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MANUFACTURING PROCESSES APPLIED TO THE STEEL WHEELS PRODUCTION.

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Abstract: *This study has the objective to introduce the detailed manufacturing process to the steel wheels production, showing the most important tools, as the Technical Specifications, Process Flowchart, Control Plan, Process FMEA, Equipment and Tooling and Layout of Production Line.*
In this study were addressed the definitions about the manufacturing processes used to the steel wheels production, in other words, Lamination, Flash Butt Welding, Mig-Mag Welding, Stamping, Machining and Phosphating.

Keywords*: Steel Well, Manufacturing Processes, Manufacturing Tools and Machinery.*

1. INTRODUCTION

The steel wheels are responsible for the vehicle locomotion, they are the simpler and cheaper alternative than alloy wheels, the production of steel wheels in the industry demands a number of manufacturing processes the production of steel wheels in the industry demands a number of manufacturing processes responsible for making a simple steel plate into a wheel that will be used in the various vehicles of the automotive industry, to ensure the security for this vehicles, the production must have a number of tools responsible for ensuring the security and the good quality of the wheels before to send to the consumer.

2. METHODS USED

For the purpose of this article was reached, was studied the assembly process of the steel wheel and the manufacturing processes used on them, were also studied and made in practice the production tools used in the industry.

3. TECHNICAL SPECIFICATIONS

3.1. Definitions

For the purposes of this article, the following definitions shall be adopted:

- **Wheel**

Rotating load bearing component, located between the tires and the axles, generally composed of two main parts, the rim and the disc of the wheel, it can be integral, permanent, connected or separable

- **Rim**

Part of the wheel on that the tire is mounted

- **Unmounted rim**

Wheel mounted so that one or two unmounted rims are fixed to the cast spindle, which also functions as a support for drum brake or disc brake.

- **Entry of the tire**

Part of the rim that provides radial support for the tire.

- **Disc**

Part of the wheel that is the support between the rim and the shaft

- **Family of steel wheels for cars**

Mixed-use vehicles or cargo vehicles. It is constituted by the dimension of the ring (nominal diameter and width), fastening system (circle diameter of the holes for fixing in the case of disc wheels), and load capacity.

- **Flange**

Part of the rim that provides lateral support for the tire

(Joe Luiz Tolezano, 2011)

3.2. Wheel settings

Wheel according to Houaiss (2002) is an object, piece or circular machine that moves around an axis or its center, with various uses; circular object; circular shaped mechanical device; Wheel of any vehicle that, once added, allows the movement of the vehicle.

The wheel, for a vehicle, is a part with structural safety function, together with the vehicle, it is responsible for keeping the vehicle on track and transmitting from the vehicle to the track all efforts due to the weight of the vehicle in order of march and of the traction systems, braking and steering, as well as, in reverse, It is also responsible for transmitting to the vehicle every effort from irregularities and track obstacles during its journey. Because it is a piece that undergoes rotation, the burdens and efforts for which it is submitted vary cyclically as a function of the rolling of the vehicle.

(Edgar Ferreira de Barros Neto, 2010)

3.3. The steel wheel

The steel wheel is composed of two components, the rim and the disc, which are produced separately and through different processes, the rim being produced by lamination processes, and the disc being produced by stamping process, and then joined through the Mig-Mag Welding.

According to MIZUI, M; SONEDA, S, in addition to the appearance aspect, the wheels must satisfy several requirements (described below), But of all the functions required on a wheel, the durability is the most important:

- Fatigue, that aims to check the durability of the components (rim and disc) and the weld joint rim/disc;
- Impact, which aims to verify the product's resistance to frontal collisions and side;
- Resistance of the welded joint;
- Stiffness of fixing holes;
- Corrosion;
- Minimum oscillation and unbalance (greater uniformity).

(Danilo de Castro Denúbila, 2015)

Figure 1. Steel Wheel Model, source: Chevrolet Nova

3.4. Discs

The designation used for the external face of the steel wheels is disc, and for the alloy, wheels are rays. The steel wheels use stamped disks, with ventilation windows, drilling and ribs.

The disc or the spoke of the wheels has important structural function, because it suffer great lateral efforts, the flexors being the most significant. The disc or the rays are one of the critical points in the design of a wheel, because it is in them that the structural failure of the wheel is verified, when submitted to the axial fatigue test.

(Edgar Ferreira de Barros Neto, 2010)

3.5. Rims

The rim is the part of the wheel that allows proper mounting of the tire. The dimensions of the rim are determined by the dimensions and type of the tire to be mounted, being the project quotas standardized by the Latin American Tire and Ring Association (ALAPA). The thickness of the rim is according to the loading that the wheel will be subjected, the properties of the chosen material, and the wheel manufacturing process.

The rim determines one of the main dimensions for the design of a wheel, to know, the diameter, that, by convention, is expressed in inches. For the tire to be inflated and its internal pressure controlled, in the rim a bore must be provided for mounting a nozzle that will house a valve responsible for maintaining the internal pressure of the tire. In the rim are also fixed weights that have the function of compensating the imbalance of the wheel and tire assembly when assembled, dynamically balancing the set.

(Edgar Ferreira de Barros Neto, 2010)

3.6. The Low Carbon Steel

Low carbon steels have, normally, low resistance, hardness and high toughness and ductility. Besides that, are quite machinable and weldable and have a low production cost. These steels are usually not heat-treated. Among its typical applications are the automotive plates, structural profiles and plates used in the manufacture of tubes, civil construction, bridges and cans

(Natalino de Paula Oliveira, 2007)

The 1045 low carbon steel is the main component of the steel wheels

4. MORE USED MANUFACTURING PROCESSES

In the production line of the steel wheels, some of the various manufacturing processes are used, such as Lamination, Stamping, Flash Butt Welding, Mig-Mag Welding and Phosphatizing.

4.1. Lamination

Lamination is a conformation process that essentially consists of the passage of a solid body (piece) between two cylinders (tools) that rotate at the same peripheral speed, but in opposite directions. In this way, the body of the piece having a larger dimension than the distance between the sides surfaces of the cylinders, it undergoes a plastic deformation in the passage between the cylinders, which results in the reduction of its cross-section and in the increase of its length, and width. In order to obtain a certain size (thickness) of the body, the part must be subjected to successive passes through the cylinders, with decreasing distance between them. The passage of the piece through the cylinders occurs through the action of the friction force that acts on the contact surface between the parts and the cylinders. This force is proportional to the coefficient of friction between piece and cylinder and to the normal force on the contact surface.

The lamination process can be conducted either cold or hot, Depending on the dimensions and structure of the part material specified for beginning and end of processing.

Cold Lamination - The initial part for processing, in this case, is a semi-finished product (plate), pre-hot laminated. Since a, working temperature (ambient temperature) is below the recrystallization temperature, The workpiece material has a higher resistance to deformation and an increase of this resistance with the deformation (hardening), Not allowing, in this way, high degrees of reduction of the cross section. An annealing heat treatment, between one and another sequence of passes, May become necessary in accordance with the established reduction program and the required properties of the final product. The cold lamination is applied, so for the final operations (workmanship), when the product specifications indicate the need for superior surface workmanship (obtained with smoother cylinders and in the absence of heating, which prevents the formation of oxide shells) and structure of the crushed metal with or without final annealing.

(Eettore Bresciani Filho, Iris Bento da Silva, Gilmar Ferreira Batalha, Sérgio Tonini Button, 2011)

During the manufacture of steel wheels, the cold lamination is the most used process, being present at the beginning of the operation when the steel plate is rolled and during the roll-formings of the rim.

4.2. Stamping

Stamping is the set of operations with which without producing splinter we subjected a flat plate to one or more transformations in order to obtain pieces with their own geometries. The stamping is a plastic deformation of the metal. The stamps are composed of elements common to all and any kinds of tools (Base, bottom, top or top base, spigot, guide columns, shock plate, guide plate, fastening screws and pins, and others) And by specific elements and responsible for the shape of the plate to be produced (die and punches)

(Ivar Benazzi Junior, Elpidio Gilson Caversan, 2012)

In steel wheels, the stamping is present in the manufacture of disc, where it gives the desired plate of the disc in the steel plate

4.3. Flash Butt Welding

The simplest configuration for welding metal elements is the Flash Butt Welding.

This type of welding is used to join the ends of two elements, such as pins, plates and etc ...

The Flash Butt Welding design consists of separating the normal stress to which the parts are subjected to the flow resistance or the rupture of the material of the weld or the weaker material between the soldiers. If there is variation in the load over time, fatigue concepts must be applied.

(Prof. Dr. Auteliano Antunes dos Santos Júnior, 2001)

In the production line, the Flash Butt Welding is used to join the two ends of the steel sheet after being rolled up

4.4. Mig-Mag Welding

In the electric arc welding with shielding gas (GMAW – Gas Metal Arc Welding), also known as 4.4. Mig-Mag Welding (MIG – Metal Inert Gas e MAG – Metal Active Gas), an electric arc is established between the part and a consumable in the form of wire. The arc continuously melts the wire as it is fed into the melting pool. The weld metal is protected from the atmosphere by the flow of a gas (or gas mixture) inert or active.

(Cleber Fortes, Cláudio Turani Vaz, 2005)

In the manufacture of small and medium steel wheels, Mig-Mag welding is used to fasten the disc to the rim

4.5. Phosphating

Phosphatization creates on the metal surface, phosphate crystals of the metal, converting it from metallic to non-metallic. The purpose of phosphating is to improve the adhesion of paints and make the surface more resistant to corrosion. Only phosphating increases the corrosion resistance by about five times, But with phosphating plus paint (2 coats of synthetic paint), the increase is about 700 times.

Phosphatization consists of the reaction of alkaline, such as caustic soda. The pieces in this case, they are immersed in an alkaline bath that dissolves the greasers and then is washed with clean water. Since the mineral oils are not saponifiable And therefore require cleaning with appropriate organic solvents, or with solutions of surfactants (detergents), which are more efficient in cleaning, because besides the oils, also remove salts and oxides soluble in water It is necessary, Rinse thoroughly with clean water to remove residues from the surfactant.

(Celso Gnecco, Roberto Mariano, Fernando Fernandes, 2003)

Steel wheels also undergo the phosphatization process to receive their paint

4.6. Machining - Drilling

Drilling is a mechanical machining process for obtaining a generally cylindrical hole in a part, with the aid of a cutting tool. For this, the tool or part moves along a straight-line path, Coincident or parallel to the main axis of the machine. The drilling is divided in these operations:

- Full drilling – rilling process for the opening of a cylindrical hole in a piece, removendo todo o material compreendido no volume do furo final, in splinter form. If you need to drill holes of great depth, there is the need for special tools;

- Staggered drilling – Drilling process used to obtain a hole with two or more diameters simultaneously;

- Reaming – A drilling process for opening a cylindrical bore in a pre-drilled part;

- Center drilling – Drilling process to obtain center holes, aiming at a later operation in the part;

- Trepanation – Drilling process in which only a part of the material comprised in the final hole volume is reduced to splinter, Staying a massive core.

(Prof. Éder Silva Costa, Denis Júnio Santos, 2006)

5. RIM PRODUCTION PROCESS

The process of organizing the production line of rims for steel wheels is based on the steel plates customers use. The steel supplier, according to your needs, cuts these steel plates into different lengths

5.1. Cutting of Steel Sheet

In the manufacturing process, the steel plates pass through the guillotine, which is a type of tool used for cutting metal plates, including aluminum, steel, brass, bronze and copper. Despite the name, they are also a popular device for cutting or shaping plastic sheets. Unlike traditional blades or cutting devices, they have relatively square edges.

Figure 2. Cutting of steel plate, source: Rodabrás

5.2. Lamination Process - Conformation of the rim

It is understood as conformation of the metals the modification of a metallic body to another definite one.

The forming processes can be divided into two groups: mechanical processes, in which the changes in style are caused by applying external voltages, and metallurgical processes, in which the shape modifications are related to high temperatures

The mechanical processes are constituted by the plastic forming processes, for which the applied stresses are generally lower than the tensile strength limit, and by forming machining processes, For which the applied stress are always higher than the limit mentioned. The Final Form, therefore, it is obtained by removal of material. These processes are also called "Forming Processes Mechanics" by nature

(Otávio Fernandes Lima da Rocha, 2012)

In the production of the Steel Wheel rim, the conformation is used to give the rounded shape the steel plate, which will be ready to have its ends welded

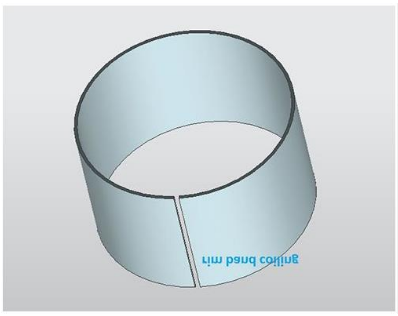

Figure 3. Design of steel plate conformed in the shape of a rim, source: LittleDuck, wheelmachinery

5.3. Flash Butt Welding

In the production of steel wheels the Flash Butt Welding is used to join the two parts of the steel plate after being conformed, Soon after it goes through processes of removal of slag left by the weld, planishing welding sean, cooling and re-rounding

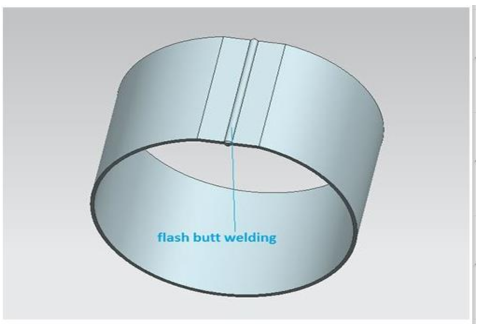

Figure 4. Design of welded and conformed steel plate, source: LittleDuck, wheelmachinery

5.4. Lamination Process – Roll formings and edge flanging

Roll formings are lamination processes responsible for giving varied and regular shapes to the rim, they are divided into three stages each responsible for a part of the roll forming, after the roll formings the rim passes through perforation stages of the valve orifice, and the formed rim is ready to receive the disc.

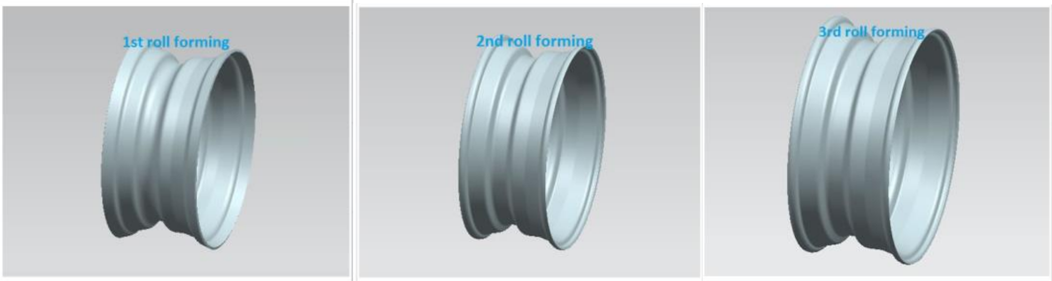

Figure 5. The three roll formings of the rim, source: LittleDuck, wheelmachinery

After roll forming the rim can receive a flange if required.

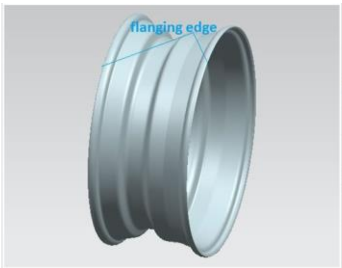

Figure 6. Flanged steel wheel, source: LittleDuck, wheelmachinery

6. DISC PRODUCTION PROCESS

The manufacturing process of the disc is made from the stamping of the steel plate, which gives the required shape to the disc

6.1. Application of Stamping Lubricant Oil

Lubricant is all or any solid or liquid material of low shear strength, Whose function is to keep the tool surfaces (punch and die) separated from the material to be conformed, reducing friction. The performance of lubricants in part stamping can have a significant impact on the process, as in some inlay and stretch applications. Dieter (1996), says that lubricants reduce friction by introducing an interface that is easily sheared. Keeler (2001) defines a lubricating barrier as a film that completely isolates the surface of the sheet metal from the surface of the matrix.

(Sávio Sade Tayer, 2011)

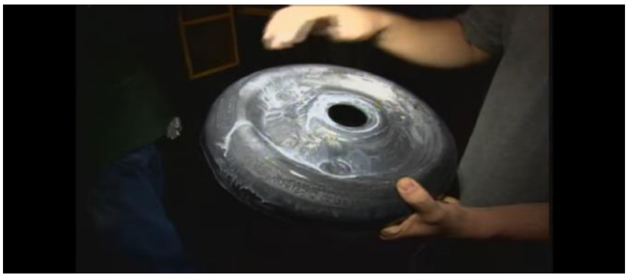

Figura 7. Óleo de estampagem sobre um disco, Fonte: Rodabrás

In the disc production line the lubricating oil is used in the steel sheets before the stamping, in order to avoid aggression to the material, then the steel plate passes through a pre-stamping process before passing through the final stamping and receiving the disc shape

6.2. Stamping

In the production of disc the sheet steel is placed on the die of stamping and under pressure by them, thus giving the format of the disc.

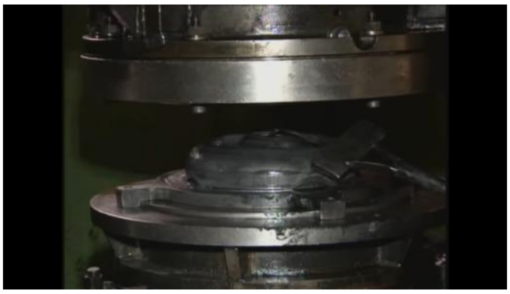

Figure 8. Stamped disc, source: Rodabrás

6.3. Machining Process - Drilling

In the drilling the holes of the disc are realized, typically having 3 to 5 holes, After the drilling the disc is finished and ready to be fixed to the rim

Figure 9. Disc drilling, source: Rodabrás

7. TERMINATION OF STEEL WHEEL

The steel wheel finalization happens after the rim and the disk are completely finalized, and involves the steps of attaching the disc to the rim, painting and workmanship to end being packaged and sent to the consumer.

7.1. Pressing Disc into Rim

After completion of the production of the rim and the disc must be both pressed before welding.

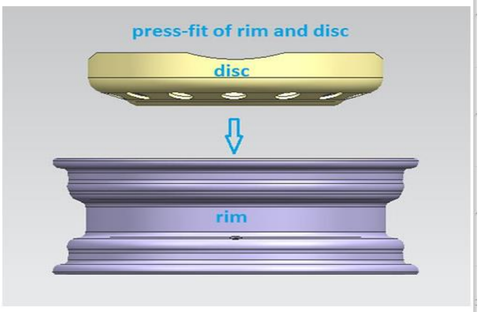

Figura 10. Figura da prensagem do aro no disco, Fonte: LittleDuck, wheelmachinery

7.2. Mig-Mag Welding Among Rim and the Disc

Mig-Mag welding is required to ensure complete attachment of the disc to the rim, It is made on most small and medium wheels, on big wheels, generally larger than 26 inches, the Mig-Mag Welding is replaced by bolting, after welding the wheel undergoes a degreasing in order to remove any impurities before being taken to paint.

Figure 11. Mig-Mag Welding among rim and the disc, source: Rodabrás

7.3. Phosphating Process

After the solder is cooled and the degreaser has been made the wheel is already mounted, leaving only its painting is made in the phosphatization

Figure 12. Phosphating process, source: Rodabrás

After the wheel receives the phosphate powder it must wait inside a stove until it receives its painting, after completion of painting the wheel is ready to be packed and sent to the consumer.

8. DISCUSSION

The article showed how the various manufacturing processes are used in the production of steel wheels, from the macro processes such as welding the rim to the smallest ones such as the planishing welding sean, we can notice how important it is to have knowledge of the processes and how it can be used in industry

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INMETRO, Instituto Nacional de Metrologia, qualidade e tecnologia
http://www.inmetro.gov.br/

IQA, Instituo de Qualidade Automotiva
http://www.iqa.org.br/publico/?1481920675

Volkswagem, Montadora de Veículos

https://wwws1.volkswagen.com.br/suprimentos/anexosatual/CG/UFPORTE-852012104331-CompraDeFerramentalProdutivo.pdf

LittleDuck, Fabricante e Especialista Chinês em Design de Máquinas de Roda de Aço

http://wheelrimmaking.com

Cobrimetal, Caldeiraria e Estamparia
http://www.cobrimetal.com.br/

10. RESPONSIBILITY NOTICE

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The author(s) is (are) the only responsible for the printed material included in this paper.

11. ATTACHMENTS

It will present the production tools used in industries, which aim to avoid errors, product failures, delays in the production lines and to ensure the good quality of the final product

Attachment A

Standards and Certification Process

Attachment B

Process FMEA

Attachment C

Control Plan

Attachment D

Layout of the Production Line

Attachment E

Process Flowchart

Attachment F

Equipment and Tooling

11.1. ATTACHMENT A – STANDARD AND CERTIFICATION PROCESS

Attestation of Conformity

Issue of a statement, Based on a decision made after the critical review, that the fulfillment of the specified requirements has been demonstrated.

Authorization for Use of the Conformity Identification Seal

Authorization given by Inmetro, Based on the principles and policies adopted under the SBAC and in accordance with the requirements established in the relevant regulation, On the right to use the Conformity Identification Seal on products, process, services and systems regulated by Inmetro. According to Ordinance No. 179/2009, the use of the Seal is restricted to objects that have been evaluated based on Conformity Assessment Programs implemented by Inmetro. For certified product that can be registered, according to Resolution Conmetro nº 05/2008, the authorization for the use of the Conformity Identification Seal shall be granted in the form and in the cases provided for in this Resolution, which authorizes conditional on the existence of the Certificate of Conformity, the use of the Conformity Identification Seal and marketing the product.
(INMETRO)

Certification Process

So that the manufacturer can guarantee the certification of Inmetro, It needs to meet some requirements.

INMETRO Ordinance No. 445/2010 and its annex: Regulation of Conformity Assessment of steel wheels for automobiles, mixed-use vehicles or their loads, Mixed-use vans and their trailers, demountable wheel rims and steel and aluminum for cargo trucks, trucks, tractor-trucks, bus, micro bus and its aluminum alloy wheels and wheels for automobiles, light commercials and SUVs

Conformity assessment mechanism

Certification Models:

Evaluation and Approval of the Quality Management System of the Manufacturer and tests on the product.
(INMETRO)

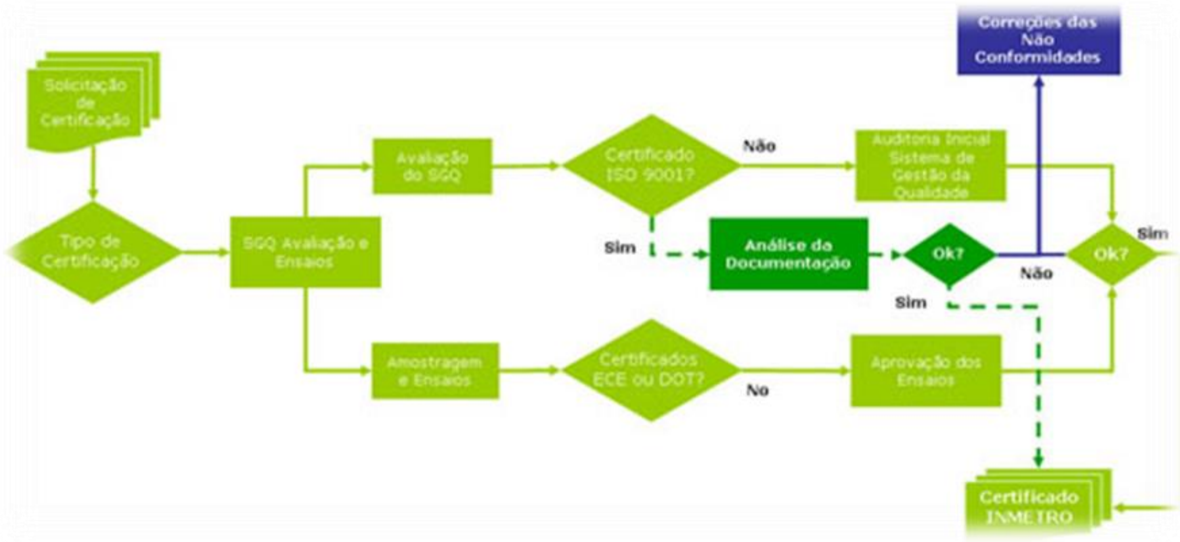


Figure 13. Certification Model, source: INMETRO

Evaluation and Approval of the Quality Management System of the Manufacturer and tests on the product

Certification Request

- Presentation of the documentation of the Quality Management System.
- Analysis of the documentation submitted.
- Correction of non-compliance found in the documentation (if applicable)
- *NOTE: The existence of ISO9001 Certificate, for the aforementioned scope, exempts the presentation of documentation.*

Type tests

The tests shall be carried out in accordance with the following standards:

- ABNT NBR 6750:2009
- Wheels for cars - Check for durability and strength.
- ABNT NBR 6751:2009
- Wheels and rims for trucks, buses and the like - check for durability and resistance.
- ABNT NBR 6752:2009
- Aluminum alloy wheels for cars, light commercials and SUVs - Performance verification tests.
- ABNT NBR 6608:2009

Type tests – Sampling

Tests	Item	Sampling		
		Proof	Counterproof	Witness
Rotary disc fatigue	4.1.1	3	3	3
Fatigue under radial load	4.1.2	2	2	2

Surface workmanship (resistance and other characteristics)	6.1	1	1	1
Surface workmanship (adhesion)	6.3.1	1	1	1
Surface workmanship (resistance in saline mist)	6.3.2	1	1	1
Surface workmanship (wet chamber resistance)	6.3.3	1	1	1

Table 1. ABNT NBR 6750, source: ABNT

The surface workmanship endurance test shall be performed for each type of finish, Regardless of automotive wheels families.

(IQA, Instituto de Qualidade Automotiva)

Production Tools

The production tools that are discussed in this article are intended to avoid errors, product failures, Delays in the production lines and to ensure the good quality of the final product

11.2. ATTACHMENT B – PROCESS FMEA

Process FMEA

Process FMEA - Failure Mode Effects Analysis																
PRODUCT: Steel wheel					RESPONSIBLE: Flavio Rebello						FMEA N º: 0001					
SECTOR: Production					DATE: 01/11/2016						REVIEW: 00					
Process Steps		Potential Failure Mode	Potential Failure Effect	SEV	Potential Cause of Failure	OCC	Current process control	DET	NPR	Recommended Preventive Action	Responsibility and Target Completion Date	Action Recommended	SEV	OCC	DET	NPR
CP 1	Steel Plate Cutting	Slag on plate.	Disapprove of the plate, necessary rework.	5	Defect in guillotine blade	7	Visual and manual analysis	3	105	No action. (Operators are already trained and qualified to carry out the operation).						
		Incomplete cutting of plate.	Disapprove of the plate, necessary rework.	5	Defect in guillotine blade	7	Visual and manual analysis	3	105	No action (Operators are already trained and qualified to carry out the operation).						
CP 2	Conformation of the Rim	Lack of parallelism in conformation	Disapprove of the plate, Disposal of materiall.	8	Lack of attention (operator orientation).	5	Visual analysis.	2	80	No action.						
		Lack of parallelism in conformation.	Disapprove of the plate, Disposal of materiall.	8	Lack of attention (operator orientation).	5	Visual analysis.	2	80	No action.						
CP 3	Flash Butt Welding	Excess welding on the rim.	Disapprove of the piece, needing rework.	2	Incorrect machine setting parameters.	5	Visual and manual analysisl.	2	20	No action. (When the problem is detected, separate pieces and perform necessary rework).						
		misalignment.	Disapprove of the piece, Disposal of materiall.	4	lack of attention (operator orientation).	3	Visual and manual analysis.	3	36	No action.						
CP 4	Trimming Welding Slag	Welding slag not completely removed.	Disapprove of the piece, needing rework.	3	Tool sharpening has no compensation for height	5	Visual and manual analysis.	2	30	No action. (When the problem is detected, separate pieces and perform necessary rework).						
		scratch on plate.	Disapprove of the piece, needing rework.	5	lack of attention (operator orientation).	5	Current process control	3	75	No action. (When the problem is detected, separate pieces and perform necessary rework).						
CP 5	Planishing Welding Seam	Weld splash.	Disapprove of the piece, needing rework.	4	lack of attention (operator orientation).	5	Visual and manual analysis.	2	40	No action. (When the problem is detected, separate pieces and perform necessary rework).						
		Sheet deformation.	Disapprove of the plate, Disposal of materiall.	6	lack of attention (operator orientation).	3	Visual and manual analysis.	3	54	No Action						
CP 6	Cooling	Coolant liquid with inadequate viscosity.	incomplete cooling.	4	Non-standard chemical composition	5	Visual analysis	2	40	No Action.						
		Crack in the piece	Non-standard temperature.	3	operation failure.	6	Visual analysis.	1	18	No action. (When the problem is detected, separate pieces and perform necessary rework).						

CP 7	**Re-rounding**	Decentralized piece.	Disapprove of the piece, Disposal of materiall.	**8**	lack of attention (operator orientation).	**7**	Visual and manual analysis.	**2**	**112**	No action.						
		Deformation in the rim.	Disapprove of the piece, needing rework.	**6**	Machine with non-standard setting.	**3**	Visual analysis.	**2**	**36**	No action. (When the problem is detected, separate pieces and perform necessary rework).						
CP 8	**1st Roll Forming**	Non-standard Roll Forming.	Disapprove of the piece, needing rework.	**5**	Lack of attention (operator orientation).	**5**	Visual analysis.	**2**	**50**	No action.						
CP 9	**2nd Roll Forming**	Hole in piece.	Disapprove of the piece, needing rework.	**5**	Lack of attention (operator orientation).	**3**	Visual and manual analysis.	**2**	**30**	No action. (When the problem is detected, separate pieces and perform necessary rework).						
CP 10	**3rd Roll Forming**	Piece ovalization.	Disapprove of the piece, Disposal of materiall.	**5**	Lack of attention (operator orientation).	**5**	Visual analysis.	**2**	**50**	No action.						
CP 11	**Edge Flanging**	tear on the edge.	Disapprove of the piece, Disposal of materiall.	**5**	Defect in flanging machine	**5**	Visual analysis.	**3**	**75**	No action.						
		Non-standard flaging.	Disapprove of the piece, needing rework.	**4**	Lack of attention (operator orientation).	**5**	Visual and manual analysis.	**2**	**40**	No action.						
CP 12	**Valve Role Punching**	Hole out of position.	Disapprove of the piece, Disposal of materiall.	**6**	Lack of attention (operator orientation).	**6**	Visual analysis.	**3**	**108**	No action. (When the problem is detected, separate pieces and perform necessary rework).						
		Slag in the valve hole.	Disapprove of the piece, needing rework.	**4**	Lack of attention (operator orientation).	**5**	Visual and manual analysis.	**2**	**40**	No action. (When the problem is detected, separate pieces and perform necessary rework).						
CP 13	**Steel Plate Cutting**	Incomplete cutting of plate.	Disapprove of the plate, necessary rework.	**4**	Defect in guillotine blade	**7**	Visual analysis.	**2**	**56**	No action. (When the problem is detected, separate pieces and perform necessary rework).						
		Slag on plate.	Disapprove of the plate, necessary rework.	**5**	Lack of attention (operator orientation).	**7**	Visual and manual analysis.	**2**	**70**	No action. (When the problem is detected, separate pieces and perform necessary rework).						
CP 14	**Application of the Stamping Oil**	Excess of stamping oil.	Disapprove of the piece, necessary rework.	**3**	Lack of attention (operator orientation).	**5**	Visual analysis.	**2**	**30**	No action.						
		Improper stamping oil.	Disapprove of the piece, necessary rework.	**4**	Lack of attention (operator orientation).	**5**	Visual analysis.	**2**	**40**	No action.						
CP 15	**Pre-Stamping**	Worn stamping die.	Non-standard stamped piece.	**7**	Lack of attention (operator orientation).	**4**	Visual and manual analysis.	**3**	**84**	No action. (When the problem is detected, separate pieces and perform necessary rework).						
		inadequate centralization.	Disapprove of the piece, necessary rework.	**3**	Lack of attention (operator orientation).	**5**	Visual and manual analysis.	**2**	**30**	No action.						
CP 16	**Stamping**	inadequate centralization.	Disapprove of the piece, necessary rework.	**4**	Lack of attention (operator orientation).	**5**	Visual and manual analysis.	**2**	**40**	No action. (When the problem is detected, separate pieces and perform necessary rework).						
		Worn stamping die.	Non-standard stamped piece.	**6**	Lack of attention (operator orientation).	**5**	Visual and manual analysis.	**2**	**60**	No action. (When the problem is detected, separate pieces and perform necessary rework).						

CP 17	Drilling	Inaccurate drilling.	Disapprove of the piece, Disposal of materiall.	6	Lack of attention (operator orientation).	6	Visual and manual analysis.	2	72	No action.						
		Defects in cutting tool.	Disapprove of the piece, Disposal of materiall.	5	Lack of attention (operator orientation).	5	Visual and manual analysis.	2	50	No action. (When the problem is detected, separate pieces and perform necessary rework).						
CP 18	Pressing Disc into Rim	Deformation in the rim.	Disapprove of the piece, Disposal of materiall.	6	Lack of attention (operator orientation).	7	Visual analysis.	2	84	No action.						
		Non-standard disk diameter.	Disapprove of the piece, necessary rework.	5	Lack of attention (operator orientation).	5	Visual and manual analysis.	2	50	No action. (When the problem is detected, separate pieces and perform necessary rework).						
CP 19	Mig-Mag Welding Among Rim and Disc	Weld splash.	Disapprove of the piece, necessary rework.	4	Lack of attention (operator orientation).	6	Visual analysis.	2	48	No action. (When the problem is detected, separate pieces and perform necessary rework).						
		Excess deposition in the piece.	Disapprove of the piece, necessary rework.	3	Lack of attention (operator orientation).	5	Visual analysis.	2	30	No action.						
CP 20	Degrease	Crack in the piece	Disapprove of the piece, Disposal of materiall.	5	Lack of attention (operator orientation).	6	Visual and manual analysis.	2	60	No action. (When the problem is detected, separate pieces and perform necessary rework).						
		Excess of oil in the piece.	Disapprove of the piece, necessary rework.	5	Lack of attention (operator orientation).	5	Visual and manual analysis.	2	50	No action.						
CP 21	Eletrostatic Coating Process	Lack of adherence of phosphate.	Disapprove of the piece, necessary rework.	6	Lack of attention (operator orientation).	5	Visual and manual analysis.	2	60	No action.						
		Faulty paint.	Disapprove of the piece, necessary rework.	4	Lack of attention (operator orientation).	5	Visual and manual analysis.	2	40	No action.						
CP 22	Stove	Inappropriate time in stove.	Disapprove of the piece, necessary rework.	6	Lack of attention (operator orientation).	6	Visual analysis.	2	72	No action.						
		Inadequate stove temperature.	Disapprove of the piece, necessary rework.	4	Lack of attention (operator orientation).	5	Visual analysis.	2	40	No action.						
CP 23	Packing	Lack of packaging components.	delivery delay.	4	Lack of attention (operator orientation).	4	Visual and manual analysis.	2	32	No action.						
		Damaged package.	delivery delay.	4	Lack of attention (operator orientation).	4	Visual and manual analysis.	2	32	No action.						

Figure 14. Process FMEA

11.3. ATTACHMENT C – CONTROL PLAN

Rim Control Plan

	Verification	Defects	Equipment used	Frequency of measurement
Stage 1 Guillotine - Steel plate cutting				
Preview				
1.1	Plate out of square	Plates out of perimeter	Check if the plates are being cut correctly through the visual analysis with square	1 each 10 pieces manufactured
		Corrugated plates		
1.2	Slag	Follow the cutting procedure	Visual and manual analysis	1 each 10 pieces manufactured
		Piece with excess material		
Stage 2 Lamination process - Conformation of the rim				
Preview				
1.1	Plate lamination process	Check cracks and defects in the plate	visual analysis	1 each 10 pieces manufactured
		Pieces with lamination out of the required thickness		
1.2	Lack of parallelism	1 each 10 welded pieces	visual analysis	1 each 10 pieces manufactured
		Non-parallel pieces with curled edges		
Stage 3 Flash Butt Welding process				
Preview				
1.1	Check if the union has been welded correctly	Check for weld irregularity after the welding process	Visual analysis by the operator	1 each 10 pieces manufactured
		Check welded points and check cracks in weld		
1.2	Check excess weld on peace	Check for welding at joints that are already welded.	Visual and manual analysis by the operator	1 each 10 pieces manufactured
		Insufficient solder deposition on the site to be welded		
Stage 4 Trimming Machine				
Preview				
1.1	Check for excess slag caused by welding	Check excess slag on the peace that has been welded	Make a visual analysis so that the burr can be removed.	1 each 10 pieces manufactured
		Check for cracks in welds		
1.2	Check all slags in the part	Check the excess slag in the part	Visual and manual analysis	1 each 10 pieces manufactured
		Remove excess slag that was caused by welding		

Stage 5 Planishing welding seam				
Preview				
	Verification	Defects	Equipment used	Frequency of measurement
1.1	Check for excessive welding	Visual analysis where the welding will be polished	Visual analysis	1 each 10 pieces manufactured
		Check for welding after polishing in the chips		
1.2	Splash check on the rim	Check Splash Defects	Polishing done by the operator with Industrial sander on the weld of the part	1 each 10 pieces manufactured
		Inspect if polishing did not cause damage to piece		

Stage 6 Cooling				
Preview				
	Verification	Defects	Equipment used	Frequency of measurement
1.1	Rim with polished solder	Dip the piece into a tank with water	Work done by the operator manually	1 each 10 pieces manufactured
		Check for cracks or defects on the weld		
1.2	Cooling and polishing verification	Check if the part has not been scratched or damaged by polishing	Work performed by an operator that verifies that the piece is already in perfect condition	1 each 10 pieces manufactured
		Check if the polishing was done in the correct place without causing damage to the part		

Stage 7 Re-rounding				
Preview				
	Verification	Defects	Equipment used	Frequency of measurement
1.1	Checking the wheel diameter	Check if the piece is in the proper diameter	Work done by the operator manually and by visual analysis	1 each 10 pieces manufactured
		Wheel with smaller diameter and having a defect that could damage the diameter		
1.2	Wheel check with ovalisation and cleaning	Check if the wheel is oval and out of specification	Work done by an operator that checks if the part is oval, and then go through the machine to re-round	1 each 10 pieces manufactured
		Check that the rim is with some excess material that is causing the ovalization		

Stage 8 1st Roll forming				
Preview				
	Verification	Defects	Equipment used	Frequency of measurement
1.1	Symmetry check	Check if there is a piece out of symmetry and with a suitable size of the rim	Work done by the operator manually and by visual analysis	1 each 10 pieces manufactured
		Roll forming out of the specified		
1.2	Verification of pieces without symmetry	Check if there is a piece out of symmetry and with a suitable size of the rim	Work done by an operator that checks if the part is symmetrical	1 each 10 pieces manufactured
		Profiling out of the specified		

Stage 9 2nd Roll forming				
Preview				
	Verification	Defects	Equipment used	Frequency of measurement
1.1	Symmetry check	Check if there is a piece out of symmetry and with a suitable size of the rim	Work done by the operator manually and by visual analysis	1 each 10 pieces manufactured
		Roll forming out of the specified		
1.2	Verification of pieces without symmetry	Check if there is a piece out of symmetry and with a suitable size of the rim	Work done by an operator that checks if the part is symmetrical	1 each 10 pieces manufactured
		Profiling out of the specified		

Stage 10 3rd Roll forming				
Preview				
	Verification	Defects	Equipment used	Frequency of measurement
1.1	Symmetry check	Check if there is a piece out of symmetry and with a suitable size of the rim	Work done by the operator manually and by visual analysis	1 each 10 pieces manufactured
		Roll forming out of the specified		
1.2	Verificação de peça sem simetria	Check if there is a piece out of symmetry and with a suitable size of the rim	Work done by an operator that checks if the part is symmetrical	1 each 10 pieces manufactured
		Profiling out of the specified		

Stage 11 Lamination Process - Edge flanging				
Preview				
	Verification	Defects	Equipment used	Frequency of measurement
1.1	Checking Edge Expansion	Check if the expansion is overflowing Out-of-specification and out-of-size expansion	Work done by the operator manually and by visual analysis	1 each 10 pieces manufactured
1.2	Piece verification without proper edge expansion	Piece with expansion defects on its edge Excessive expansion piece at the edge	Work done by an operator who checks if the piece is in the correct expansion through caliper	1 each 10 pieces manufactured
Stage 12 Valve role punching				
Preview				
	Verification	Defects	Equipment used	Frequency of measurement
1.1	Hole check on the rim	Piece with hole outside diameter Hole with oval surface	Work done by the operator manually and by visual analysis	1 each 10 pieces manufactured
1.2	Check if the hole is in a marked location	Drill in an improper place and without the correct thickness Cracked piece after the hole	Work done by an operator checking if the piece is with the hole in its proper location	1 each 10 pieces manufactured

Figure 15. Rim Control Plan

Disc Control Plan

Stage 13 Guillotine - Steel plate cutting				
	Verification	Defects	Equipment used	Frequency of measurement
1.1	Cut to disc process	Check plate thickness Check if the part is free of undulations	Guillotine type machine	1 each 10 pieces manufactured
1.2	Verificar procedimentos de corte das peças	Seguir o procedimento de corte Verificar o alinhamento da chapa	Visual analysis	1 each 10 pieces manufactured
Stage 14 Application of the stamping oil				
	Verification	Defects	Equipment used	Frequency of measurement
1.1	Disc Stamping Process	Check for cracks, slags and defects caused by welding Check if the part is not distorted in its dimensioning	Ultrasound	1 each 10 pieces manufactured
1.2	Analysis of disc molds	Check if the staamp was successful Molds out of specification and unsuitable	Operational analysis by the operador	1 each 10 pieces manufactured
Stage 15 Pre-stamping				
	Verification	Defects	Equipment used	Frequency of measurement
1.1	Permanent stamping	Check if the plate is free of cracks Check stamping irregularity	Surface visual analysis	1 each 10 pieces manufactured
1.2	Disc Stamping Process	Check if the stamping does not show cracks Check if the stamp has a distortion defect	Controlled by visual analysis	1 each 10 pieces manufactured

	Verification	Defects	Equipment used	Frequency of measurement
Stage 16 Stamping				
1.1	Disc without proper stamping	Check if the stamping has folds in the plate Check if the stamping has clacks in the plate	Stamping Machine	1 each 10 pieces manufactured
1.2	Non-standard stamping	Check if the stamping has rips Check the side thicknesses of the part	Visual analysis	1 each 10 pieces manufactured
Stage 17 Drilling				
1.1	Piece with smaller diameter hole	Check if the part has any restrictions that deforms drilling Check if the piece shows any crack that may damage the hole and the piece	Drilling Machine	1 each 10 pieces manufactured
1.2	Drilling off marking	check if the location is marked and does not show any change Check if the hole is too short or too wide	Drilling Machine and visual analysis	1 each 10 pieces manufactured

Figure 16. Disc Control Plan

Wheel finalization Control Plan

	Verification	Defects	Equipment used	Frequency of measurement
Stage 18 Pressing disc into rim				
1.1	Pressing disc into rim	Check the fitting of the two parts make sure there is no leftovers or slags in the piece	Visual and manual analysis	1 each 10 pieces manufactured
1.2	One of the pieces is out of diameter	Check if the disc or the rim is out of diameter Inspect the workings of the pieces before the welding process	Handwork	1 each 10 pieces manufactured
Stage 19 Mig-Mag Welding among ring and disc				
1.1	Welding process between rim and disc	Check for cracks, slags and defects caused by welding Inspect for excess weld present around the rim	Visual and computer analysis	1 each 10 pieces manufactured
1.2	Weld analysis process	Check for lack of weld penetration into material Check for uneven weld edges near material	Analysis through computers	1 each 10 pieces manufactured

Stage 20 Degrease				
	Verification	Defects	Equipment used	Frequency of measurement
1.1	Removal of oil or grease from piece	Check for excess oil in the piece Check if the oil or grease has been removed without damaging the piece	Removal by the operator in a chemical tank	1 each 10 pieces manufactured
1.2	Removal of oil or grease from piece	Inspect for excess grease, oil or any material that may cause damage to the product Check if the oil or grease has been removed without damaging the piece	Removal by the operator in a chemical tank	1 each 10 pieces manufactured

Stage 21 Eletrostatic coating process				
	Verification	Defects	Equipment used	Frequency of measurement
1.1	Eletrostatic coating chemical process	Check for lack of electrostatic powder in the piece Check for excess of electrostatic powder in the piece	Visual and manual analysis	1 each 10 pieces manufactured
1.2	Adhesion of powder on the pieces	Check if the part has been completely filled with dust Piece that has little electrostatic powder	Visual and manual analysis	1 each 10 pieces manufactured

Stage 22 Stove				
	Verification	Defects	Equipment used	Frequency of measurement
1.1	Paint with chemical powder	Check if the piece covers full range of painting and drying piece with defect of the electrostatic dust absorption	Visual and manual analysis	1 each 10 pieces manufactured
1.2	Piece that does not adhere to the electrostatic powder	Piece without uniformity in painting Piece with little electrostatic powder and low absorption	Visual and manual operator analysis	1 each 10 pieces manufactured

Stage 23 packing				
	Verification	Defects	Equipment used	Frequency of measurement
1.1	Packaging (box)	Verification of final product for packaging Check the box dimensions (diameter, thickness, and deformation capacity)	Analysis done in laboratory, specialized technician	1 each 10 pieces manufactured
1.2	Packaging without suitable conditions already with the final product	Check if the package does not cause damage to the product Analyze the situation that the finished product is going to be transported	Visual and manual analysis	1 each 10 pieces manufactured

Figure 17. Wheel finalization Control Plan

11.4. ATTACHMENT D – LAYOUT OF THE PRODUCTION LINE

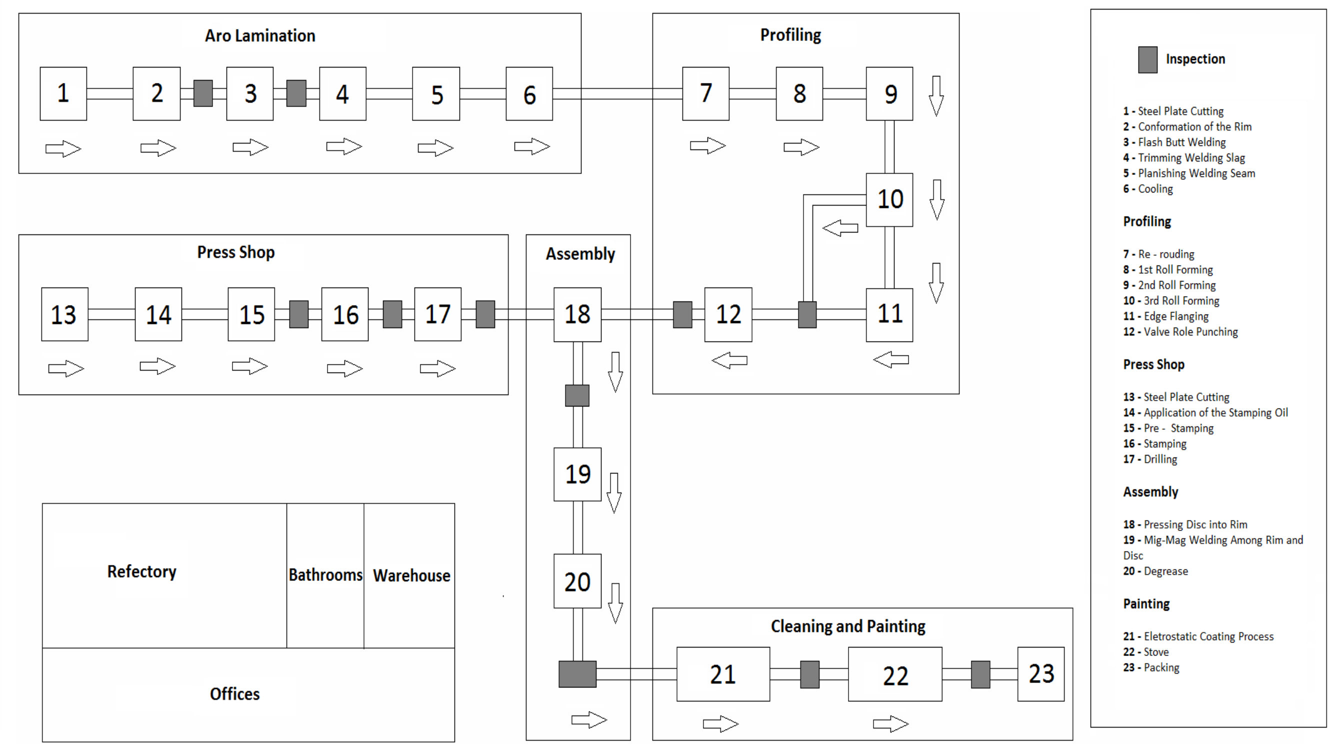
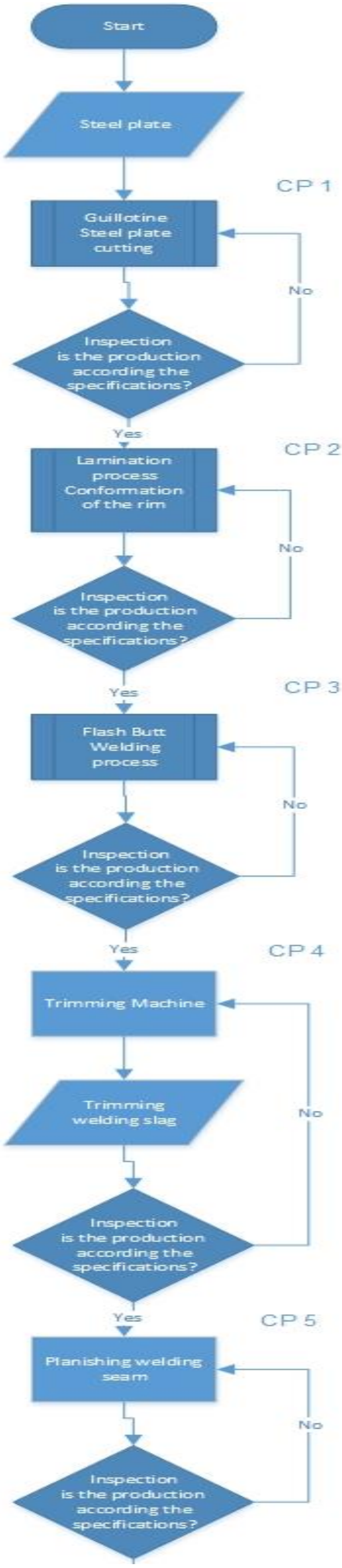
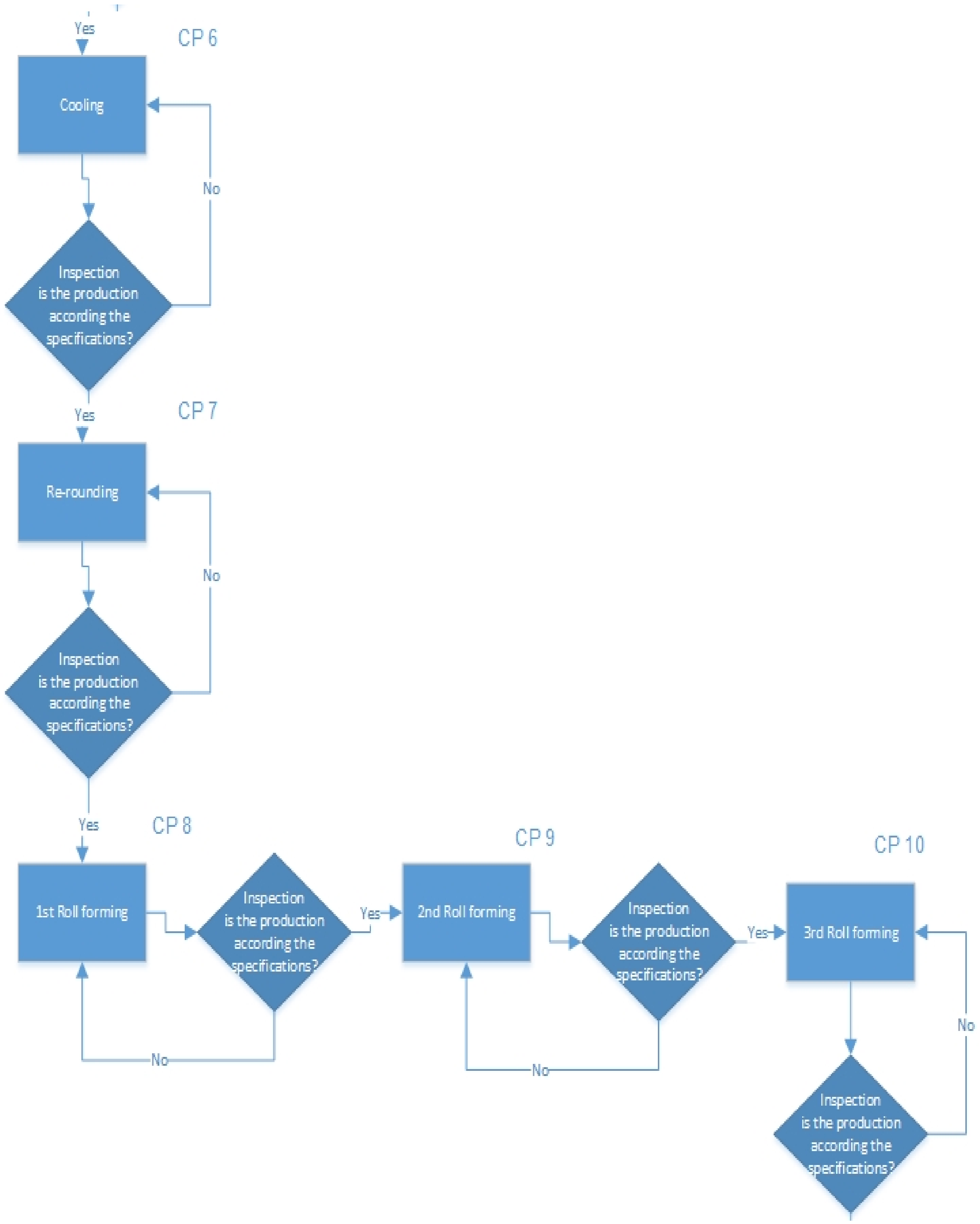


Figure 18. Layout of production line

11.5. ATTACHMENT E – PROCESS FLOWCHART


Start
Steel plate
CP 1
Guillotine Steel plate cutting
No
Inspection is the production according the specifications?
Yes
CP 2
Lamination process Conformation of the rim
No
Inspection is the production according the specifications?
Yes
CP 3
Flash Butt Welding process
No
Inspection is the production according the specifications?
Yes
CP 4
Trimming Machine
Trimming welding slag
No
Inspection is the production according the specifications?
Yes
CP 5
Planishing welding seam
No
Inspection is the production according the specifications?


Yes
CP 6
Cooling
No
Inspection is the production according the specifications?
Yes
CP 7
Re-rounding
No
Inspection is the production according the specifications?
Yes
CP 8
1st Roll forming
Inspection is the production according the specifications?
No
Yes
CP 9
2nd Roll forming
Inspection is the production according the specifications?
No
Yes
CP 10
3rd Roll forming
No
Inspection is the production according the specifications?

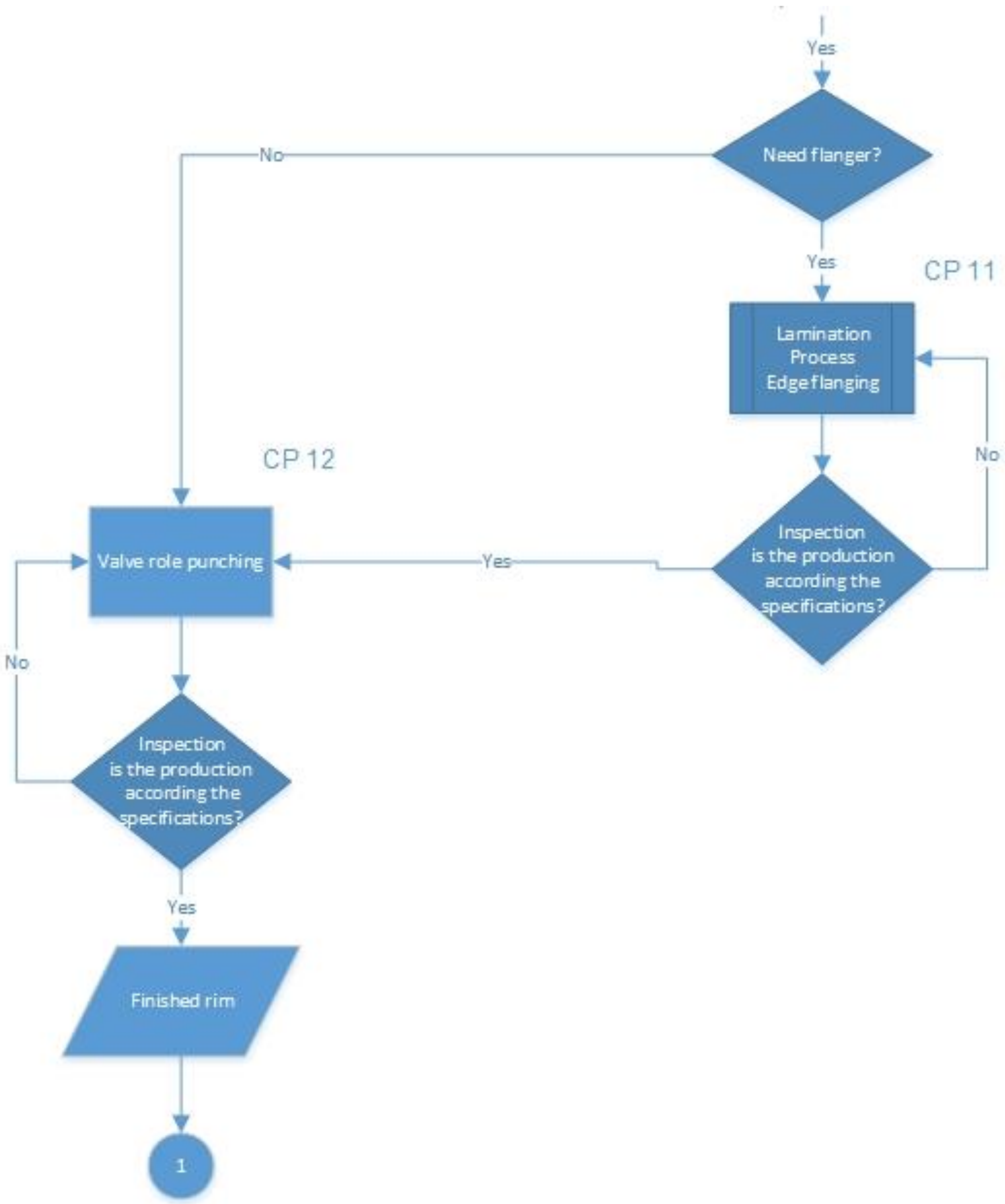


Figure 19. Rim Flowchart

Disc flowchart

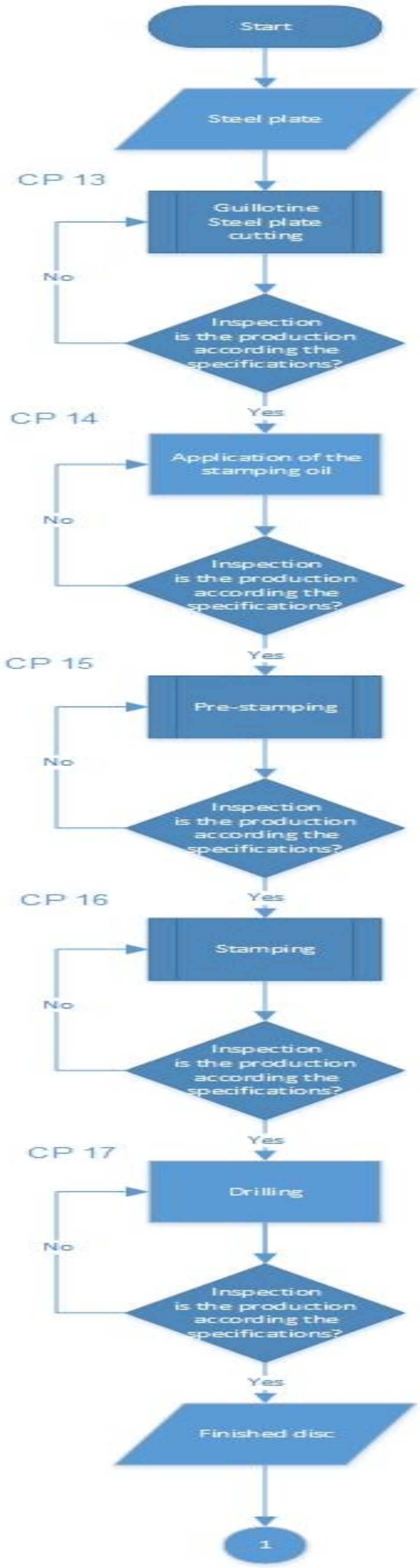
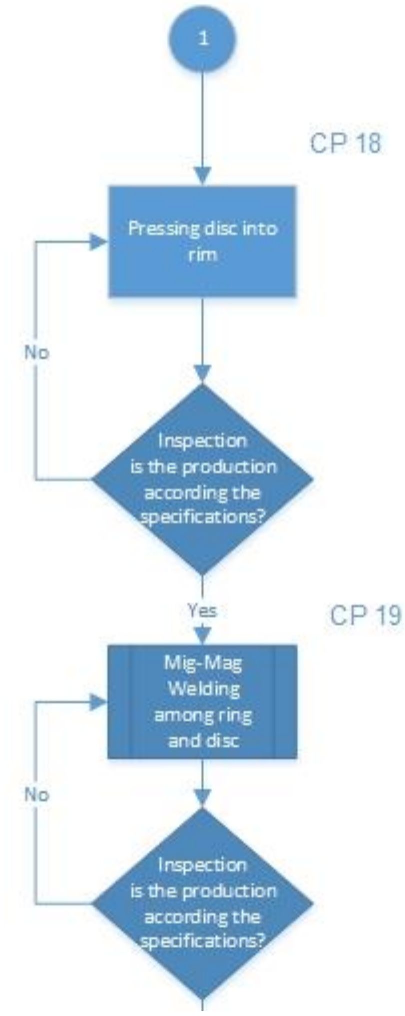


Figure 20. Disc flowchart

Whell Finalization Flowchart



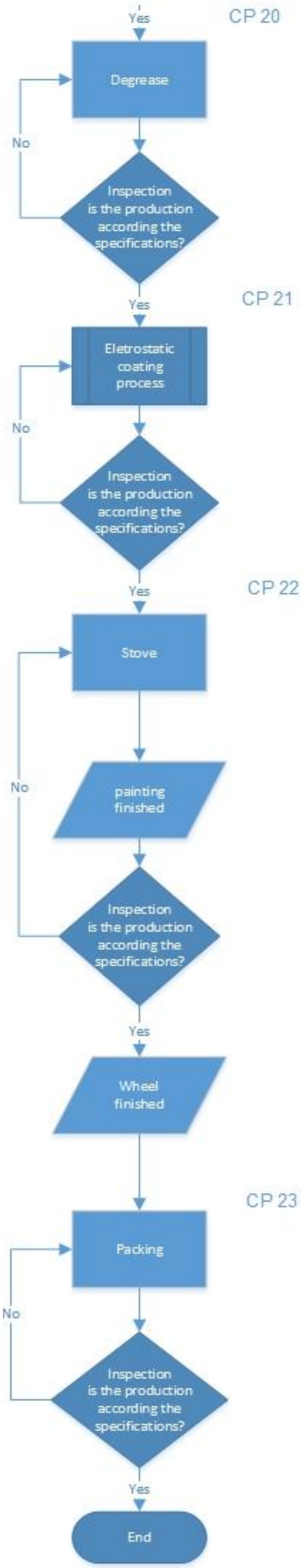

Yes
CP 20
Degrease
No
Inspection
is the production
according the
specifications?
Yes
CP 21
Eletrostatic
coating
process
No
Inspection
is the production
according the
specifications?
Yes
CP 22
Stove
No
painting
finished
Inspection
is the production
according the
specifications?
Yes
Wheel
finished
CP 23
Packing
No
Inspection
is the production
according the
specifications?
Yes
End

Figure 21. Wheel finalization flowchart

11.7. ATTACHMENT F – EQUIPMENT AND TOOLING

TOOLS AND RELATED COSTS	Acceptable	Not acceptable
Accessories or Accessories and Perishable Items – Many manufacturing processes require special drill bits; Cutters; Welding Cables; Electrical cable covers or welding cables; Resistances; Etc, Which are extremely important to be replenished. Must pay only the initial complement of these items, which usually means the set in use and another to be replaced.	x	
design services – Tools – Acceptable when included in the price of the part, do not include the cost of the product design or capital equipment	x	
Freights – Limited to the normal expenses initially required to get the built tooling. The freight cost for additional travel due to repairs or recurring tooling adjustments is non-refundable. It does not include the cost of equipment, machines, Even if the tooling is mounted on such equipment	x	
Financial Costs – These costs are not accepted because it deals with indirect cost of the supplier. Interest is only acceptable when the tooling is paid, In periodic transactions previously negotiated.		x
Launch costs – These costs must be included in the indirect cost of the supplier. The cost relative to the learning curve of the manufacturing process is not considered a tooling expense.		x
Installation Costs – Mounting and tooling adjustment costs. These costs are generally considered to be acceptable for the initial installation only when referring to the subcontracted tooling. These expenses, If attributed to authorized engineering modifications are acceptable. The costs in turn associated with these items must be incremental to the costs recovered in the price of the part And must be fully documented, based on the hours spent for each function performed. A general percentage of mark - up applied to tools purchased from third parties will not be admitted. These costs should be excluded from the cost of adapting machinery, Equipment or installations or in the layout of factories, which must be recovered only in the price of the piece..	x	

Table 2. Tooling and costs, source: Volkswagem, Montadora de Veículos, 2016

MATRICES	Acceptable	Not Acceptable
Air Cylinders Inside the devices Out the devices	x	x
Automation		
Inside the stamp Other out the stamp Support Plates	x	x
Design – Directly related to the matrix and its details	x	
Development resins – Resin models	x	
standard models – Acceptable when not provided by the developer company and provided that they are designed and designed by the developer company when the CAD project is not considered as standard (master)	x	
Lifting plates – Only when they are an integral part of the matrix	x	
Coining matrix	x	
Cold forming molds	x	
Compaction dies – For piece of sintered material before the sintering process.	x	
Extrusion Dies	x	
Forging matrices	x	
Progressive matrices	x	
Format Matrices – For pieces of sintered material before the sintering process	x	
Stamping die – Including blank, embossing, forming, cutting, boring, folding, and their combinations	x	
Straightening matrices	x	
Transfer matrices	x	
Resins for copiers molds	x	
Prototypes – For tool development support – Only when used for reproductions in Mylar – When required to assist in the development of tooling – Only used to build the production tooling, With proof of costs and absence of additional specific request.	x	
Sheets used in tests – Material used to try – Out of the tool.	x	

Table 3. Matrices, sources: Volkswagem, Montadora de Veículos, 2016

Electrical components of lashings - Components, Assemblies and tests	Acceptabl	Not accept
Matrices and details – Required for Terminals, Closing / application matrices, Wire frame, Bars, conductors, supports, terminais, progressive stamping, etc.	x	
Devices – check, greasing, continuous block devices.	x	
Calibrators (when this is project and design of the company)	x	
Grease application equipment		x
Injection Molds – For connectors, wire guards, junction blocks, power plant boxes, etc.	x	
Handling devices – Which "hold" the components during manual or automated assembly operations, when specific to the company's producers.	x	
Testing equipment - analyzers, indicators, gauges, TSK table, test and assembly tables, etc.		x

Table 4. Components required for terminals. source: Volkswagem, Montadora de Veículos, 2016

Designs – Only cost of device drawings. Excludes design cost of equipment required due to integration of devices into a specific line of operation.	x	
Drilling Plates	x	
Devices – All specially designed.	x	
Stamping tools – Only the first complement.	x	
Standard Curve Axis – Contours, axis and cams.	x	
Checking Gears – Only the first complement.	x	
Lapping of Gears – Only the first complement.	x	
Gears Reference – Only the first complement.	x	
Emery wheel – only when the part configuration requires special design.	x	
Hand tools – Acceptable when designed for a specific purpose.		x
Head Tools – Only the first complement.	x	
Thermal Treatment Protectors		

Table 5. Tooling items, source: Volkswagem, Montadora de Veículos, 2016

Molds and Models	Acceptable	Not Acceptable
Design – Directly related to molds and models.	X	
Molding Resins – Resin models.	x	
Resins for Copier Models	x	
Mold - foundry	x	
Molds - For rubber, plastics, non-ferrous metals.	x	
Mold Models	x	
Casting Models	x	

Table 6. Molds and models, source: Volkswagem, Montadora de Veículos, 2016

Welding and assembly devices	Acceptable	Not Acceptable
Air Cylinders	x	
Hydraulic and pneumatic items • Inside the devices • Out the devices	x	x
Automated Solder Mounting Equipment – Some typical items in an assembly and welding system that are considered vendor equipment and not tooling are "cages", landscapes, mats and butchers, control panels, structure, etc.		x
Automation • Inside the devices • Out the devices (Example: material transfer lines, articulated arms, material handling equipment, material transfer equipment)	x	x
Armatures, Cabins and Welding Tables		x
Corrosion Application Devices	x	
Design – only device design – care should be taken to exclude projections facilities, Due to the integration of the devices into a specific line of operation at the supplier's premises	x	
Handheld Devices		x

Table 7. Welding Devices, source: Volkswagem, Montadora de Veículos, 2016

Mold tooling for wheel disc manufacturing

Series of automatic stamping lines

Light weight, high strength and an attractive appearance have become the basic requirements for choosing passenger car wheels. High strength plates are also become popular materials for steel wheels. In order to accommodate fast and large scale production of automatic and efficient wheel disc production lines, manufacturers have higher requirements for the standardized production and the service life of the dies

(LittleDuck, wheelmachinery, 2016)

Blanking-punching Coumpound Die

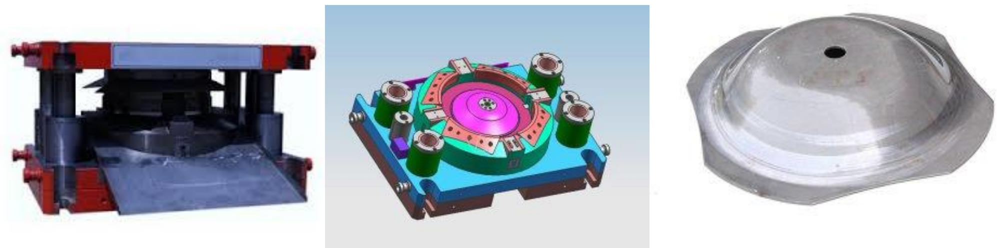


Figure 22. Compound mold, source: LittleDuck

Forming Die

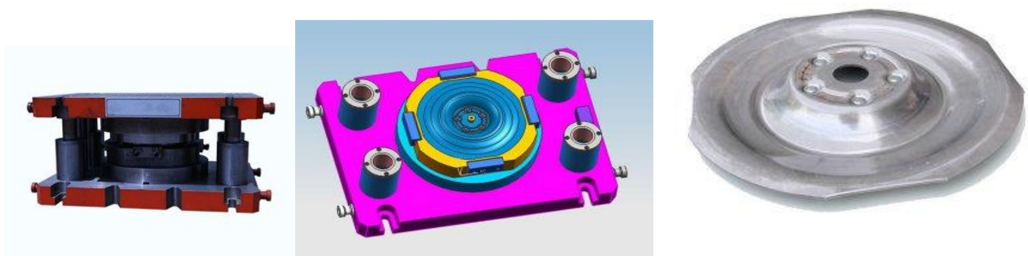


Figure 23. Forming mold, source: LittleDuck

Trimming and Punching Die

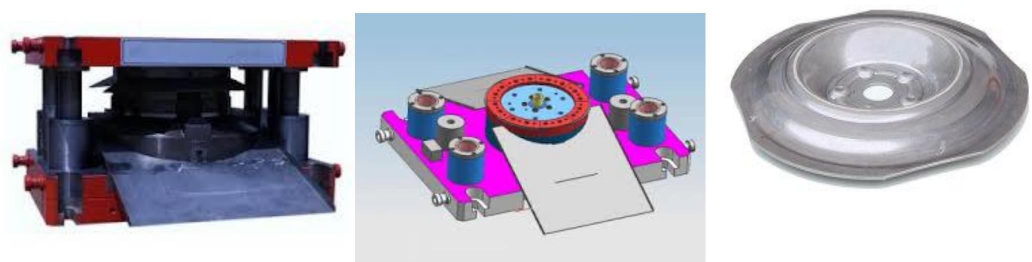


Figure 24: Drilling mold, source: LittleDuck

Flanging Die

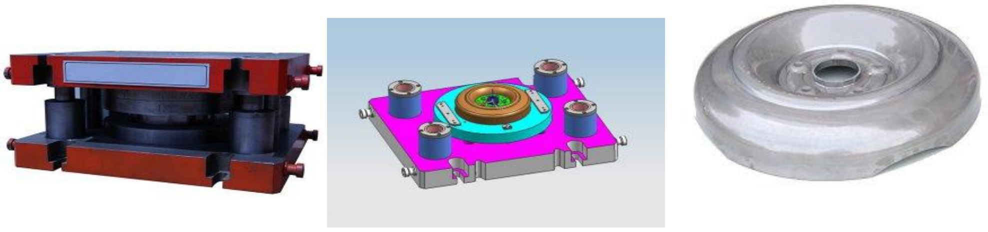


Figure 25. Flanging die, source: LittleDuck

Piercing Die

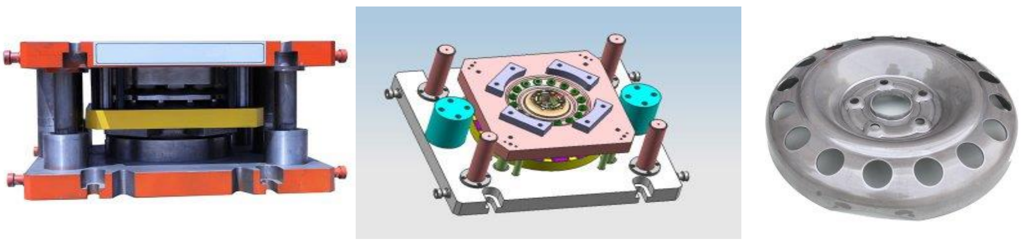


Figure 26: Piercing die, source: LittleDuck

Vent Hole Deburring Tool

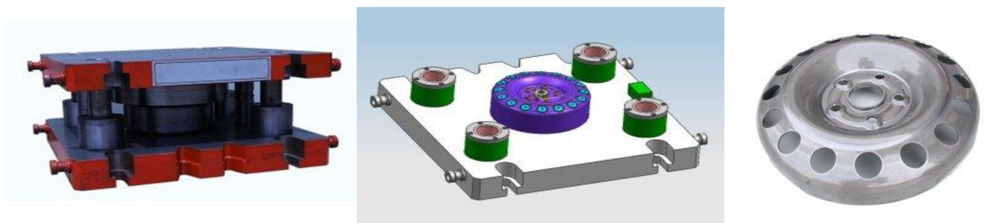


Figure 27: Vent hole deburring tool, source: LittleDuck

Bolt Hole Deburring Tool

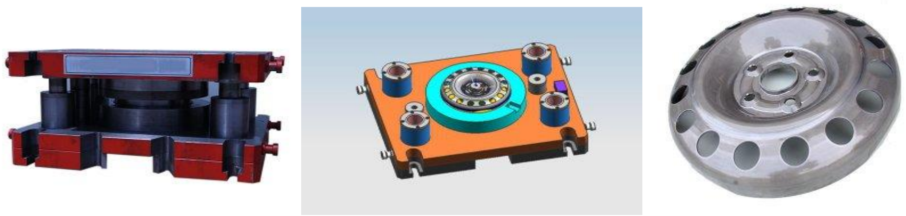


Figure 28. Bolt hole deburring tool, source: LittleDuck

Stone Alone Series

To meet the requirements of traditional wheel disc production lines for standalone operation, we conduct specifc process design.
(LittleDuck, wheelmachinery, 2016)



Air hole punching die   Screw hole punching die   Forming die



Profiling Die   Compound punching die   Pressing die

Figure 29. Stone alone series, source: LittleDuck

Tooling for Tubeless Wheel Rim Manufacturing


Roll forming die I   Roll forming die II   Flaring die

Figura 30. Roll forming dies, source: LittleDuck

The core of the flaring die goes through an NC finish machining after vacuum thermal treatment, wich ensures the hardenability and dimensional accuracy

(LittleDuck, wheelmachinery, 2016)

Espandig Tools

Figure 31: Espanding Tools, source: LittleDuck

Tooling for Structural Steel Wheel Rims Manufacturing

Espanding tool Shrinking die Check ring finishing die

Figure 32. Tooling for Structural Steel Wheel Rims Manufacturing, source LittleDuck

Roll Forming Machine

The Roll Forming machine is also know as a wheel rim-forming machine, and is used for symmetrical or asymmetrical roll forming of steel wheel rims. The roll forming equipment consists of the main machine, hydraulic transmission system, pneumatic system, PC control system and lubrification system

(LittleDuck, Fabricante e Especialista Chinês em Design de Máquinas de Roda de Aço)

Figure 33. Roll Forming machine, source: LittleDuck, wheelmachinery

Conformation of the rim

The conformation is made by the coiler machine, rolling machine consisting of a set of rollers or cylinders, with rotary movement and adjustable pressure, responsible for rolling the steel sheet giving the shape of the rim

(LittleDuck, Fabricante e Especialista Chinês em Design de Máquinas de Roda de Aço)

Figure 34. Coiler machine, Fonte: Rodabrás

Flash Butt Welding Machine

The Flash Butt Welding machine is an important piece of equipment in wheel rim production lines. It is used for welding the steel wheel rim after the welding joint has been flattened.
(LittleDuck, Fabricante e Especialista Chinês em Design de Máquinas de Roda de Aço)

Figure 35. Flash Butt Welding Machine, source: LittleDuck, wheelmachinery

Other machines of production of the rim

Figure 36. Steel Stamping Machine, source: Cobrimetal

The stamping of steel parts works by means of a press, which, under pressure on a sheet of steel, receives the desired shape to a piece. Following this step, you can give a coating of zinc or other material on its surface. The process of stamping steel utensils can give rise to the formation of several important materials.

(Cobrimetal, 2016)