldering tweezers, which like the robot itself, vary in size and characteristics according to the operation it will perform.

MIG/MAG welding is an example of a robotized weld (welding with gas protection and consumable electrode), because the device is capable to follow joints, changing its direction and making eventual corrections in an automated form, without the presence of a welder (Kavamura, 2007).

Laser welding was created due to the quality of the laser radiation. Its usage in welding makes it possible to obtain an impossible characteristic compared to other process, such as high welding velocity, absence of touch between heat and welding part sources, low thermal delivery, low distortion and few zones affected by heat (Kavamura, 2007). The high concentration of the laser beam provides excellent quality radiation, allowing several applications; only in the metal-mechanics are can be mentioned: cutting and drilling of parts of complex geometries. Some of the advantages of laser welding is the welding in one go; it doesn’t require adding metal, therefore, it is free of eventual contaminations; facilitation in difficult spot welding, once there is no contact with the part; welding in very thin parts; possibility of automation process (Kavamura, 2007).

The use of laser welding has increased considerably in the last years and some automakers see a production point of a vehicle 100% welded a short-term laser (Kavamura, 2007). Several companies consider the laser welding process to evolve from the spot welding process and are therefore difficult to avoid. One of the advantages of the laser welding process is that it does not require access from both sides of the part, which implies in reducing the number of body reinforcements for the same resistance.

As the parts do not have openings or holes for the access of the welding machine, the number of parts is reduced and, thus, the body weight is decreased (Kavamura, 2007). Although laser welding already has considerable use in regions such as Europe and the United States, this process is still rarely used in Brazil.

In this type of welding some equipment is needed, such as (Kavamura, 2007):

- Fixing device of the assembly;
- Laser generator;
- Robot;
- Welding head.

5.2 Cleanning

5.2.1 Degreasing

The function of the degreaser is to remove all contaminants such as oil / grease and solids from the surface of the part to ensure efficient phosphatizing and good adhesion of the paint (Gnecco, 2003). At this stage the piece is "washed" with a heated alkaline solution, aiming at the removal of contaminants that have been added to the part during its manufacturing process. This washing can be by immersion, spray or both methods, and may have more than one stage depending on the type and complexity of the part to be washed. Unlike the solvents that dissolve dirt, the alkaline degreasers emulsify the dirt in the solution, reacting with them to form water-soluble soaps (Gnecco, 2003).

The control of the degreasing process is very important because, if all the oils and greases are not removed from the surface of the part, it does not obtain a final quality product (Gnecco, 2003). For these reasons the concentration should not leave the established standards and the temperature of the bath should be between 70 and 80 ° C. The high temperature helps to dissolve some dirt and increases the kinetic energy of the molecules increasing the reaction capacity (GNECCO, 2003).

5.2.2 Phosphatization

At the end of the cleaning process, the parts need to receive a protective layer to avoid oxidation (Gnecco, 2003). According to the need for resistance it is necessary to ensure the best anchoring of the paint to be applied later.

Phosphatization creates on the metallic surface phosphate crystals of the metal, converting it from metallic to non-metallic (GNECCO, 2003). The purpose of phosphating is to improve the adhesion of paints and make the surface more resistant to corrosion. Only phosphatization increases corrosion resistance by about five times, but with phosphating more paint (two coats of synthetic paint), the increase is about 700 times.

The use of products with adequate concentration improves the efficiency of the process (Gnecco, 2003). The application of the product in the temperature between 50 and 80°C and pressure between 1 and 2 kgf/cm² (specification according to the supplier of chemicals) improves the efficiency of the system and accelerating the process.

According to the need for protection of the processed parts auxiliary stages may be added (Gnecco, 2003). Another issue taken into consideration is the isolation through the process between one bath and another in order to avoid contamination of the products. To do this, intermediate washing baths are installed with water to remove the products and the stages are spaced to avoid dragging through the work parts in the process.

5.3 Painting

The painting process is at the heart of the durability and beautification of a car's body, aesthetics and quality link (Gnecco, 2003). Its treatment processes are used for corrosion protection and weather resistance, whose materials previously qualified in exhaustive laboratory tests result in the covering of the inner plates and, externally, in the formation of final color film, synthesis of the excellent protection and appearance of the product. The application of absorbent materials produces comfort and protection to the passenger compartment against dust, water, noise and stone. The body "travels" through the production facilities by air carriers, cabins and robotic applications, are very widespread in the painting process.

The vehicle is the main constituent of the paint (Gnecco, 2003). It is made up of oils and resins. In most paints, the vehicle is a mixture of resins. There are several types of resins: resins resistant to acids, resistant to high temperatures, resins with high flexibility. The resin is the one that imparts the properties of the paint film; hardness, flexibility, temperature resistance, abrasion, adhesion and influence on the durability of the paint.

The paints are classified following the vehicle composition (Gnecco, 2003). They can be classified as conventional, noble and semi-noble. Alkyd resin paints are found in our everyday life in the process of painting home appliances and automobiles, because they support medium aggressive environments.

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5.3.1 E-coating

The painting by electro deposition was developed to meet the anti-corrosive requirements demanded by the automobile industry, auto parts and appliances (Pfanstiehl, 1998). The coating applied onto the phosphatized metal surfaces may or may not be followed by subsequent coatings.

The basic concept of the operation of the electro deposition process and the ink formulation is that particles with opposite charges attract (Pfanstiehl, 1998). Basically the electro deposition process occurs when a metal object (substrate) is immersed in a paint bath diluted in water, through which a continuous electric current is passed through. The part to be painted is connected to a pole, the other pole being the immersion tank itself, or the electrodes placed on its side walls.

There are two types of electro deposition: anodic and cathodic (Pfanstiehl, 1998). Anodic electro deposition is a process that deposits negative charges on the substrate of a positively charged surface. Cathode electro deposition is a process that deposits positively charged paint particles onto a negatively charged (grounded) substrate. The anodic system was initially developed, however the cathodic has more application in the coatings by electro deposition today.

The particles of paint, resins and pigments, migrate initially to the places of greatest intensity of the electric field, depositing in them (Pfanstiehl, 1998). The layer of deposited paint does not conduct electricity. Therefore, the layer formed at the privileged points isolates the electricity and the paint migrates to other points, covering the whole surface of the substrate. The layer thus formed is uniform throughout the surface, emphasizing the excellent coverage of corners, tips and edges, which cannot be achieved by any other painting process.

The e-coat paint (or KTL) is made by applying a direct current (rectifier) at a voltage between 240 and 320V (the normal working voltage, in the current process conditions is 260 V) (Gnecco, 2003). The painting process takes about 4 minutes and 20 seconds. Equipment (Gnecco, 2003):

Recirculation and agitation is intended to keep the paint in constant motion, thus avoiding the coagulation of the same. This system is provided with several water supply and drainage points, positioned at strategic points;

Ultrafiltration system is used to generate the permeate used to rinse the part after painting;

Anolyte system is composed of dialysis cells, reservoir, centrifugal pump, manometer, conductivity meter, solenoid, rotameter;

DI water system has the function of feeding the various points of rinsing and cleaning the set and feeding the anolith tank;

Water cooling system has the function of feeding the tank located in the backwash assembly of the UF generator, and feeding the heat exchanger;

Current rectifier system has the function of feeding the bus located on the overhead conveyor;

Power generator group is used to power equipment during any accidental power outage;

Control panel controls and monitors all equipment connected to the KTL paint line;

Conveyor makes continuous movement without leaps as well as a good electrical contact of the hooks with the mass guarantee a better quality in the painting.

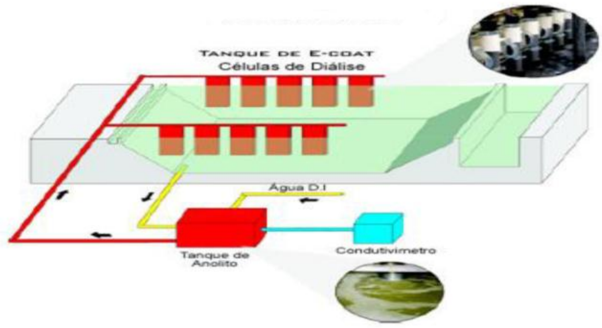

Figure 3. Anolyte system

5.3.2 Primer and Topcoats

Primer painting is essential for the durability and appearance of the final paint (Pfanstiehl, 1998). It is made having as a substrate the KTL layer deposited in the previous process and is used for corrosion protection, chip resistance, leveling of the surface and adhesion promoter for the application of the final layer. The application can be done either manually or by electrostatic automatic machines, which, through a system of rotating bells immersed in high voltage, ionize the particles of paint, causing them to be strongly attracted to the surface of the unit that is grounded.

The primer paint may be of generic color, ie whatever the final color of the unit is, it does not vary or specify, or specifies, where the ink color is very close to the final color of the car, thus bringing various advantages such as For example (Pfanstiehl, 1998):

- As the color is similar, the final paint layer can be reduced, reducing the final cost of the product;
- The emissions of Organo-volatile compounds into the atmosphere can be reduced;
- The chips that may occur are less visible to the eye.

The denomination of topcoats refer to the most external and superficial layer of a painted unit being manufactured by an application of basecoat, which gives the final coloration of the units and a varnish layer, applied over itself, responsible, mainly, for assuring brightness and coat protection (Pfanstiehl, 1998).

Topcoats have two primary functions: provide a more attractive appearance to the car; protect the primer layer and subsequently, the substrate of physical damage and related to the environment (Pfanstiehl, 1998).

The color and brightness are the primary attributes to the general appearance of the vehicle (Pfanstiehl, 1998). However, top coating is also a fundamental in maintenance of the substrate durability. The topcoat constitutes a barrier against the penetration of ultraviolet light, which can deteriorate both the corrosion resistance of the primers and the resistance to the abrasion and humidity penetration.

The application of these layers can be done manually or automatic (Pfanstiehl, 1998). In the more modern automotive painting plants, the application is mixed, the internal parts of the units are painted manually and the external pars are automatic. The automatic application of the base paint is done in one step to the solid colors and in two steps to the metallic and the pearly ones. In the first step, the particles of the paint are ionized and vaporized through a “bell” plugged into high voltage (60 KV) and rotating at high rotations (3,000 RPM), which, with the aid of mechanical arms following the configuration of the bodywork that, because is locked, attracts these particles to the surface. In the second step, the particles are vaporized by robots that follow all the bodywork settings, ensuring a complete and homogenous application in every spot. During the application of varnish, only the first step is executed, with bell machines.

6. FINALIZING

6.1 Stove curing

Coat curing is the process by which the coat film is formed (Gnecco, 2003). Drying is the simple evaporation of the solvent. Curing involves polymerization processes with or without the addition of heat. Conventional coats dry by the oxidation of the oils and evaporation of the solvent. The stove reaches up to 200ºC where the pieces are transported remaining approximately 30 minutes for the cure.

6.1.1 Stove

Responsible for the polymerization of the paint on the parts guarantees energy saving through a good constructive form and good thermal insulation. The heat source must have the necessary power to maintain the temperature at the required levels with sufficient time and thus to obtain a rapid heating response, aiding productivity (Gnecco, 2003).

6.2 Cleaning

In this step, any discrepancies are eliminated, as well as an extremely careful cleaning so that these discrepancies are not shown in the final painting (Pfanstiehl, 1998). Cleaning is performed by equipment called ostrich feather cleaning machine, it works as a duster roller found in scrubbers (Pfanstiehl, 1998).

6.3 Inspection

All sectors have a material inspection system, which verifies that everything is in accordance with specifications and the predetermined interval (Pfanstiehl, 1998). Robots do this process by using at their tips, photographic sensors that send the images to a computer, where the inspection will be approved according to the original computerized model. The robots used are differentiated by their size, feature and functionality. According to the operation to be carried out, the tip has the necessary tool for the operation. The items to be inspected in each process and the equipment used are detailed in the chapter 3.3 Control Plan.

7. CONCLUSION

The objective was to search for a body in white production process. Its success and concretization are related to quality assurance, in which it demands that the results of a process do not vary, and that unforeseen ones don't occur, or, when they occur, it is known exactly where the origin of the problem is; correcting them as soon as possible and as cheap as possible. In order to carry out such processes it is necessary to know in depth the magnitude of the parameters and variables that have a significant influence on the expected results, ensuring that what is being manufactured corresponds to the required demand.

This systematic approach confronts and formalizes the mental discipline that an engineer goes through in any manufacturing planning process (Ford Motor Company, 1997). Your development doesn't depend on intellection alone, but also the capacity to work and take decisions in harmony, meeting the objective of both parties.

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10. RESPONSIBILITY NOTICE

The authors: André, Anderson, Felipe, Renan, Vitor, Waldir acknowledge that the article is original, is not under consideration by another journal, has not previously been published elsewhere and its content has not been anticipated by any previous publication.

Fig. A.1. 5W2H

5W2H Planning

Objective: BODY IN WHITE (BIW)

Group 07: Anderson Souza / André / Felipe / Renan / Vitor / Waldir

Leader: Waldir

WHAT	WHO	WHEN		WHERE	HOW	WHY	HOW MUCH	% Complet	Today	Situation
		Start	End							
Internet Research	Felipe	8-Aug	15-Aug	UNISAL/ Whatsapp	Google	Applications	-	100.0%	100.0%	✓
Theoric Research	Renan	16-Aug	9-Sep	Factories (Assemblers)	Visits	Theoric Basis	-	100.0%	100.0%	✓
3D Projects (Tools, etc)	Felipe	16-Aug	9-Sep	Unisal / Facic	Solid Edge ST6	Design, model	-	100.0%	100.0%	✓
Technical Specifications of Materials	Vitor	16-Aug	30-Aug	Unisal / sites / email	MS Excel/ Power Point/ Softwares	Product Development	-	100.0%	100.0%	✓
Process Flowchart	Waldir	16-Aug	30-Aug	Unisal / Assemblers	MS Excel/ Power Point/ Softwares	Product Development	-	100.0%	100.0%	✓
Control Plan	Anderson	16-Aug	30-Aug	Unisal	MS Excel/ Power Point/ Softwares	Product Development	-	100.0%	100.0%	✓
FMEA	Renan	1-Sep	13-Sep	Unisal	MS Excel/ Power Point/ Softwares	Product Development	-	100.0%	100.0%	✓
Raw Material List	Anderson / Vitor	9-Sep	27-Sep	UNISAL/email/Novelis	MS Excel/ Power Point/ Softwares	Product Development	-	100.0%	100.0%	✓
Tool List	Felipe / André	9-Sep	27-Sep	UNISAL/email/Whatsapp	MS Excel/ Power Point/ Softwares	Product Development	-	100.0%	100.0%	✓
Device List	Felipe / Vitor	9-Sep	27-Sep	UNISAL/email/Whatsapp	MS Excel/ Power Point/ Softwares	Product Development	-	100.0%	100.0%	✓
Layout	Waldir	28-Sep	11-Oct	Lab UNISAL	MS Excel/ Power Point/ Softwares	Setup / Use	-	100.0%	100.0%	✓
Partial Report	Waldir	19-Aug	1-Nov	Unisal / Library	MS Word	To deliver to the professor	-	20.0%	100.0%	✗
Preparation of Presentation	André	26-Oct	1-Nov	UNISAL / Felipe's Office	MS PowerPoint	For Final Presentation	-	50.0%	100.0%	✗
Final Presentation	Everyone		18-Nov	UNISAL	Written Work and Presentation	Evaluation	-	0.0%	100.0%	✗

Fig A.2. BIW Flowchart

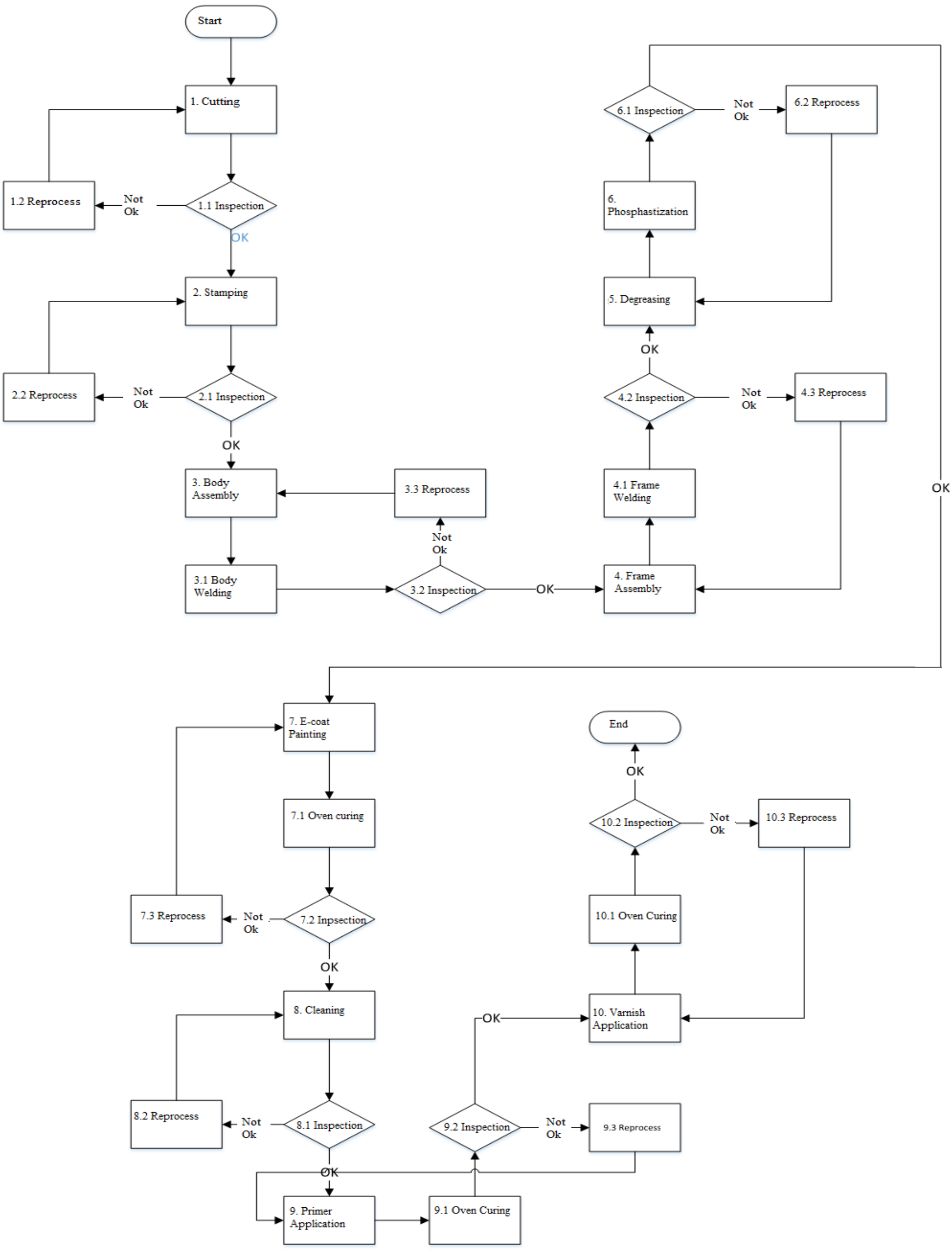

Table A.1. Control Plan of Production Processes

Start the cutting process of the part, knowing the procedure of demand.					
Phase	1	Previous Marking			
	Verification	Number of Controls	Rejection Criteria	Measuring Equipment	Frequency
1.1	Part dimension accuracy	1 - Vertex of the perimeter of the piece.	Errors ± 0,05%.	Online Sensors/ via soft	100%
		2 - Blank's thickness	Thickness variation ± 0.2 mm	Caliper	100%
		3 - Cutting Reburr	Variation ± 0.02 mm	Rough Meter	100%
Stamping process and sample analysis.					
Phase	2	Previous Marking			
	Verification	Number of Controls	Rejection Criteria	Measuring Equipment	Frequency
2.1	Stamping accuracy	1 - Check irregularity of surface creases	0.8° a 1.0°	Rough Meter	2 parts
		2 - Side ear	0.8° a 1.0°	Indicator	2 parts
Assemblying process / Basis.					
Phase	3	Previous Marking			
	Verification	Number of Controls	Rejection Criteria	Measuring Equipment	Frequency
3.A	Parts assembly	1 -Torque on the model bolts M4 / 4.6 MM	1.3 N.M	Robot inspection	2 parts
		1 - Weld	No cracks	Ultra sound	100%
Welding process / Basis.					
Phase	3.1	Previous Marking			
	Verification	Number of Controls	Rejection Criteria	Measuring Equipment	Frequency
3.1.A	Welding accuracy	1 - Longitudinal cracking in ZTA	Irregular Welding	Ultrasound / Visual	100%
		1 - Longitudinal cracking in ZF	Irregular Welding	Ultrasound / Visual	100%
		3 - Crater Craft	Irregular Welding	Ultrasound / Visual	100%
Frame assemblying					
Phase	4	Previous Marking			
	Verification	Number of Controls	Rejection Criteria	Measuring Equipment	Frequency
4.A	Coatings fixing	1 - Check whether the lining	Vibration of 0.2mm	Vibration Sensor	5 parts
		2 - Check space between parts	Space of 1mm between parts	Laser regulated	5 parts
Welding process / Basis.					
Phase	4.1	Previous Marking			
	Verification	Number of Controls	Rejection Criteria	Measuring Equipment	Frequency
4.1.A	Welding accuracy	1 – Crack in the welding cutter	Irregular Welding	Ultrasound / Visual	100%
		2 – Welding splash	Irregular Welding	Ultrasound / Visual	100%
Degreaser					
Phase	5	Previous Marking			
	Verification	Number of Controls	Rejection Criteria	Measuring Equipment	Frequency
5.1	Removal of oils, greases and impurities	1 - Residual analysis of oils and greases	Specified < 10 mg/m²	Carbon reader	10 parts
		2 – Chemical bath treatmeng	Concentration of 50% aqueous bath	Titration analysis / physic-chemical laboratory	Weekly
Phosphatization					
Phase	6	Previous Marking			
	Verification	Number of Controls	Rejection Criteria	Measuring Equipment	Frequency
6.1	Phosphate Conversion Coatings	1 – Application Uniformity	Application failed	Inspection cameras	100%
		2 – Application weight	Specified 5 < 6 µ	Specmetrix (online)	100%
		3 – Phosphate layer control	1 < 3 g/m2	Analytical scale	20 parts
E-COAT Panting					
Phase	7	Previous Marking			
	Verification	Number of Controls	Rejection Criteria	Measuring Equipment	Frequency
7.A	Paint weight	1 – Visual analysis	Coating application failed	Visual / Cameras	100%
		2 – Online Weight equipment	Weight specification 5 < 6 µ	Specmetrico (online)	100%
Oven curation					

Phase	7.1	Previous Marking			
	Verification	Number of Controls	Rejection Criteria	Measuring Equipment	Frequency
7.B	Curation	1 - Adherence	According to the norm TT-C-490D / 1993	Adherence test	10 parts
		2 - Impact test	1µ Defoliation	Impact+G81o ASTM - 2794-93	10 parts
Cleaning					
Phase	8	Previous Marking			
	Verification	Number of Controls	Rejection Criteria	Measuring Equipment	Frequency
8.1	Removal of phosphatization impurities	1 - Concentration of the bath	According to the norm TT-C-490D / 1993	Neutralization Titration	3 every week
		2 - Cleaning parts	Residuals and impurities	Cameras and Visual	100%
Primer application					
Phase	9	Previous Marking			
	Verification	Number of Controls	Rejection Criteria	Measuring Equipment	Frequency
9.A	Application uniformity	1 - Visual analysis	Coating application failed	Visual / Cameras	100%
		2 - Online weight equipment	Weight specification 5 < 6 µ	Specmetrico (online)	100%
Oven curation					
Phase	9.1	Previous Marking			
	Verification	Number of Controls	Rejection Criteria	Measuring Equipment	Frequency
9.B	Primer curation	1 - Adherence	ABNT normal specification 11003/ 1990	Adherence test	10 parts
		2 - Impact Test	1µ Defoliation	ASTM - 2794-93 impact	10 parts
Varnish application					
Phase	10	Previous Marking			
	Verification	Number of Controls	Rejection Criteria	Measuring Equipment	Frequency
10.A	Application uniformity	1 - Visual analysis	Failure to apply varnish	Visual / Cameras	100%
		2 - Online weight equipment	Weight specification 5 < 6 µ	Specmetrico (online)	100%
Oven curation					
Phase	10.1	Previous Marking			
	Verification	Number of Controls	Rejection Criteria	Measuring Equipment	Frequency
10.B	Varnish curation	1 - Adherence	ABNT normal specification 11003/ 1990	Adherence test	10 parts

Table A.2. FMEA

Process 1: Cutting Part: Body in White											
Item / Function	**Requisite**	**Potential Failure Mode**	**Potential Failure Effect(s)**	SEVE	CLAS	**Potential Cause (6M) Mechanisms**	OCOR	**Actual Preventive Control**	**Actual Detection Control**	DETC	NPR

1.1 Perimeter vertex of the part	Control and Monitor	Operational Error	Rework	5		Operational Error	4	Inspection	Online Sensor via Soft	3	**60**
1.2 Blank's Thickness	Inspection	Thickness out of Specification	Not Executed in the Process	8		Operational Error	4	Inspection	Pachymeter	1	**32**
1.3 Reburr of Cut	Reburr Elimination	Operational Error	Rework	6		Operational Error	4	Inspection	Rugosimeter	2	**48**
Process 2: Stamping and Sample Analysis Part: Body in White											
2.1 Check Irregularities of creases on surface	Control and Monitor	Operational Error	Rework	5		Operational Error	4		Rugosimeter	5	**100**
2.2 Lateral Ear	Inspection	Operational Error	Rework	5		Operational Error	4	Inspection	Indicator	1	**20**
Process 3: Frame Assembly Part: Body in White											
3.1 Torque screw m4 / 4.6mm	Torque Inspection	Operational Error	Loss of Material	5		Operational Error	4	Inspection	Robots	5	**100**
3.2 Welding	No Cracks	Operational Error	Rework	5		Operational Error	4	Inspection	Untrasound	1	**20**
Process 4: Frame Assembling Part: Body in White											
4.1 Check if the reinvestment is fixed	Fix Reinvestment	Operational Error	Rework	5		Operational Error	4	Inspection	Vibration Sound	5	**100**
4.2 Check space between parts	Standard Spaces	Operational Error	Rework	8		Operational Error	4	Inspection	Laser Ruler	1	**32**
Process 4A. Frame welding Part: Body in White											
4.A.1 Crack on the welding cord	Inspect Defects	Variable Control	Rework	5		Operational Error	4	Inspection	Visual Untrasound	1	**20**
4.A.2 Welding Splash	Inspect Defects	Variable Control	Rework	8		Operational Error	4	Inspection	Visual Untrasound	1	**32**
Process 5: Degreasing Part: Body in White											
5.1 Analysis of oil residual	Fix Reinvestment	Operational Error	Rework	5		Operational Error	4	Inspection	Visual Sensor	5	**100**
5.2 Treatment of chemical bath	Standard Spaces	Operational Error	Rework	5		Operational Error	4	Inspection	Laser Ruler	1	**20**
Process 6: Phosphatization Part: Body in White											
6.1 Application Uniformity	Paint weight	Control the painting variables	Rework	8		Operational Error	4	Inspection	Cameras of Inspections	4	**128**
6.2 Application Weight	Paint weight	Control the painting variables	Rework	8		Operational Error	4	Inspection	Specmetrix	1	**32**
6.3 Control of the phosphate layer	Analyse the coat curing	Control of the phosphate layers	Rework	4		Operational Error	4	Inspection	Analytical Scale	5	**80**

Process 7: E-Coat Painting Part: Body in White											
7.1 Visual Analysis	Paint weight	Operational Error	Rework	5		Operational Error	4	Inspection	Visual and Cameras	5	**100**
7.2 Online Weight	Specific Weight	Operational Error	Rework	8		Operational Error	2	Inspection	Specmetric	5	**80**
Process 7.1: Oven Curing Part: Body in White											
7.2.A Adherence	Specification abnt 11003 / 1990	Operational Error	Rework	5		Operational Error	4	Inspection	Adherence Test	5	**100**
7.3.A Impact Test	Defoliation	Operational Error	Rework	5		Operational Error	4	Inspection	Impact astm 2794 - 93	1	**20**
Process 8: Cleaning Part: Body in White											
8.1 Bath Concentration	Norm Specification TT-C-490D	Operational Error	Rework	5		Operational Error	4	Inspection	Neutralization Titration	5	**100**
8.2 Cleaning of the Parts	Impurity Residues	Operational Error	Rework	5		Operational Error	4	Inspection	Visual	1	**20**
Process 9: Primer Application Part: Body in White											
9.1 Visual Analysys	Uniformity	Operational Error	Rework	5		Operational Error	4	Inspection	Visual and Cameras	5	**100**
9.2 Online Weight Equipment	Uniformity	Operational Error	Rework	5		Operational Error	4	Inspection	Specmetric	1	**20**
Process 9.1.A Oven Curing Part: Body in White											
9.2.A Adherence	Primer Curing	Operational Error	Rework	5		Operational Error	4	Inspection	Adherence Test	5	**100**
9.3.A Impact Test	Primer Curing	Operational Error	Rework	5		Operational Error	4	Inspection	Impact astm 2794-93	1	**20**
Process 10: Varnish Application Part: Body in White											
10.1 Visual Analysis	Uniformity	Operational Error	Rework	5		Operational Error	4	Inspection	Visual and Cameras	5	**100**
10.2 Online Weight Equipment	Uniformity	Operational Error	Rework	5		Operational Error	4	Inspection	Specmetric	1	**20**
Process 10.1.A Oven Curing Part: Body in White											
10.2.A Adherence	Varnish Curing	Operational Error	Rework	5		Operational Error	4	Inspection	Adherence Teste	5	**100**
10.3.A Impact Test	Varnish Curing	Operational Error	Rework	5		Operational Error	4	Inspection	Impact astm 2794-93	1	**20**

Fig. A.3. Main Steels Used in the Automobile Industry

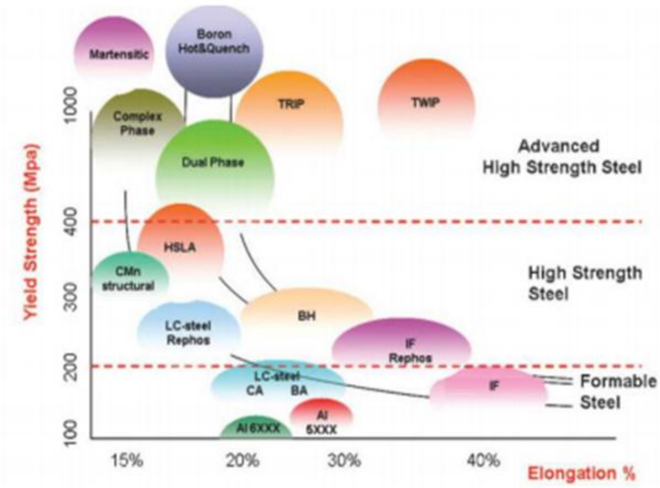

Fig A.4. Main steels used in the BIW body

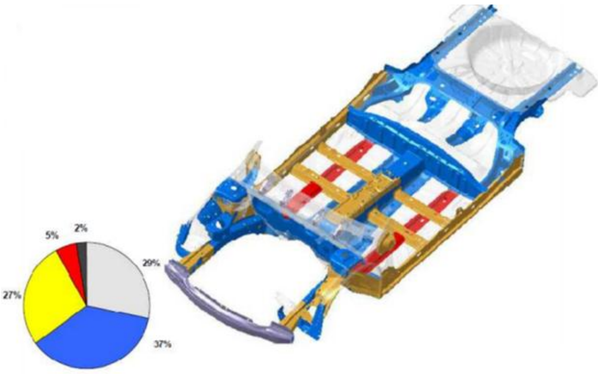

Fig A.5. Main steels used in the BIW frame

Fig. A.6. Automotive Pressing Machine

Fig. A.7. Spot welding robot with tweezers

Fig. A.8. MIG/MAG welding robot

Fig. A.9. Laser welding station

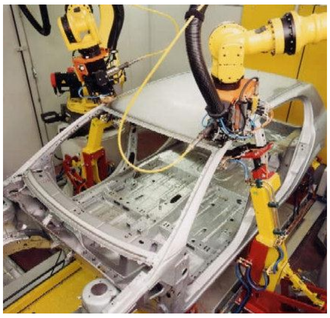

Fig. A.10. BIW E-coat application

Fig. A.11. BIW primer application

Fig. A.12. BIW varnish applcation

Fig. A.13. Oven curing.

Fig. A.14. Ostrich feather duster

Fig. A.15. Robot with integrated camera for inspection