Graz University of Technology

Market potential and entry opportunities with high- and ultra high-strength steels for roll forming

MASTER THESIS

By

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Abstract

High- and ultra high- strength steels offer special material properties, in particular a poor formability and the large spring back. Present forming technologies need to be adapted to meet those challenges. With the knowledge of the process limits of state of the art forming technologies, the basis for producing profiles with roll forming technology is created.

This thesis includes a section covering the purchase of a roll forming line for the Institute for Tools & Forming. The main scope of the line is research and development in the field of high- and ultra high strength steels. In the course of developing know-how for the project partner it is the goal to gather information about process limits of roll forming these materials. The first step is to produce and analyze simple, open profile geometries such as V- C- L- and O-profiles to gather first impressions and experiences of the material behavior. With this information it is possible to give an outlook on necessary process improvements and the expansion of the profile spectrum.

A further objective is to gather information about the roll forming industry within Europe. The goal is to identify the future market potential and the entry opportunities in the roll forming market with high- and ultra high strength steels. The particular focus of the market survey lies on the automobile industry.

Kurzfassung

Durch die speziellen Materialeigenschaften von hoch- und höchstfesten Stählen, im Besonderen die schlechte Umformbarkeit und die große Rückfederungsneigung, ergeben sich bei der Verarbeitung dieser Materialien neue Herausforderungen. Mit dem Wissen über die Verfahrensgrenzen vorherrschender Umformtechniken ist die Basis für die Profilherstellung durch das Verfahren des Walzprofilierens geschaffen.

Im Rahmen dieser Arbeit soll am Institut für Werkzeugtechnik & Spanlose Produktion eine Versuchsanlage zum Walzprofilieren angeschafft und in Betrieb genommen werden. Im Zuge des Kompetenzaufbaus für den Projektpartner auf dem Gebiet des Walzprofilierens geht es um die Festlegung von Verfahrensgrenzen und den Erfahrungsgewinn bei der Verarbeitung höchstfester Stähle zu einfachen offenen Profilquerschnitten durch Walzprofilieren. Dazu sollen V-, C- L- und O-Profile untersucht werden.

Aus der Bestimmung des Einflusses unterschiedlicher technologischer Parameter, wie z.B. Profilblume, Rollendurchmesser, Gerüstabstand oder Umformgeschwindigkeit, soll deren Sensitivität auf den Prozess ermittelt werden.

Weiteres Ziel dieser Arbeit ist es mittels einer europaweiten Branchenanalyse herauszufinden, welche zukünftigen Marktpotentiale das Walzprofilieren von hoch- und höchstfesten Stählen mit sich bringt. Der besondere Fokus liegt hierbei auf der Automobilindustrie.

Mit Hilfe der Erkenntnisse aus dieser Arbeit soll es möglich sein, einfache Profile aus hoch- und höchstfesten Stählen durch das Walzprofilieren auf einer eigenen Anlage herstellen zu können. Des Weiteren soll ein Ausblick auf notwendige Prozessoptimierungen und auf die Erweiterung des Bauteilspektrums gegeben werden.

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Symbols and Abbreviations

n	[-]	Needed forming steps for profile
a	[mm]	Flange height
HD	[mm]	Distance between two forming stages
α	[°]	Final forming angle
d	[mm]	Material thickness
Θ_p	[°]	Forming angle between two forming stages
$R_{p0,2}$	[N/mm^2]	0.2% material yield strength
L	[mm]	Forming length

1 Introduction

The automobile industry is setting a clear trend towards lightweight design. The origin of this trend is coming from regulations like CO_2 emissions standards, the worldwide need of fuel consumption decrease and the increasing requirements in the field of passenger safety. With the use of high- and ultra high- strength materials, an increase in passenger safety is given. Moreover its reduced weight also decreases the CO_2 emissions and the fuel consumption. One of the main challenges of forming high- and ultra high- strength steels is their moderate formability and their large springback effect. Press hardening is the predominant forming technology for manufacturing products up to strengths of 1800 MPa. The unwished material properties are partly negated with this technology. However, industrial press hardening need large process lines and it is a time consuming process. Due to this reasons, the main focus of the research is to come up with innovative ideas in order to overcome or compensate these unfavorable material properties or process parameters.

Roll forming technology effortlessly negates a large number of manufacturing issues compared to conventional forming processes. This leads to a cheaper manufacturing process and thereby to cheaper products for the industry while maintaining the same material properties. In order to get knowledge about roll forming, the Institute for Tools & Forming will purchase a roll forming line for research and development purposes. The main focus lies in the experimental testing of the forming technology and the used materials. As a result, synergies should be identified in order to be able to optimize the forming process and the material used. However, it remains to be seen whether this technology in combination with forming high-strength materials is capable of establishing itself in the automotive industry.

Therefore the overall market potential of high- and ultra high strength steel materials in this industry needs to be evaluated in order to estimate a base potential of the material demand. Roll forming has both, advantages, as mentioned above, and disadvantages, such as the number of possible profile geometries. It is generally only possible to form profiles with a constant cross-section over the length. Still it remains possible that current innovations in this field may lead to the possibility to even be able to form profiles with non constant cross-sections that pay of their additional production costs. It has to be shown if the combination of the base potential of this technology and the variety of possible profiles it can produce, results in high sales potentials for high-strength materials manufactured with roll forming technology.

Furthermore, also market entry opportunities need to be estimated. It is crucial to have knowledge about the forces and barriers within a market in order to be competitive. The objectives of this thesis are to estimate the chances to enter the market and sustain within it and to identify the products needed to do so.

2 State of the Art

This chapter is divided into two separate parts. First, the roll forming technology is discussed in terms of technical understanding, different facility possibilities, profile constructions, economical aspects of this young technology as well as innovative and future possibilities of roll forming. The second part includes the economical aspects of how to enter the roll forming market, what has to be considered to successfully launch a business and how to keep up with existing competitors.

2.1 Roll Forming Technique

This chapter gives a general overview of roll forming itself. After a brief introduction into the topic, the different facility types and the possibilities of further integration of processing stations will be explained. A short overview of possible materials and hence producible profiles is given as well. Furthermore, a discussion of possible production failures leads to the introduction of important construction rules and principles. Moreover, the economical aspects of the technology are discussed. Finally, actual developments and innovations in the field of roll forming are explained.

2.1.1 Introduction

Roll forming is a cold forming process for manufacturing profiles out sheet metal blanks or from sheet metal coil. The sheet metal or coil is passed through an incremental set of forming rolls mounted on consecutive stands. Each set of rolls is performing only a part of the final bend until the desired cross-section profile is obtained. Hence it represents a competitive method to conventional forming techniques like bending or deep drawing. The roll forming technique is primarily used for manufacturing thin-walled profiles made of steel. The first use of this method dates back to the 19^{th} century and is nowadays broadly used in mass production. Many industries, in which lightweight construction and design are playing an important role, are using this relatively new technology of forming. These are for example automotive-, transport-, or building- industries. [Ist02]

Roll forming facilities can produce open or closed profiles. For closed profiles an additional joining process is necessary which can be integrated into the roll forming plant. Figure 1 is giving an overview of products manufactured by roll forming.

According to Dr. Peter Groche: [Ble07]

"Roll Forming is a mercurial manufacturing technology giving the right answers to cutting-edge questions".

Figure 1: Roll formed profiles for different industries [Wag11]

The most important advantages of the roll forming technology compared to conventional forming technologies are listed below:

- High volume production
- Consistent product quality
- Minimum material handling
- Reduced number of labor
- High tensile material forming
- Low cost tooling with high tool life

2.1.2 Classification and Process Description

Classification

Roll forming is a continual bend forming process. The classical profile geometry comes with a constant profile cross-section over the length. (Researches in the field of 3D roll forming are going on and are explained in more detail in Chapter 2.2.5.)

The needed energy for handling and forming of the sheet/coil is generated from a frictional connection between the material and the rolls. The needed plastic deformation occurs mainly in the bending edge. With roll forming the material thickness stays almost the same over the whole cross section. Hence, the roll forming technique is not a rolling technique -despite of the similarity of names – because here it results in a change of material thickness. However, the position and form of the tools is the same. The forming process evoke from rotating rolls. The classification according DIN 8586 is shown in Figure 2. It is possible to heat the work piece before forming, but usually the process is done without a heat treatment. That is why roll forming is classified as a cold forming process. [Sch98] , [Bro93]

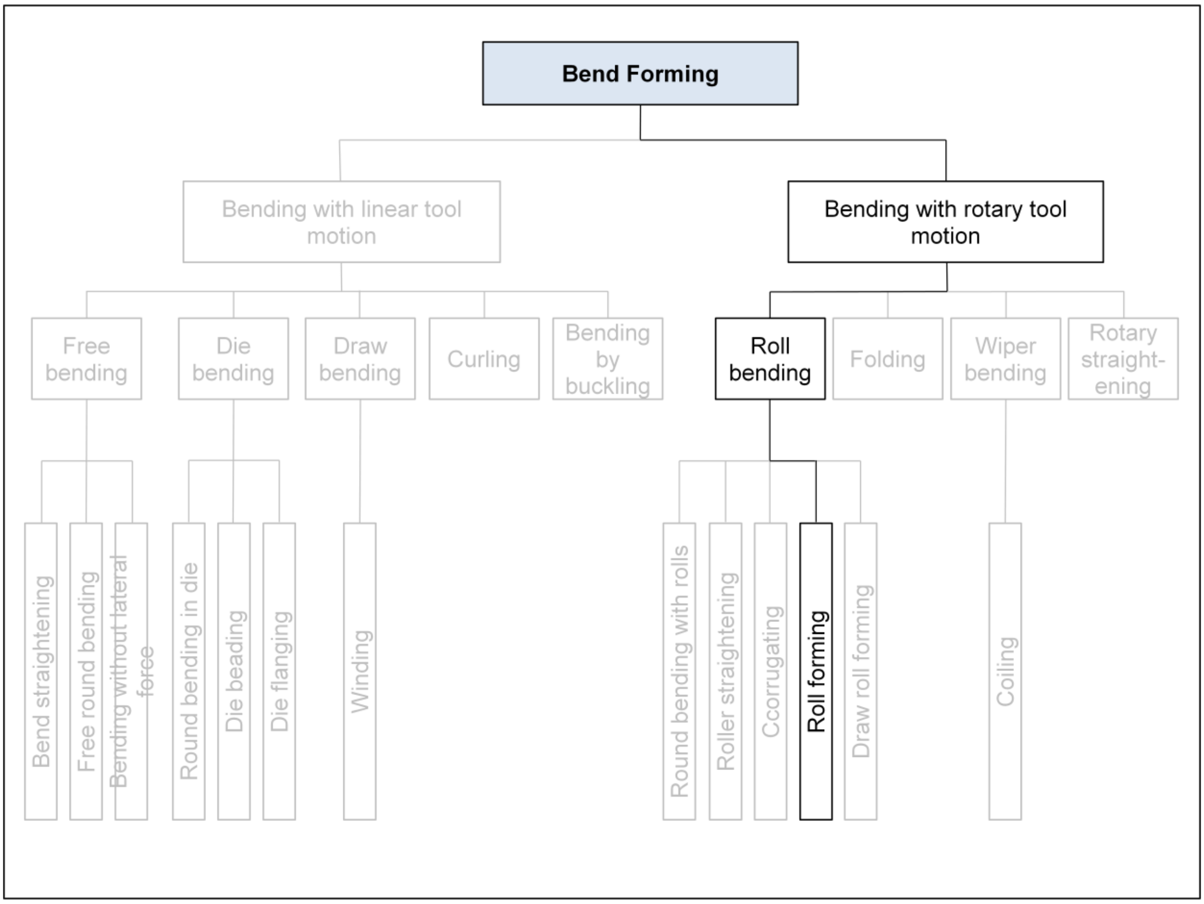


Figure 2: Classifications of bend forming techniques according to DIN 8586 [DIN03]

Roll forming process

During the roll forming process, the blanket is shoved (caused by friction) through the gap in between the upper and lower rolls and is formed thereby. The forming process is stepwise until the final geometry is reached. The geometry for each step is given by the geometry of the respective gap. Figure 3 shows a roll forming model consisting of five steps with a change of profile geometry in each roller set. Additional side rolls can also be seen in roller set three and four. The lower part of Figure 3 shows the different cross-sections of each roller step. Laying the single geometries on top of each other results in the so called flower pattern. An example for such a flower pattern is shown in Figure 30. The segmentation of the forming process is necessary due to the tensions and change of shape in the profile. The forming process causes two different kinds of strains seen in Figure 4. The first is directly in the bending edge. Compressive stresses are occurring on the inner side as on the outer side tensions are introduced. The second state of stress is located in the band edge. Here it is divided into a zone with spherical – and one with saddle natured strains. Hence, in the forming area, band edge and bending edge take different lengths during the forming process. The bigger the bending angle of a roller set is, the higher the possibility that unwanted plastic deformations occur. Such plastic deformations are the reason for many possible failures in the roll forming process and therefore have to be kept as small as possible.[Bog79]

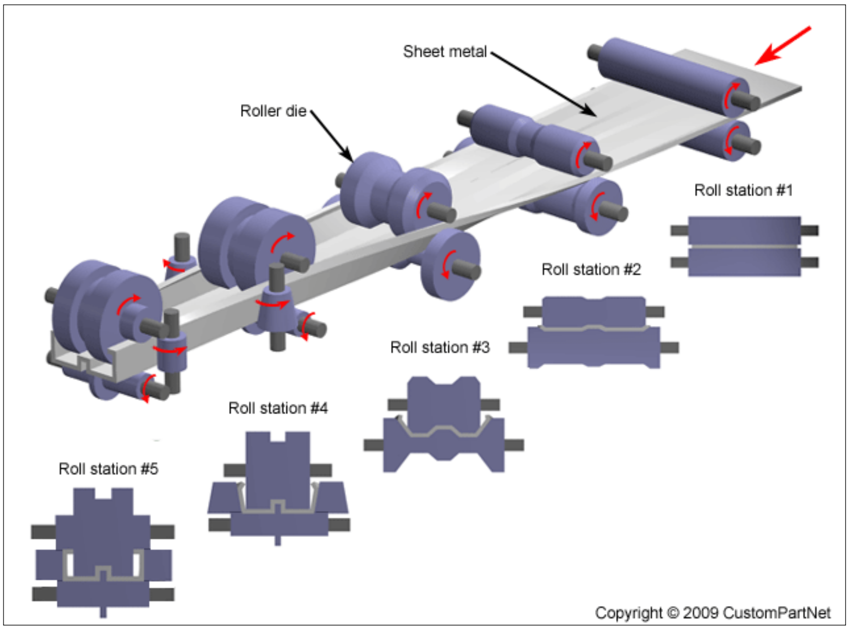


Figure 3: Roll forming principle [Cus13]

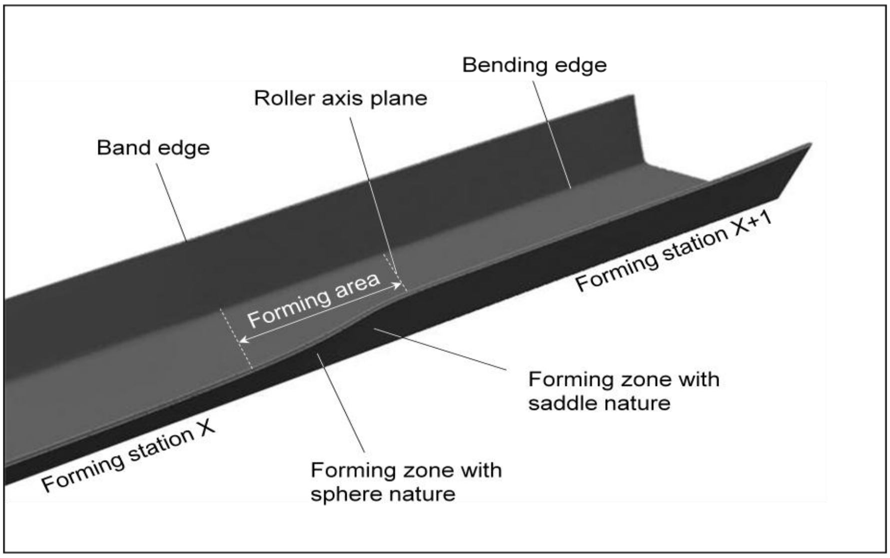


Figure 4: Three dimensional forming process between two forming stages [Wir13]

2.1.3 Classical Roll Forming Line Structures

The setup of a conventional roll forming production line always depends on the purpose and the wanted outcome and is mostly individually formed. Nevertheless a typical roll forming plant is shown in Figure 5. It consists of material preparation (1-3), a blanking unit (4), the roll forming unit itself (5), a welding station (6), a geometry detection unit (7), the profile straightening unit (8), and a disconnecting station (9). Often an additional packaging unit is installed at the end of the production line (Figure 7 left).

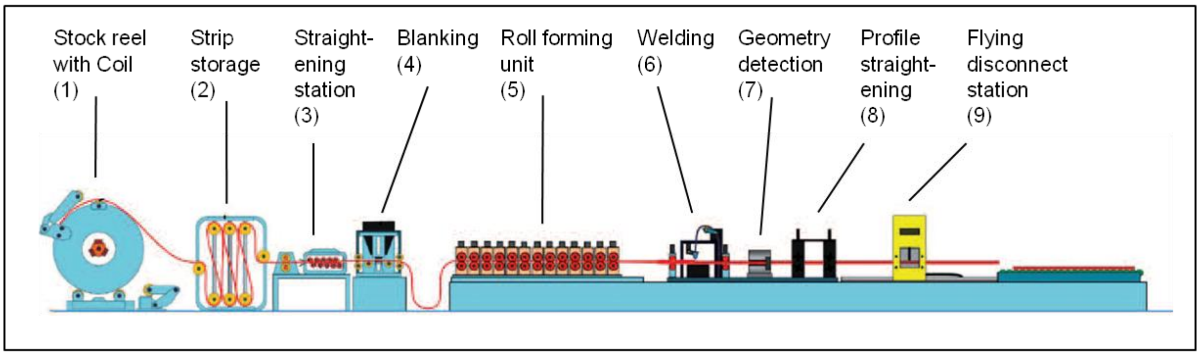


Figure 5: Model of a typical roll forming plant [Wir13]

The material preparation (Figure 6) can consist of a stock reel (1), a material storage (2), which often comes with an included welding unit to connect a new coil with the previous coil, without the need to stop the whole process and a straightening station (3), which is needed to reduce residual stresses and waviness of the basic material. This happens through multiple bending of the material in opposed directions.

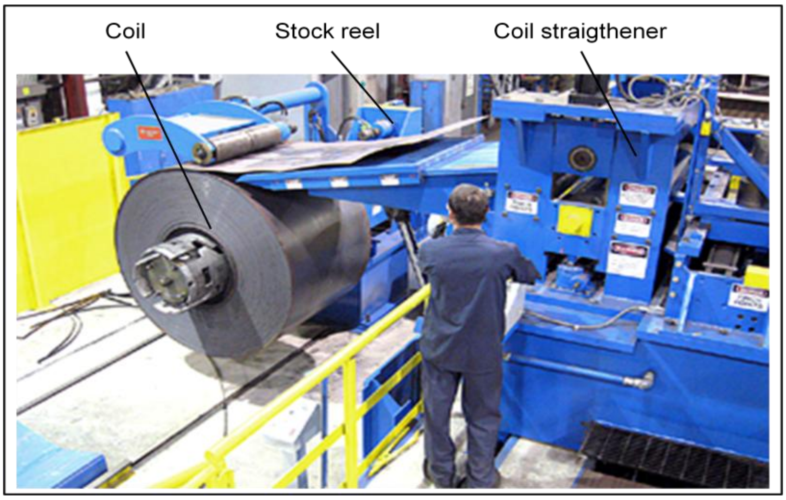


Figure 6: Stock reel followed by a coil straightening unit [Bra13]

A flying disconnect station (9) (Figure 7) is normally located at the end of a roll forming line. It is to compensate the forward speed of the plant. At a continual operating mode the disconnect station has the same speed as the material itself. Hence, the profile is cut into the right size without the need to stop the production line for the cutting process.

At the end of the line either a transport unit (Figure 7 right) can be located to carry the material over to further processing units, or a final packaging unit is installed if the product is already finished.

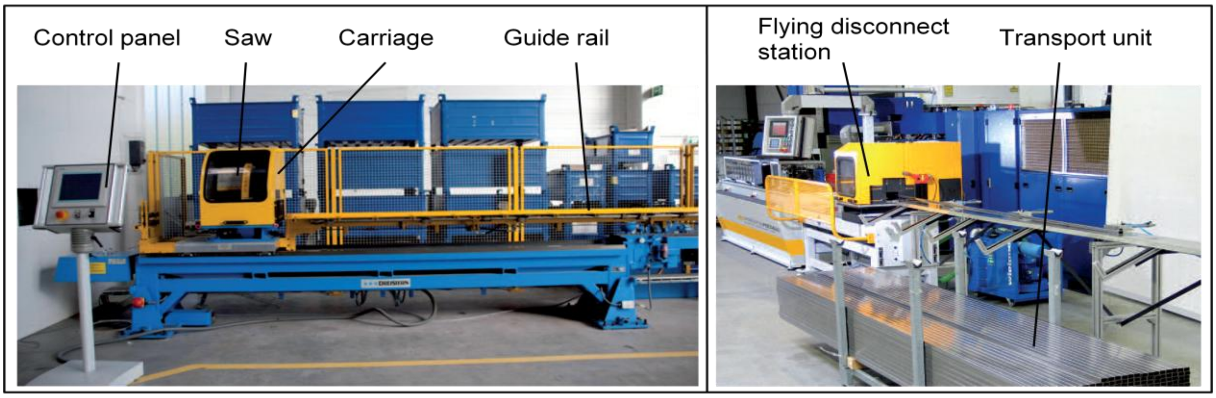


Figure 7: Typical flying disconnect station and transport unit [Wir13]

Due to a good accessibility to the line there is also the possibility to integrate additional processing steps. Blanking or joining are typical processes that can be included into the roll forming section. A good example is also welding. It is often used in combination with roll forming as for instance longitudinal welding of roll formed pipes. Figure 8 (left) shows a welding process where two different parts are welded together and Figure 8 (right) shows a profile which is welded into a closed rectangular profile, i.e. for increased stability or sealing (tightness).

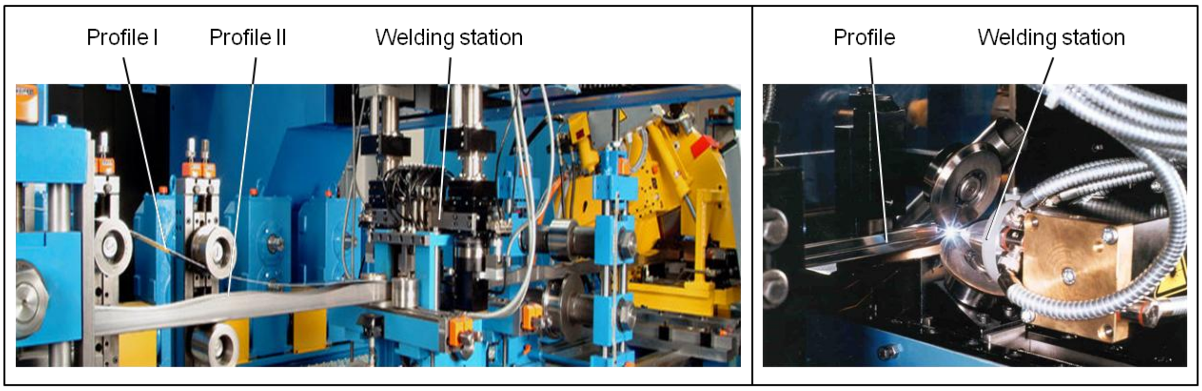


Figure 8: Welding stations integrated into the roll forming process [Dre13]

Blanking units are usually placed before (Figure 9 left) or after the roll forming process, but can as well be positioned in-between the roll forming line. Holes and notches are often used for mounting (Figure 9 right), locking or storing functions as well as for linking parts together or close a profile with itself. The most appropriate place of a press unit within a roll forming line depends on different criteria like line accessibility and needed tolerances. The deformation induced by the blanking process can lead to a deviation in form- and position tolerances because axial and transversal stresses can evoke changes of the geometry.

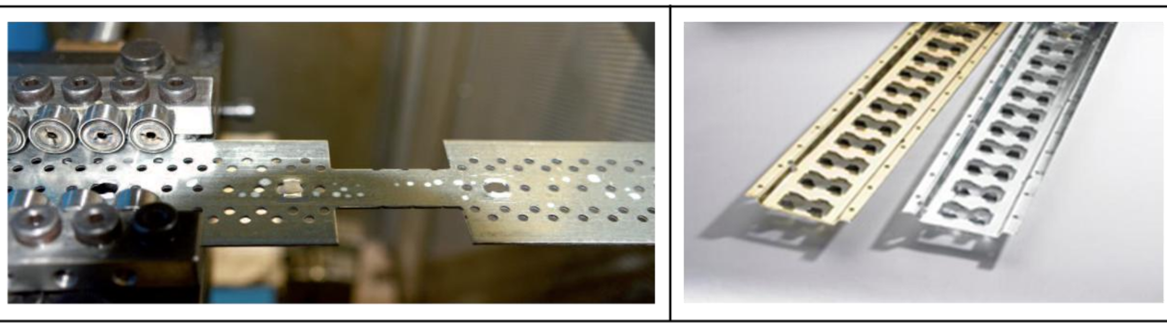


Figure 9: Left: Semi-finished part with blanked areas [Ebe11] ; right: Load securing rail [Had13]

Figure 10 shows roll formed profiles combined with welding and blanking processes for different fields of application.

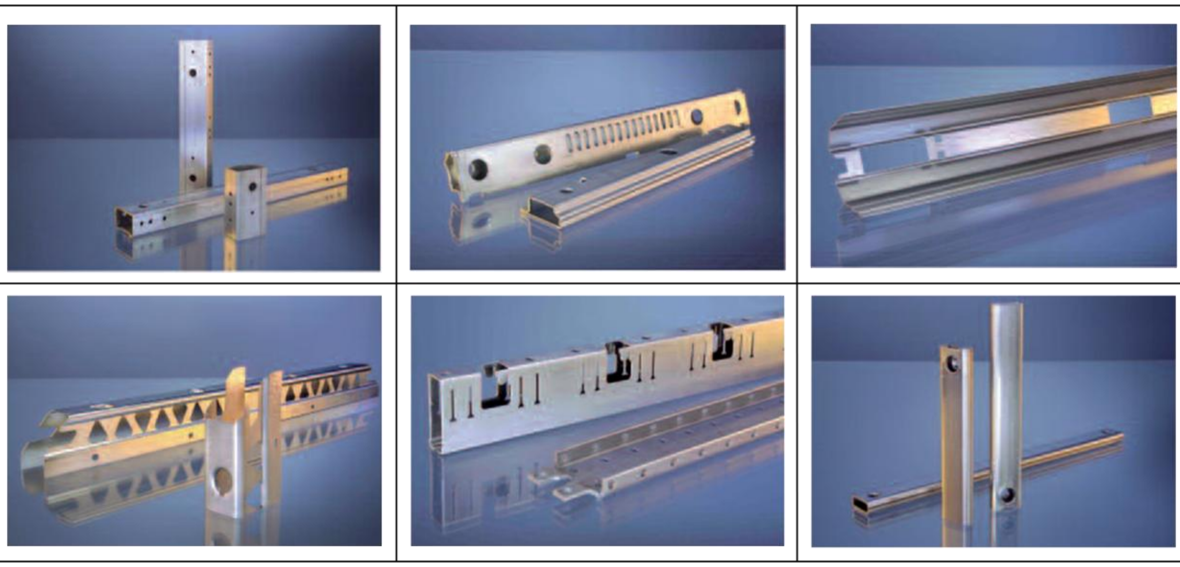


Figure 10: Roll formed profiles with additional blanking and welding processes [Joh12]

Roll forming lines can either be built continuously or discontinuously. Cutting or blanking units for example can be decoupled from the continuous process with the use of an upstream material storage or they can be built in line.

Discontinuous roll forming lines do not need moveable processing stations, which normally makes the acquisition cheaper. Nevertheless plenty accelerate and decelerate processes are needed which results in higher strain and stresses for the whole roll forming line as well as a smaller production output. [Sch98]

2.1.4 Roll Forming Unit Types

The heart of the roll forming unit is the mill. It provides the needed power to form the material. There are unlimited possible variations of mill design but in general it can be divided into:

a) Cantilevered mills
b) Bilaterally mounted mills
c) Standard (conventional) mills
d) Duplex mills

Roll forming mills that cannot be categorized in one of those four variations are normally considered as “special mills”. The four principles are shown in Figure 11 and are explained in more detail below. [Geo06]

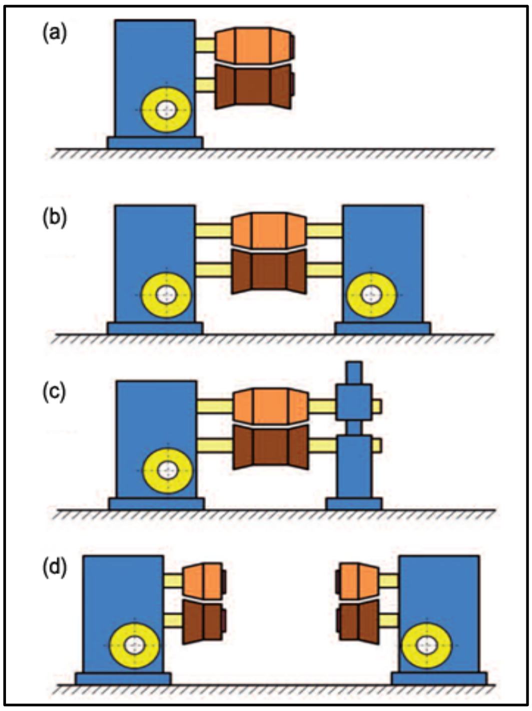


Figure 11: Roll forming mill construction types [Wir13]

Cantilevered mills

The shaft in the first mill type is built with a unilateral shaft bearing shown in Figure 12. Sometimes they are also called “overhanging” or stub-type-mills. This variant has its advantages in building light profiles or profiles with small cross sections. Through the easy accessibility from one side of the line, the rolls can be changed easily and fast. Thus, set-up times can be kept small. Furthermore, the frame is relatively low-cost compared to other mill variants. [Geo06]

It is also possible to utilize the mill for a second section to be able to form two different profiles. The dead end of the cantilevered shaft can be tooled in a way to create another section. Figure 13 shows a principle drawing of a two section cantilevered mill. [Geo06]

Figure 12: Cantilevered mill type [Sch13]

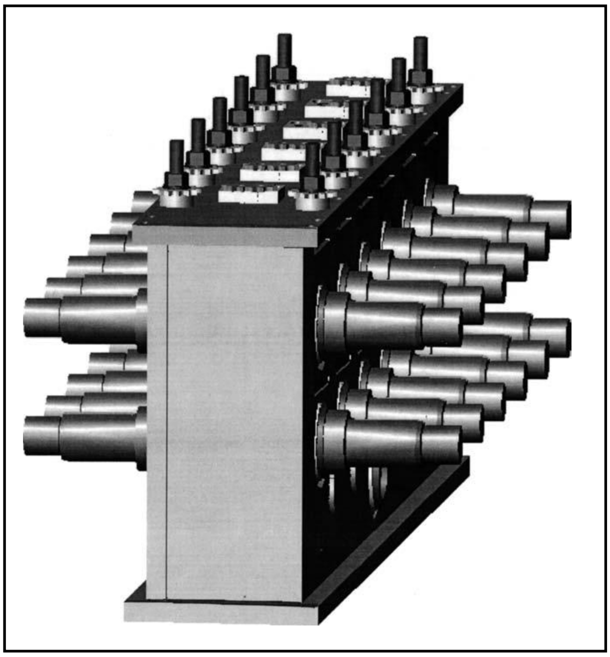


Figure 13: Cantilevered mill with two sections [Geo06]

However there are several disadvantages for this mill type:

- Only one-sided adjusting abilities make it difficult to set the required roll gap between upper- and lower roll by maintaining the parallelism between both roller shafts (depends on the number of adjusting screws used).
- Figure 14 shows the deflection of a cantilevered shaft compared to a bilaterally supported shaft. The deflection at same load is approximately four times higher. This

leads to an increase of inaccuracies. A proper counteraction to reduce the amount of deflection would be to install larger diameter shafts. This comes at the cost of a more expensive roll forming unit.

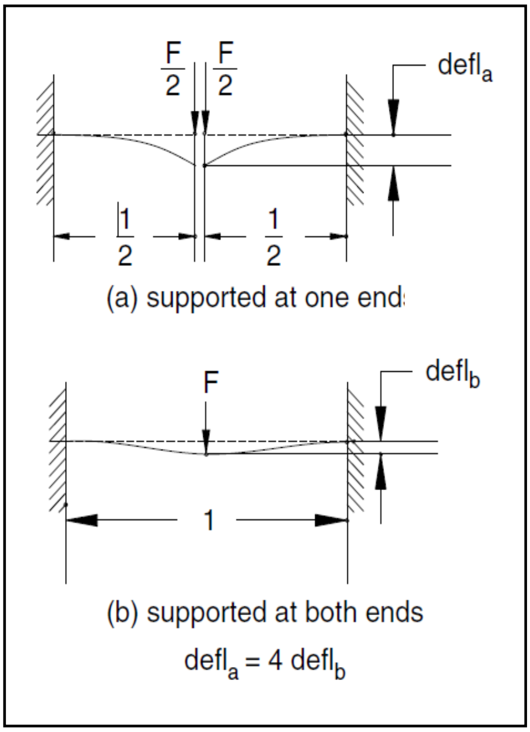


Figure 14: Deflection of a cantilevered shaft compared to a bilaterally supported shaft [Geo06]

Bilaterally mounted mills

The free-standing side of the shaft (Figure 12) is now supported by an additional power driven frame shown in Figure 15. With the extra frame the whole line is getting stiffer and as a result the deflection is four times lower than at the cantilevered mill type (Figure 14). Through the added support higher forces on the roller shafts are possible. Hence, thicker and heavier profiles can be formed. However, set-up times are increasing due to the fact that one side must always be demounted completely in order to change the roller sets. [Geo06]

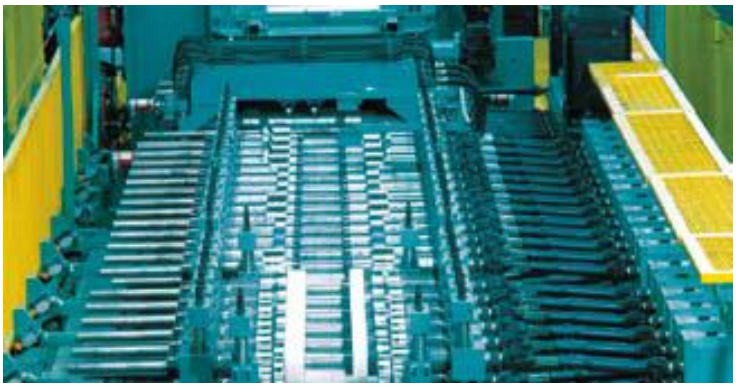


Figure 15: Bilaterally mounted mill type [Sch13]

Standard (conventional) mills

Standard mills (Figure 16) are equipped with shafts supported at both ends. They can be used for forming almost every material, thickness and width. Hence, it is the most popular mill type used to form profiles. The operator side (support side) is removable to facilitate roll changes. Both, drive- and operating side can be fixed at one position (Figure 17 left) but there are also construction types where the operator side can be placed at different positions (Figure 17 right) to adapt to different material properties (wide & thin or small & thick).

Figure 16: Standard mill type [Dre131]

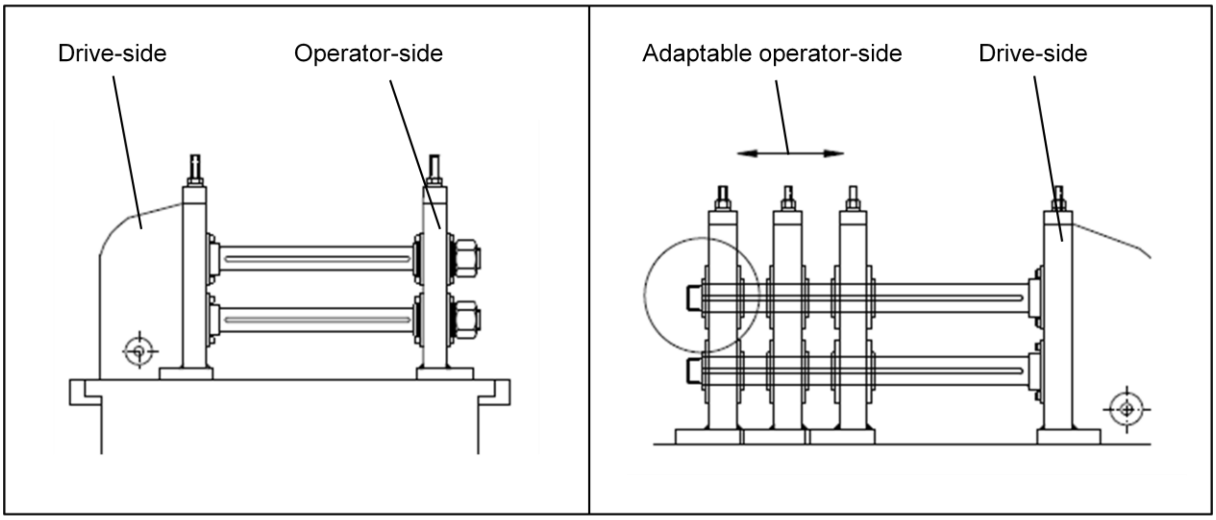


Figure 17: Standard mill type with fixed and moveable operator side [Geo06]

Duplex mills

By mirroring a cantilevered mill a duplex mill is created (Figure 18). Duplex mills are able to form both ends of the material with leaving the mid sections flat. The possible profile width only depends on the frame of the mill. In between it is infinitely variable. Therefore this type is favored when forming e.g. wall- or roof elements. [Alt11]

Figure 18: Duplex mill type [Sch13]

Duplex mills can be built with only one side or both sides adjustable. The quick and easy adjustability is shown in Figure 19. Which type is more suitable depends on further processing steps like welding or blanking. With one side fixed (a) the centerline changes when adjusting to another material width. Having both sides adjustable (b) means that the centerline can always be in the middle of both roller stands (Figure 20). [Geo06]

Duplex mills, considering the similar structure as cantilevered mills, have pretty much the same advantages and disadvantages.

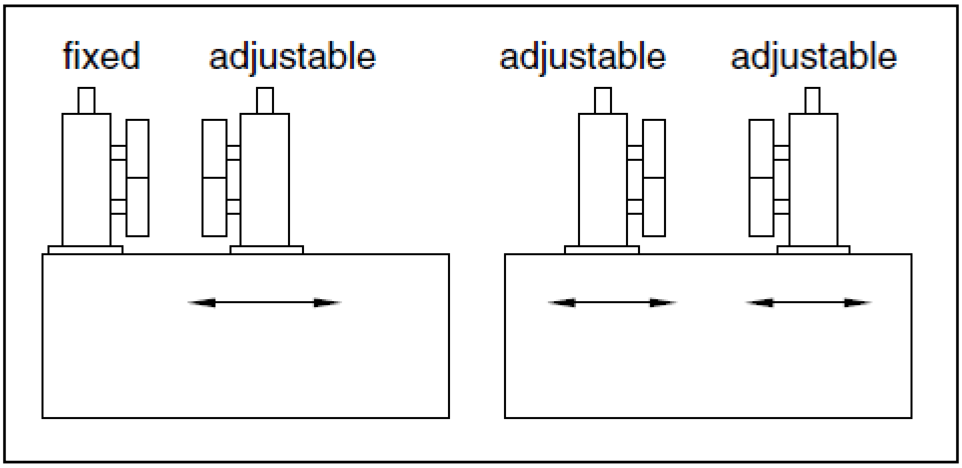


Figure 19: Duplex mill with one or two adjustable row of stands [Geo06]

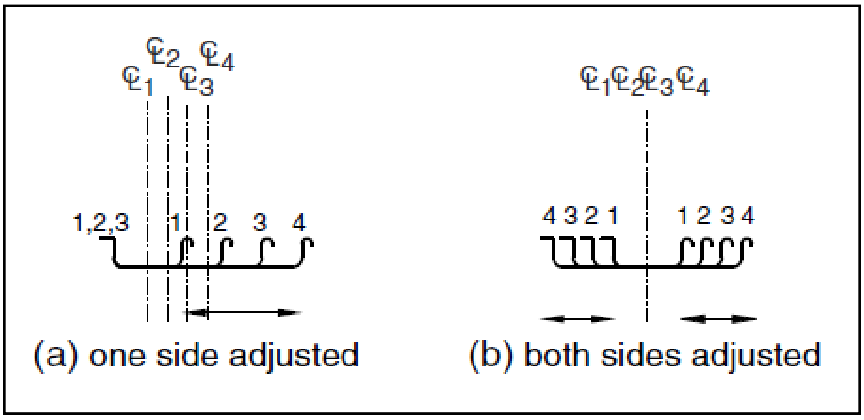


Figure 20: Channels with variable widths produced in duplex mill with one or two adjustable rows of stands [Geo06]

As mentioned earlier, there can be several other special types or even combinations of the four general mill types. For example a through-shaft duplex mill is a combination of a standard and a duplex mill. It combines the advantages of both mill types.

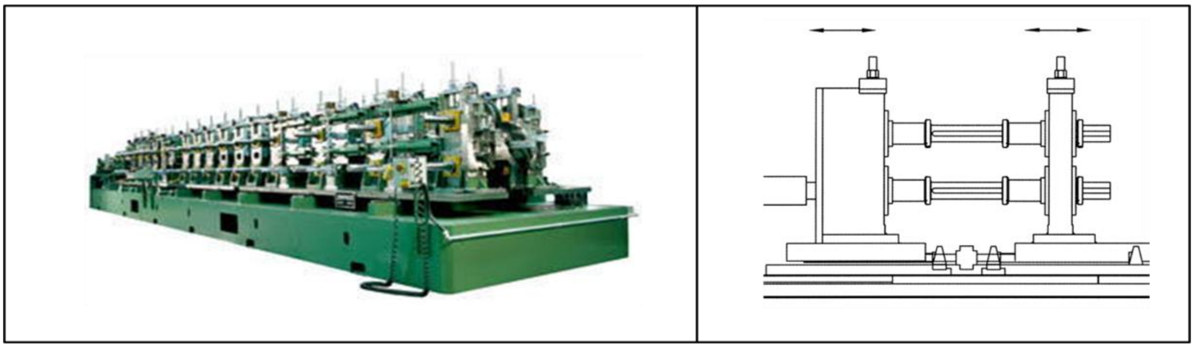


Figure 21: Left: Through-shaft duplex mill [Sam13] ; right: Cross-section of a through shaft mill [Geo06]

Double-high mill types (Figure 22) for instance can provide two different roller sets with the use of only one frame. This type saves not only space, but also time because changeover time between the two roller sets is relatively low.

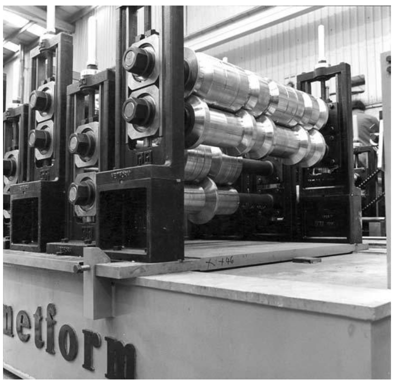


Figure 22: Double-high mill type [Geo06]

2.1.5 Roll Forming Unit Components

There are several components that are additionally needed for a successful forming process, for special purposes, as well as additional components that are preferably used for some circumstances. This chapter gives a short overview of roll forming components.

Mill bed

The mill bed is the “base” needed for the roll forming unit as well as for almost every other additional roll forming component. It supports the drive train, rolls, shafts, and stands. The main requirements for the mill bed are: [Geo06]

- Rigidity during forming operation, transportation and installation
- Possibility for a smooth installation of additional components
- A keyway to be used for aligning the stands
- Container and drainage for the lubricants

A standard mill bed does not exist, but the majority is similarly constructed either out of sections or as a whole. The surface of the mill bed is either fully machined or only the mounting areas for the stands and additional equipment is machined.

Stands

The stands are differenced in a drive- and an operator shaft. While the drive-side stands are suspended with high forces and moments, the operator-side stands are exposed with lesser forces. The needed robustness of both stands highly depends on the properties of the material that has to be formed (thickness, tensile strength, etc.). Figure 23 shows different possibilities to fasten the stands on mill base. There is no best practice. The preferable method depends on the occurring forces and moments and the wanted and acceptable set-up times for a roller set switch.

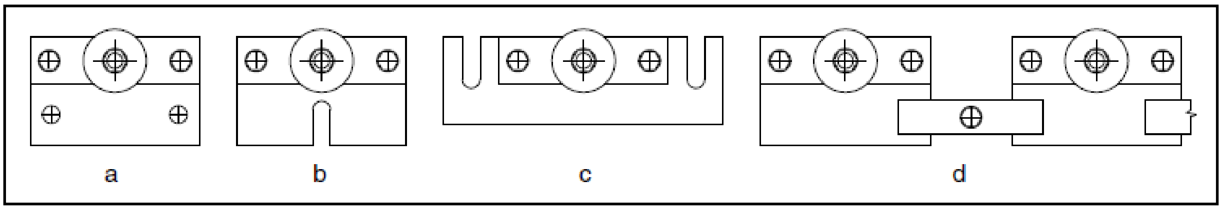


Figure 23: Different methods to fasten the stands on the mill base [Geo06]

Power train

Usually roll forming lines are powered by electrical motors. In a minority of cases, the mills are driven by hydraulic motors. However, most hydraulic pumps are driven by electrical motors. Occasionally, the hydraulic pumps are driven by diesel engines.

For speed reduction and adaption for the individual stands, gear reducers like chain or chain-gear combinations are used. A gear box between the electrical motor and the mill provides an overall speed adaption. Cheap designs are working through chains. However, most of the time V belts are used. [Geo06]

Lubrication system

Lubricants are used for several purposes. They reduce the friction between the formed material and the rolls; they are used as a coolant to reduce the heat accuring during the forming process; they keep the surface clean by washing away loose surface particles; they avoid damage on the surface like scratches. Figure 24 shows an example of a lubrication system. [Geo06]

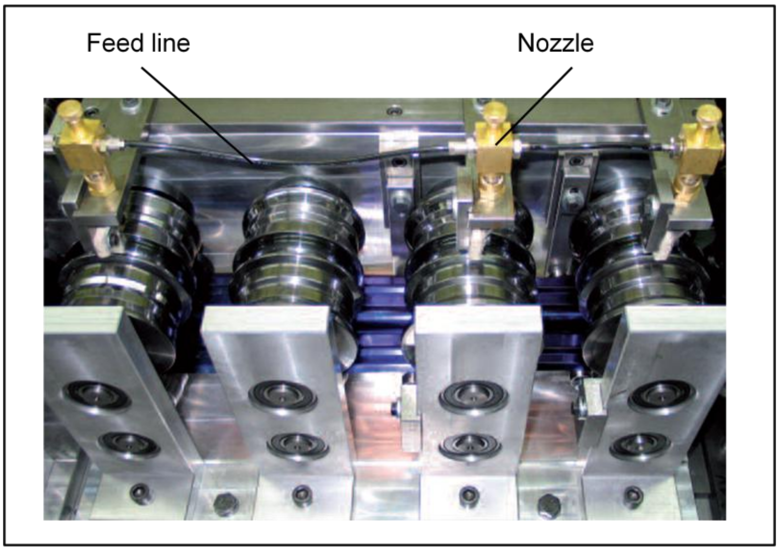


Figure 24: Lubrication system [Rot11]

Other units

The base frame can be used to install additional equipment or other units for secondary operations. These units can be placed after, in-between or ahead of the roll forming unit. This is partly discussed in Chapter 2.1.3.

2.1.6 Materials for Roll Forming

Figure 25 gives an overview of state of the art materials and their properties. On one hand materials with a low strength tend to be easier to form, on the other hand high-strength materials have a lower possible elongation. The preferable material mainly depends on the desired product properties. The material species are typically divided into four different areas:

1. Low-strength steels (LSS)
2. High-strength steels (HSS)
3. Advanced high-strength steels (AHSS)
4. Ultra high-strength steels (UHSS)

Fritz Klocke and Wilfried König set the boundaries for the different steel types as shown in Figure 25. Nevertheless, it should be noted that no clear and distinct border line between the four different areas can be set anymore. Steel producers have raised the quality of their materials in a way that they overlap each other and many steel types have a wide range and are covering two or more strength levels. [Klo06]

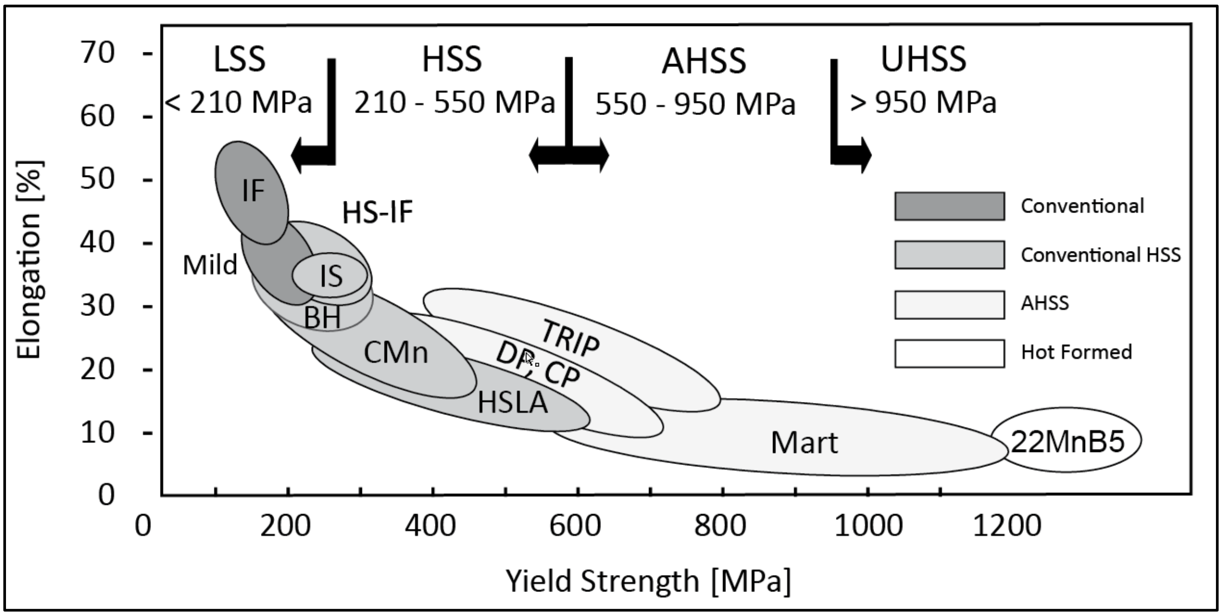


Figure 25: Classification of steel sheet materials, adapted from [Wor13]

Low-strength steels (LSS)

The yield strength of LSS reaches about ~210MPa. This material group hast the lowest possible yield strengths and hence they are also called mild steels. Low-strength steel types are typically used for deep drawing processes in which high formability is needed. The higher the possible material elongation, the more complex geometries can be produced. LSS are standardized according to DIN EN 10111 and are divided into DD (hot rolled), DC & DX (cold rolled) steel.[Wei03]

Applications for LSS are car body- and structural parts as well as chassis inner- and outer parts where formability is the main requirement. [Thy131]

High-strength steels (HSS)

High-strength steels are located around 210 – 550MPa yield strength. High-strength steels are mainly used for structural applications and are hence also called structural steels. This group of steels increases their strength primarily by adding additional micro-alloyed elements. High-strength, low-alloy steel (HSLA steel), is produced by using micro-alloying elements like Ti, Mo, Cb, V etc. Due to the low carbon and low alloy content, these grades offer acceptable formability at the needed strength levels. These materials offer also a good weldability. [Arc13]

High-strength steels are widely used in automotive industry where good durability is an essential requirement. Complex shapes can be more difficult to form than with LSS, but with an appropriate design it can easily result in successful parts. The typical range of application for this material type goes from reinforcements and rocker-panels up to different cross car beams and pillars. [Arc13]

Advanced high-strength steels (AHSS)

AHSS are multiphase steels within a yield range of around 550 – 950MPa. All AHSS are produced by controlling the cooling rate from the austenite- or austenite & ferrite phase. As shown in Figure 25, these materials have almost the same elongation than HSS, but offer a much higher yield strength. The product range for AHSS is the same as for HSS. However, the higher yield strength leads to the ability of reducing the needed material. The outcome is weight saving without a loss in performance. This is especially useful for car manufacturing.

Ultra high-strength steels (UHSS)

UHSS steels are classified as materials with yield strengths higher than 950MPa. Although martensitic steels can reach yield strengths higher than 950MPa, usually it is referred to hot stamping of boron-alloyed steels.

UHSS are used in regions where especially high forces through crash situations are applied. In the car industry for example, parts of the B-pillar, the side impact bar and the tunnel are made out of UHSS because of safety reasons.

2.1.6.1 Semi-finished product

As semi-finished products for roll forming, cold- and hot rolled coils or stripes are used. Cold rolled materials generally have a higher tensile strength, higher dimensional accuracy and a smoother, cleaner surface compared to hot rolled materials. The usual material thickness of semi-finished products is between 0.3- and 20mm but can go up to 40mm.

Surface quality is another important criterion. Besides protection from corrosion, the surface is also responsible for the optical appearance of the product. Different surface refinements of the semi-finished products can be seen in Figure 26.

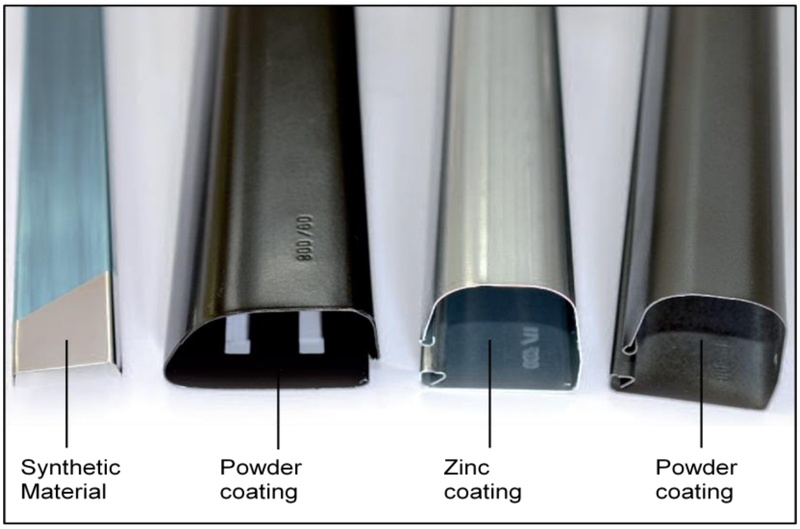


Figure 26: Profiles with different surface treatments [Met11]

Especially high surface requirements are needed, if the finished profile is in the field of vision. Semi-finished products can already have the desired surface quality. To reduce damage taken on the surface during the forming process, protection foils can be used. These foils are removed after the forming process. A comparison of surface quality is shown in Figure 27. The right profile is in a non-visible area and shows imprints of the forming rolls. Surface quality does not need to be as high as for the left profile which is in the field of vision when being build in.

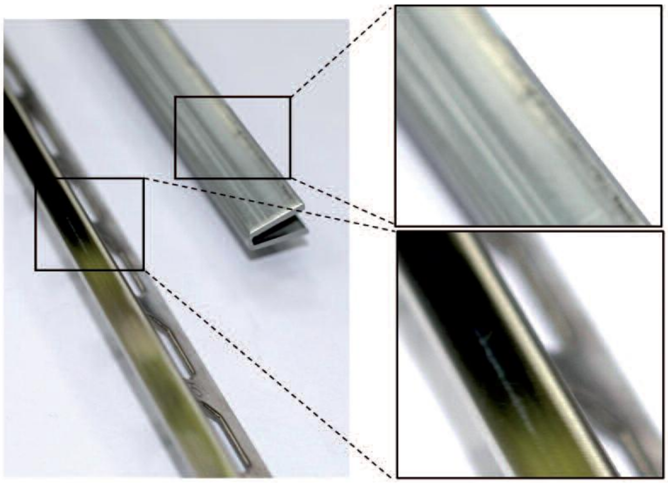


Figure 27: Different surface qualities for different requirements [Met111]

2.1.7 Profile Manufacturing

Requirements of roll formed products do not differ from any other products. The demand to "produce as cheap as possible and as accurate as needed" also applies for the roll forming industry. However, to satisfy the need of the customer you have to have a roll forming line that can build reproducible profiles without failures and within the needed tolerances. Roll formed profiles can have a large variety of possible failures that are shown in Figure 28. It is important to have knowledge of those profile failures in order to be able to develop an accurate roll forming line.

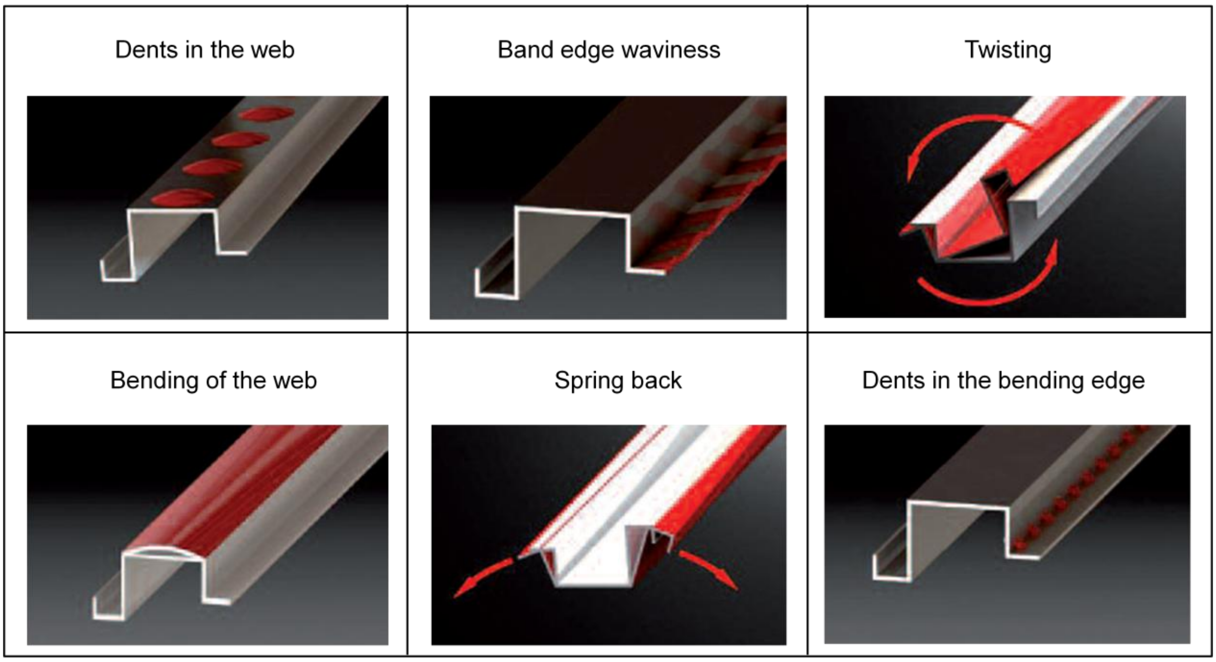


Figure 28: Possible profile failures [Wir13]

As shown in Figure 29 different forming lengths for bending edge and the band edge are introduced during the forming process. With an improper distribution of the roll forming stages unwished plastic axial expansions can occur. Profile errors, such as dents in the web, band edge waviness and twisting can occur through an unfavorable distribution of axial expansions. Especially thin walled profiles or profile sections can react with a failure in stability.[Wir13]

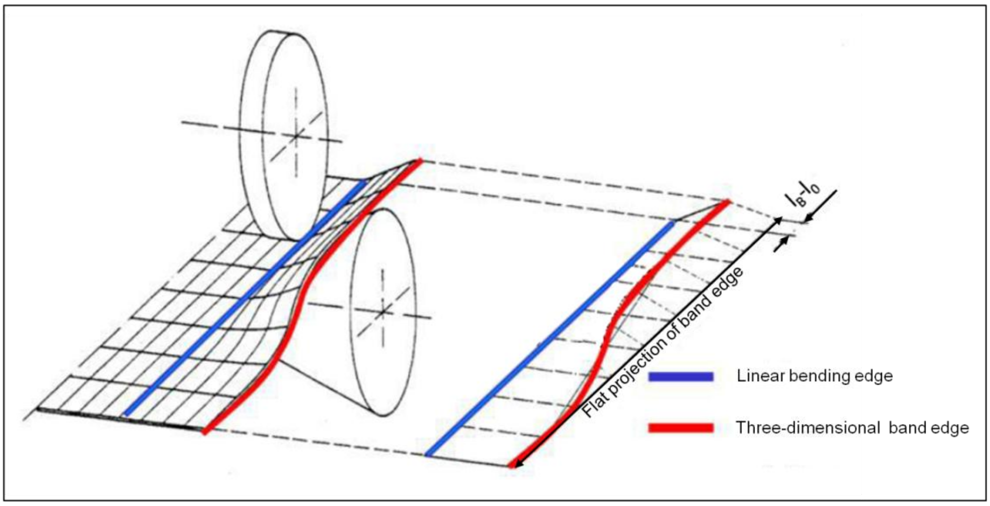


Figure 29: Forming length L on the basis of a U-Profile [Str96]

Spring back effect after the forming can also be a reason for not reaching the desired profile specifications. The energy introduced into the profile during the forming process is partly saved as elastic energy. After the forming process this energy is released and causes a change of the profile geometry. However spring back is easily preventable in the process planning of roll forming lines. The constructor provides a small over-bending in the last forming stage which can be seen in the profile example shown in Figure 30. The finished product should be a C-Profile. The flower pattern shows the single forming stages. After step 9 the profile would theoretically be in its final form but due to the spring back effect an additional forming stage is needed. From step 9 to step 10 an over bending takes place to compensate the spring back effect.

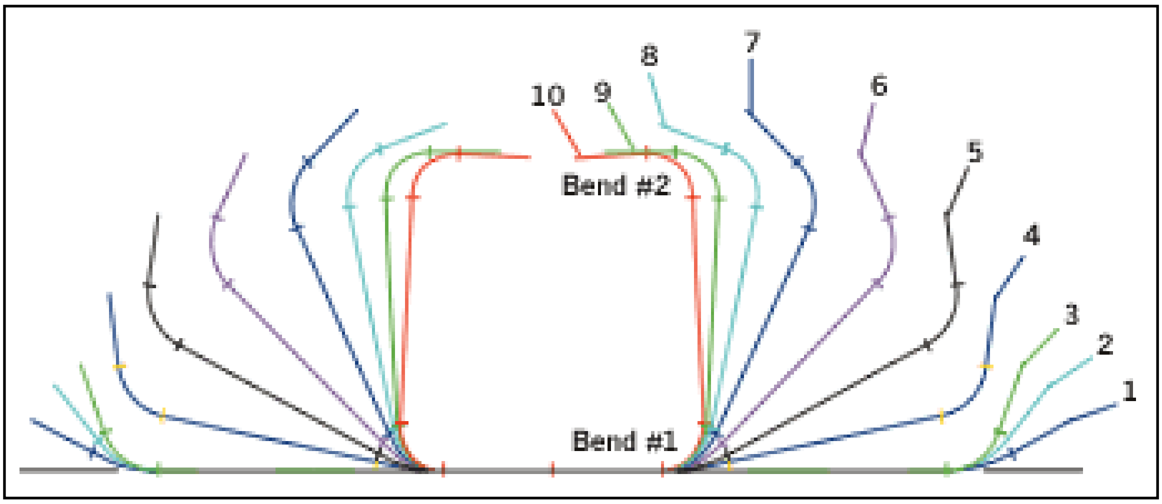


Figure 30: Flower pattern of a C-Profile [The13]

A usually good solution to avoid profile failures is to reduce the bending angle for a single forming step. This also increases the dimensional accuracy. However, this leads to a need of more forming steps in order to achieve the final geometry. Not only required space is increasing but also the tooling costs are getting higher. Therefore, as mentioned before, the best way is to find a compromise between economic viability and process safety. That means finding a way to achieve final profile geometry within the given tolerances with as little forming steps as possible. [Geo06]

Process development for roll forming

Even nowadays the number of needed forming steps is partly estimated only with experience. But simulation tools like Ubeco Profil or dataM Copra are gaining more and more acceptance in the industry and are widely used. Normally these simulation tools generate a flower pattern. With the flower pattern the number of forming steps with their bending angles is defined. The number n of needed forming steps can be estimated with equation 1.

$$n = \frac{\sqrt{2 * \mathrm{a}^2}}{\mathrm{HD} * \tan(\alpha)} + 1 \qquad (1)$$

HD is defined as the distance between two stands (roller sets), *a* stands for the flank height and α is the sum of all angles. The total material length should be chosen at least two times bigger than *HD* (Figure 33). This ensures that always three roller stages are included in the current forming process. This guideline only needs to be considered when not working from coil. [Geo06] , [Zet07]

L is defined as the forming length for a single forming process in one roller stage. It can be estimated with equation 2. *HD* should always be bigger than *L*.

$$L = a * \frac{\sqrt{8 * \mathrm{a} * \theta_{\mathrm{P}}}}{3 * d} \qquad (2)$$

d defines the material thickness while θ_{P} stands for a single difference in angle between two stands. Despite this simplification, good consensuses between mathematical approach and experimental tests can be found. However, tests were only performed with aluminum and low tensile strength steels. High- and ultra high-strength steels tend to have a different forming behavior. In this case L especially depends on the material properties. Hence another more specific equation has to be introduced. Equation 3 shows an approximation of *L* for high- and ultra high-strength steels where $R_{P0,2}$ defines the tensile strength of the formed material. [Bha83] , [Lin07]

$$L = 12 * \frac{a^{0,8} * \theta_P{}^{0,41} * R_{P0,2}{}^{0,07}}{d^{0,25}} \qquad (3)$$

Furthermore, the starting dimensions of the coil or strip need to be determined. This can be very complex because of a usually wandering neutral fiber during the forming process in direction to the compressed areas. If the profile is not symmetrical, errors can occur when dimensions are set from the profile centre. DIN6935 provides some correction factors but in fact they are not 100% accurate. [Gro11]

Another important aspect in developing a roll forming process is the construction and design of the roll geometries. The roller sections at which the material is formed are principally defined by the wanted profile outcome. The parts of the rolls which are not primarily needed for the forming process need to be viewed in more detail. On one hand, the design of the rolls should be done in a way that the production- and material costs are as low as possible. This can be realized with a multiple segment design shown in Figure 31. On the other hand, the rolls need to take care of the force transmission throughout the whole forming process. The amount of applied forces on the rolls during the forming process depends on the forming grade as well as on the material properties. High- and ultra high-strength steels normally needs a more robust roll design compared to low tensile strength materials.

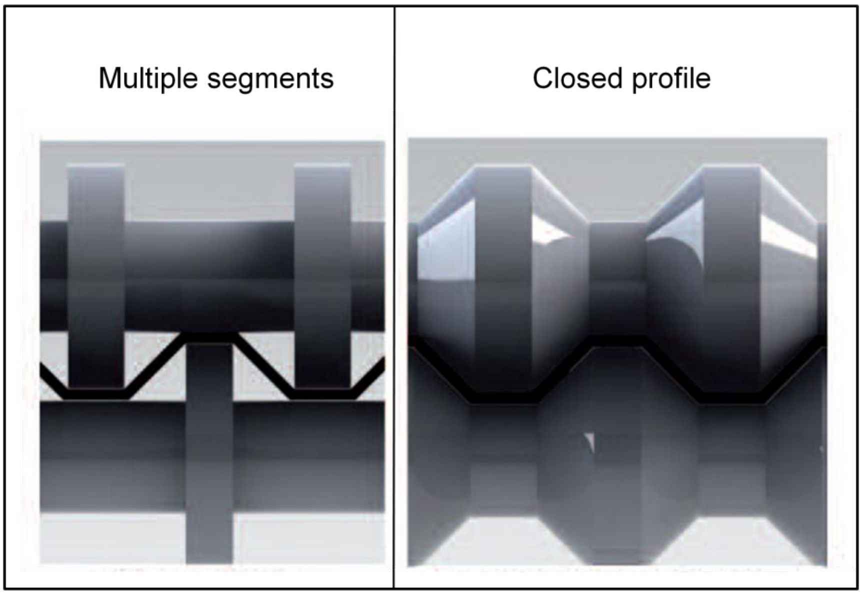


Figure 31: Possibilities of roll design [Wir13]

For the proper movement of the material during the forming process the friction force between rolls and material is responsible. In general the roll design aims for a high amount of friction force in order to reduce wear on the roll- and material surface. This applies especially for materials coated with a protective foil throughout the forming process. Regarding the roll design, it has to be kept in mind that with different roll diameters (Figure 32), different velocities are introduced onto the material. Hence, in some areas the roll speed cannot be equal to the material movement speed. This results in slippage. Through hardening wear caused by slippage can be reduced. Furthermore, with the use of lubricants direct contact between material and rolls can be prevented as well as rising temperature is kept small. With a proper choice of the gap height between a roll pair compared to the material thickness, the normal force can be kept as high as needed to ensure the material movement.

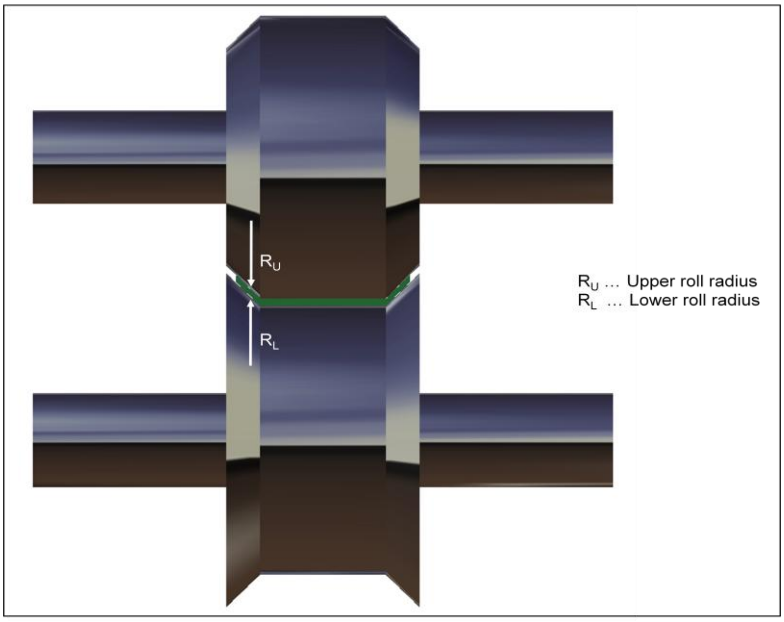


Figure 32: Emerge of slippage due to different diameters

Construction rules for profiles

The variants of possible profile designs are nearly unlimited. However, not all dimensions can be chosen freely. For a save and accurate process several criteria have to be fulfilled. With additional processes implemented into the profile manufacturing even more construction limits have to be considered. This chapter gives an overview of the most important design restrictions and recommendations. Figure 33 gives an overview of different construction rules that have to be considered for a successful profile design.

The bending radius depends mainly on the material thickness. As shown in Figure 33, the radius must not be smaller than two times the material thickness. Nowadays it is possible with the use of specific materials, such as fine-grained steels, to even reduce the radius below this restriction. It is even possible to realize radii with almost zero millimeters. On the other side, the need of a bigger bending radius comes with the threat of high spring back. [Geo06]

Various sources define the minimum flange height as at least three times the material thickness. This is only an approximation. In reality the flange height depends on the maximum possible forming forces of the roll forming line. Figure 33 shows that for a flange length of the value *a*, the force needed (F_1) for the forming process needs to be much higher than at a flange length *b*. Nevertheless, a high flange increases the ratio of band length to bending edge and therefore the threat of unwished axial tensions. [Geo06] , [Cor12] , [Sam12]

The maximum profile seam width is defined as 60 times the material thickness (Figure 33). Increasing this value can lead to an instability of the sheet metal because of missing strain hardening. In order to achieve a wider seam, maybe a given criterion from the customer, additional bending edges can be introduced into the profile geometry. Figure 34 (left) shows an example with two additional bending edges in the seam. With such a design, the seam width *B* can exceed 60 times the material thickness. The value W_O depends on the roll geometry. Unfortunately, wider seams generate a threat of profile waviness. In order to compensate the waviness, additional bending edges can be introduced as shown in Figure 34 (right). [Geo06] ,[Cor12]

The value for the minimum profile length L_B should at least be two times the distance (*HD*) between two roller sets. [Geo06]

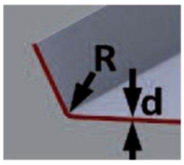
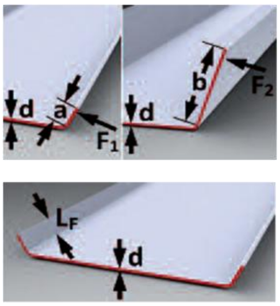
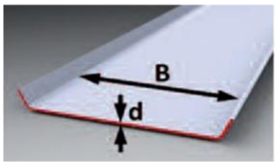
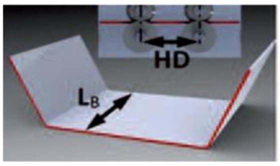
Bending radius	Flange height	Seam width	Profile length
			
$R \geq 2 * d$	$L_F \geq 3 * d$	$B \leq 60 * d$	$L_B \geq 2 * HD$

Figure 33: Various construction rules for profile design [Wir13]

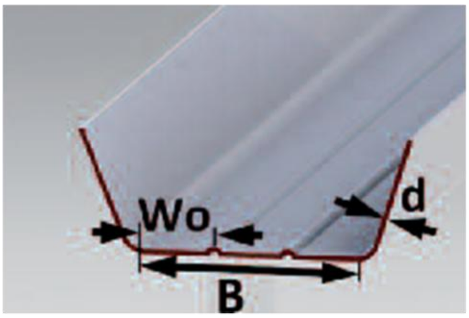
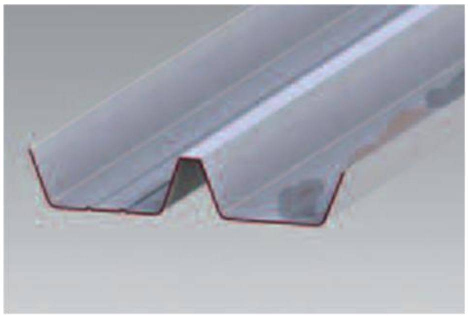
Additional bending edge for wider seam geometry	Additional bending edge for a smoother straight seam geometry
	

Figure 34: Profit of additional bending edges in a profile [Wir13]

Additional blanking rules for profiles

Blanking of materials with thicknesses up to 6 mm is nowadays easily realizable for state of the art blanking units. Figure 35 gives an overview of different construction rules that have to be considered for a successful blanking operation.

The gap (L_S) between the punch and the bending edge is limited to a minimum of four times the material thickness. [Geo06]

The constructor also needs to be careful with punches near the band edge. There is no direct guideline for the gap *i*. But as it can be seen in Figure 35 with a too little gap the punches tend to deform because of the global band edge deformation. To reduce the possibility of the punch deformation, counter-measures would be to increase the gap i or increase the number of roller stand to be able to decrease the forming angle for the single stands. [Geo06]

The gap *j* is similar to *i.* The reason for such deformations lays in the profile tension transverse to the feed speed direction. In order to avoid this deformation, the gap should be at least four times bigger than the material thickness (Figure 35). [Geo06]

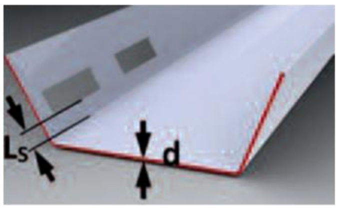
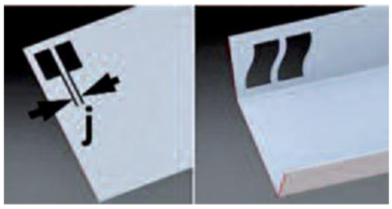
Gap between punching and bending edge	Gap between punching and band edge	Gap between punching and punching
		
$L_S \geq 4 * d$	Depends on the forming length L; L depends on the bending angle	$j \geq 4 * d$

Figure 35: Various construction rules for blanking operations [Wir13]

Roll forming is a chipless forming process. Hence, the material volume is constant through the whole forming process. A slight change of material thickness through the forming process and the constant volume of the material leads to slight changes in length. This also affects the position of the punches as seen in Figure 36 (left). [Geo06]

If the profile design requires punches in the bending edge (Figure 36 right), the constructor also needs to be aware of a potential reduction in stability of the profile. Furthermore, a discontinuous bending edge can also affect the dimensional accuracy. [Geo06]

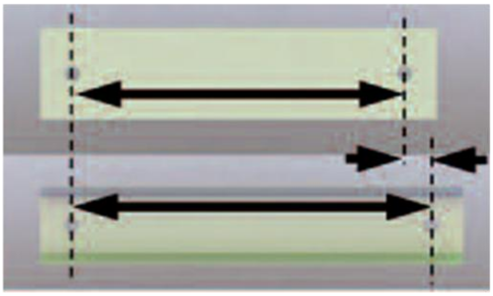
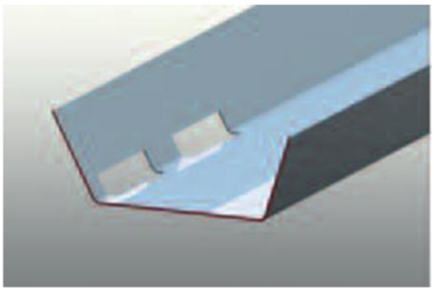
Increase of punch length due to an decrease of material thickness	Discontinuous bending edge
	

Figure 36: References for an accurate profile design [Wir13]

Additional rules for profile feasibility

Besides various construction and design rules the most important aspect is the feasibility of the profile. The profile designer needs to consider also the working space needed for the rolls. If the flange in Figure 37a creates a blind angle, the upper rolls do not have accessibility to the bending edge anymore. This results in no more possible forming steps. A shorter flange instead allows the upper rolls to have the needed accessibility for further forming steps (Figure 37b). [Geo06]

Blanking operations during the forming process need to have enough space for the blanking tools. O defines the gap between the punch and the profile seam. If the gap is too little, there is no more available place for the punch support tool (Figure 37 right). Furthermore, the removal space for the scrap also has to be considered in the design of the line. [Geo06]

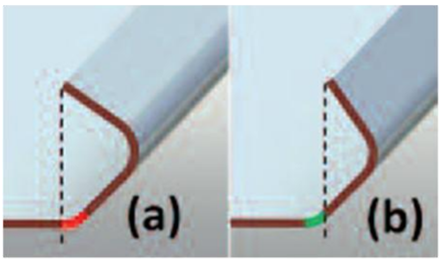
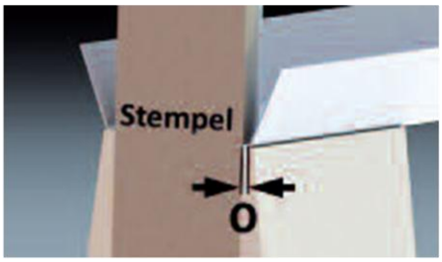
Prevention of a blind angle	Place for punching tool
	

Figure 37: Profile feasibility [Wir13]

2.2 New Roll Forming Concepts and Developments

The shortage of nowadays resources leads to an ongoing of research and development with the outcome of new roll forming technologies. The main focus of new technology developments lies in the light weight design. A good example for light weight construction is the automobile industry. Lighter car design leads to a decrease of consumption figures like fuel on the on hand and to an increase of driving performance on the other hand. Light weight design can be realized in many different ways. More efficient materials, optimized profiles or even the integration of additional functions in an existing profile can lead to a lighter product design.

This chapter focuses on recently new developments in the field of roll forming combined with light weight design.

2.2.1 Product Optimization through High- and Ultra-high Strength Steels

These kinds of steels emerge either from a combination with alloyed elements or with a proper after-treatment of the steel material. Compared with conventional steels, high- and ultra high-strength steels have higher tensile strength (Figure 25) than conventional steels at the same weight. [Sta03]

Roll forming is capable of forming high- and ultra high-strength steels. On the one hand because local frictions are kept small and therefore wear is low and on the other hand springback can easily be kept under control in comparison with other forming technologies. Materials with higher tensile strength lead to the need of stiffer roll forming frames and higher drive powers.

Nevertheless, roll forming is getting used to be called the key technology for forming high- and ultra high-strength steels. [Röc08]

2.2.2 Product Optimization trough Combination of Material Rolling and Roll Forming Technology

State of the art profiles are usually produced out of semi-finished products with constant thickness. The workload distribution on finished products is normally not constant. That means, the products cross-section in terms of thickness is not optimally distributed, because the designer has to design according to the highest workload. Thus, even sections with very low workload where the thickness could be less have the same like the section with the highest workload. Such a design decreases not only the product´s weight but also its costs.

New developments are focusing on a proper semi-finished product cross-section with an ideal thickness distribution. The two most important ones are discussed in more detail below.

1. **Tailored blanks:**
   An improved thickness distribution is achieved with tailored blanks technology. Tailored blanks are semi-finished products with different thicknesses over the sheet length. It can be further divided into Tailor Welded Blanks (TWB) and Tailor Rolled Blanks (TRB). [Gro10]

   Tailor welded blanks are produced by welding two or more different sheet metals together. Theses sheet metals can be different in thickness, tensile strength or surface treatment. With tailored blanks semi-finished products, material weight can be drastically reduced. Tailored blanks can have a simple geometry with linear welds or complex shape with non-linear welds. This type of tailored blank is usually used for automotive body parts such as rails, floor and their cross members, body side and inners, A, B and C pillars, etc. Geometry examples can be seen in Figure 38. [Arc13]

   Tailor rolled blanks are produced through flexible material rolling. The gap between the rolls is adjusted during the rolling process. As a result, a material with different thickness sections over the length is produced. Through roll forming, profiles can be produced that are perfectly shaped according to their different workloads in each section. Hence, sections with a high workload have a higher thickness while sections with lower workload are built with lower thickness. Not only weight can be reduced but also the additional welding process is redundant which makes this technology even more interesting for economical aspects.

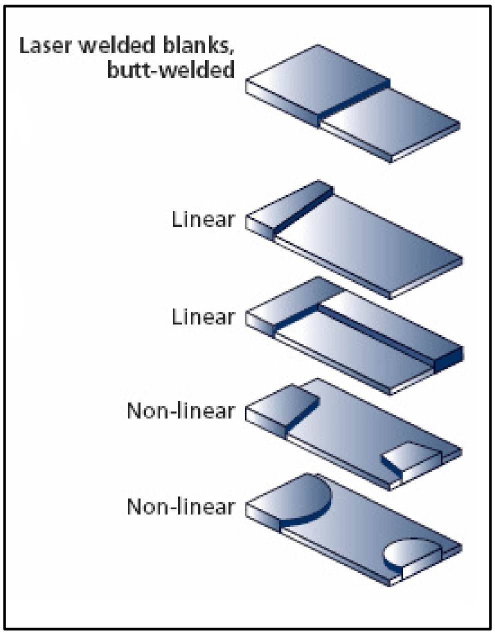


Figure 38: Geometry examples of tailor welded blanks [htt13]

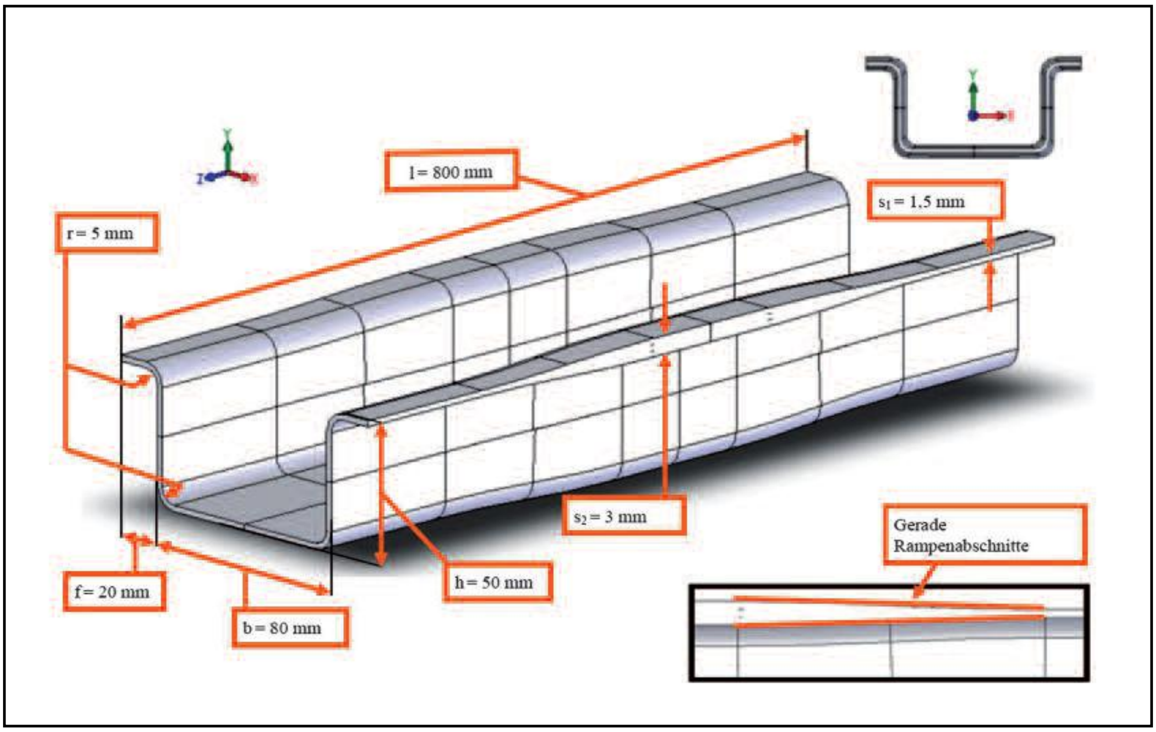


Figure 39: Model of a U-profile made of tailor rolled blanks [Gro101]

Besides all advantages, it has to be mentioned that the roll forming process is getting more complex with TWB or TRB. For both semi-finished products applies that the rolls need to be variable in height and width to cope with the differences in material thickness. Furthermore, particular attention has to be paid regarding the different springback properties of the different thickness sections.

Especially for TRB an additional problem occurs. To be able to get a straight outer edge the semi-finished product needs to be tapered in the sections with higher thickness. Otherwise, there would be a bulge occurring in these sections of the finished profile. [Bei11]

2. **Tailored strips:**
   An additional possibility to produce workload oriented profiles is achieved with tailored strips technology. Tailored strips are semi-finished products with different properties over the sheet width. It can be further divided into Tailor Welded Strips (TWS) and Tailor Rolled Strips (TRS).

   Tailor welded strips are a further developed technology of tailor welded blanks. Strips are welded together along their longitudinal band edge. The manufacturing process can be seen in Figure 40. The result is a semi-finished product with different properties over the band width. Profile examples with a difference in thickness over the width are shown in Figure 41. It can be seen that the difference in material or material properties over the cross-section can be placed in every imaginable way. [Jac10]

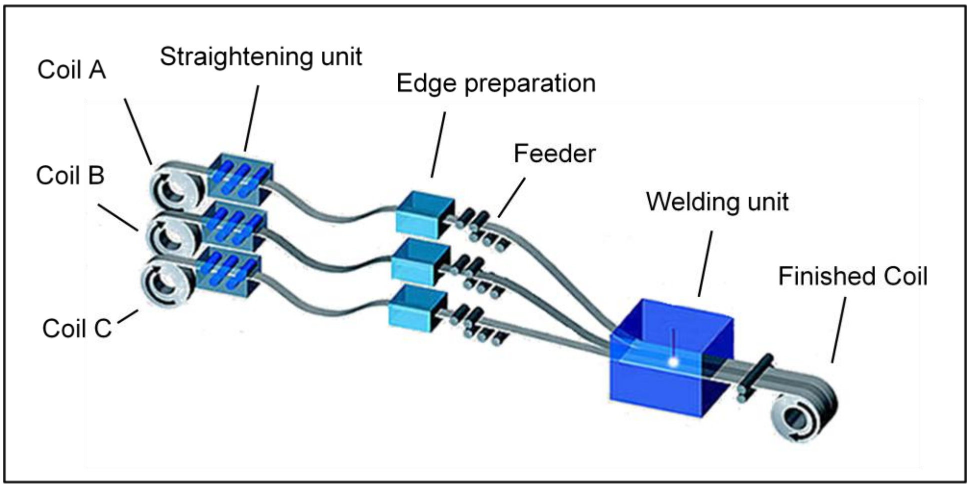


Figure 40: Manufacturing process of tailor welded strips [Kon13]

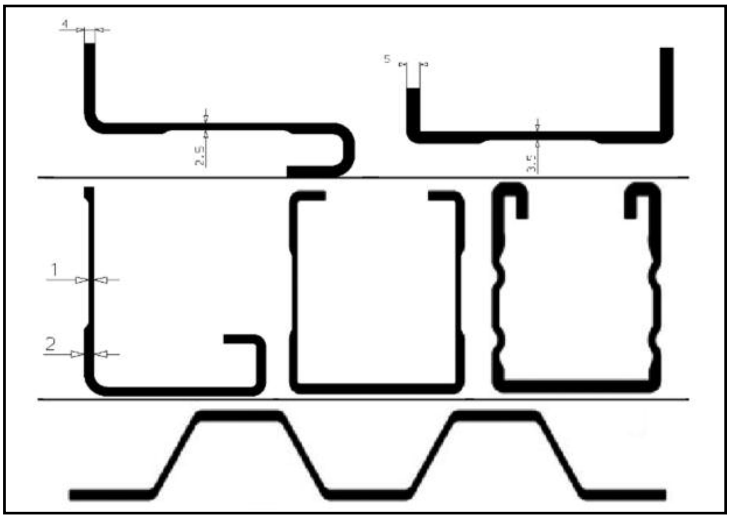


Figure 41: Profile examples with a difference in thickness [Wel12]

Tailor rolled strips have the same manufacturing process than tailor rolled blanks. Also the possible different properties of the semi-finished product are the same. The only exception is the more continual manufacturing process and therefore the slightly better compatibility with the roll forming technology.

2.2.3 Flow Splitting Technology

With flow splitting technology it is possible to manufacture profiles with more than two band edges. According to DIN 8583-1 flow splitting belongs to the compressive forming group. The manufacturing process is described in Figure 42. With the use of splitting- and supporting rolls the band edge gets cleaved into two new separate flanges. The number and the depth of the single cuts define the cross section of the finished profile.[DIN031]

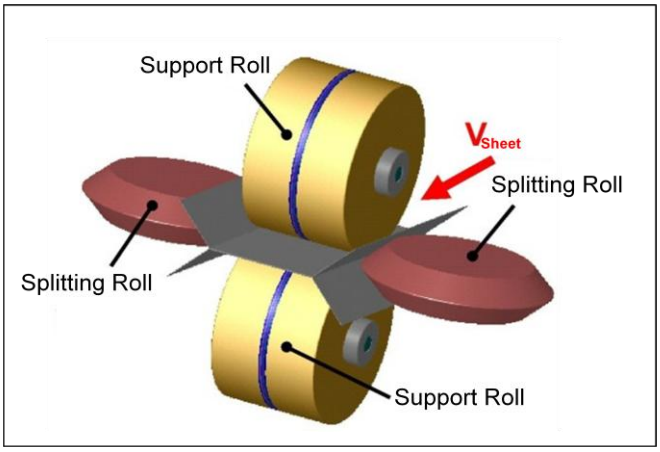


Figure 42: Flow splitting 3D-model [PTU13]

The flange length can be increased with an additional number of cuts (Figure 43). In contrast to conventional splitting techniques, the rolls are carried blunt. With such a design, the hydrostatic forces in the forming zone are much higher than with conventional sharp design. This comes with a much higher possible formability of the material.

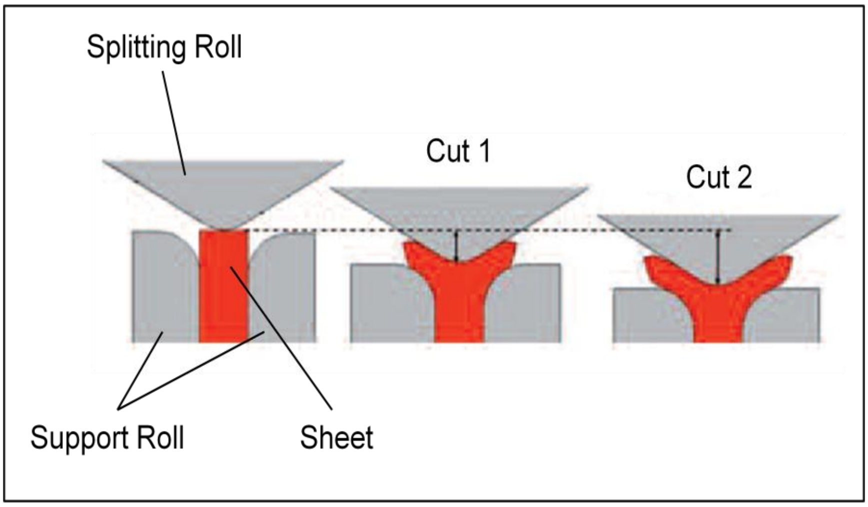


Figure 43: Flow splitting principle [Rin08]

Figure 44 (left) shows a profile with flow splitting treatment on both band edges. Figure 44 (right) shows further processing with roll forming technology with a finished product design of a single chamber profile with two flanges.

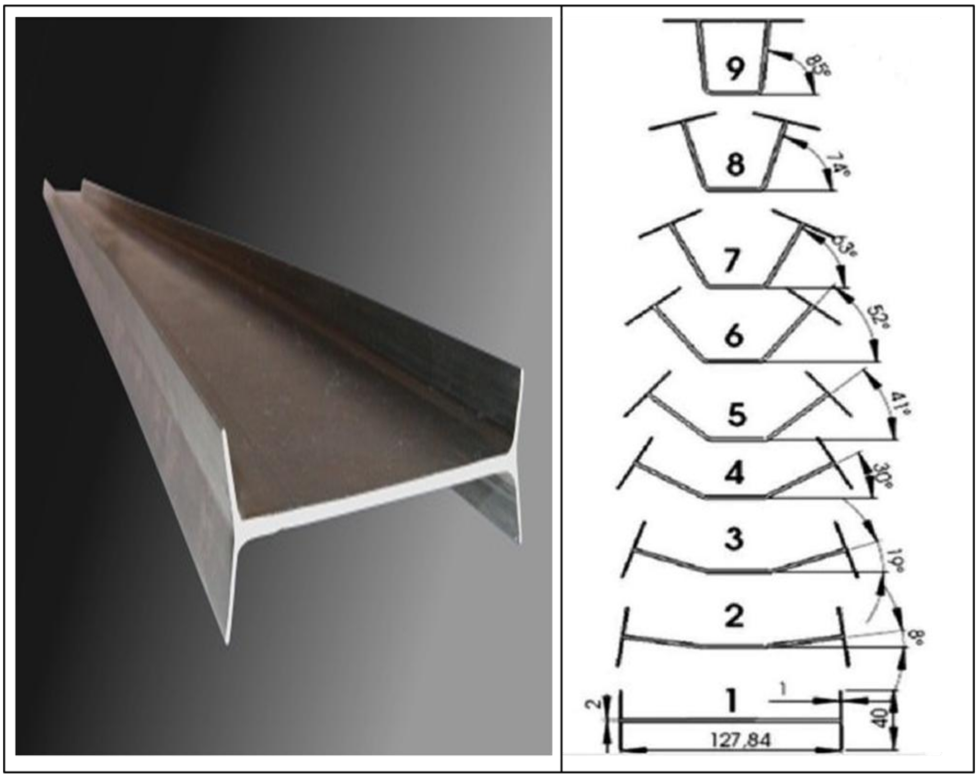


Figure 44: Flow split semi-finished product [PTU13] and further processing possibilities with roll forming [Rin08]

An additional advantage of further processing semi-finished flow splitting products is the possibility to manufacture profiles with more than two chambers. Figure 45 shows some examples of multi-chamber profiles with additional welding operations. To enable a welding process to generate a closed profile, it is important to have weld-able band edges.

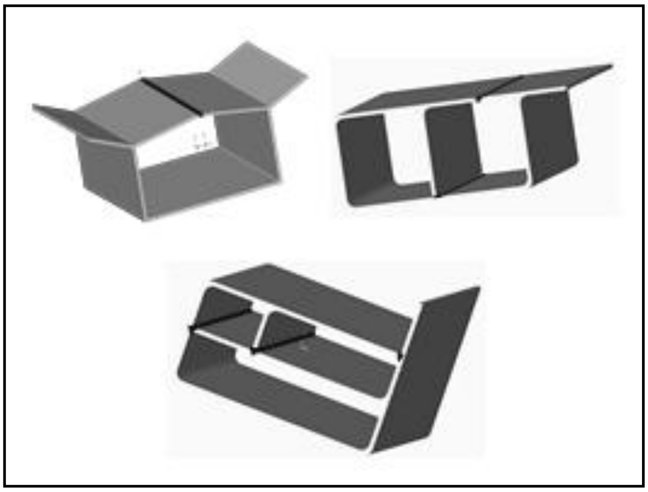


Figure 45: Multi-chamber profiles manufactured with flow splitting [PTU131]

2.2.4 Bend Splitting Technology

Bend splitting is a technology which evolved out of the flow splitting technology. Flow splitting allows building branches at the band edges but only at the edges. This limits the number of additional possible branches to two. In order to be able to make more than two branches it is either necessary to join together two or more already branched profiles or to use bend splitting. Unlike to flow splitting, bend splitting creates a flange out of a bending edge. This can be done at any random bend edge of the material. Hence, an already bent sheet metal is the basis. In this case it is an asset to pre-manufacture the sheet metal with roll forming. Figure 46 (left) shows the principle of bend splitting. It can be seen that the used forming tools are quite similar to flow splitting. Figure 46 (right) shows the formation of a flange with several single strips. [Rin081]

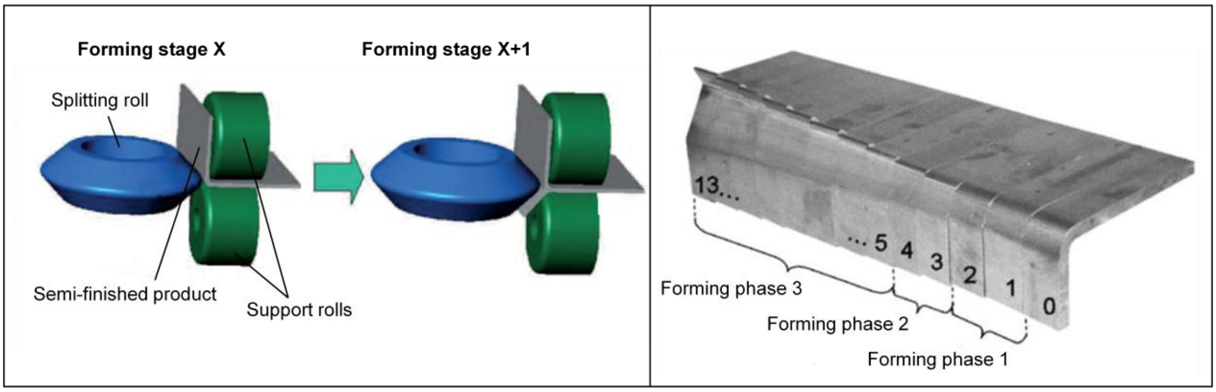


Figure 46: Left: Process principle for bend splitting [Gro04] ; right: Flange formation at the bend edge [Gro09]

With a combination of roll forming, flow- and bend splitting, it is possible to create an almost infinite number of possible profile geometries with a different amount of branches and chambers and different thicknesses through the cross-section. Figure 47 shows four profile examples for a better understanding of the unlimited possibilities.

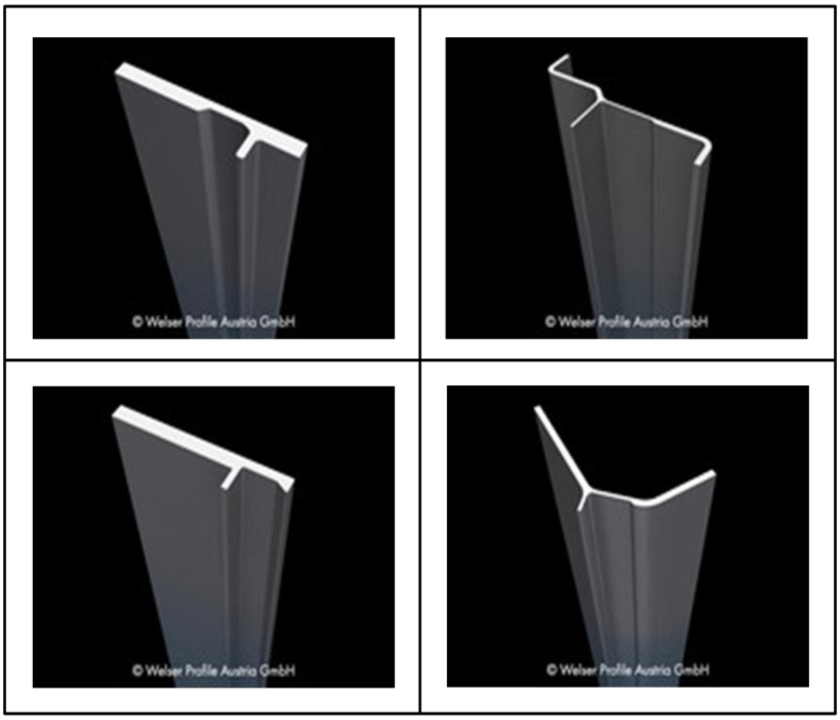


Figure 47: Profile examples manufactured with bend splitting [Wel13]

2.2.5 Flexible Roll Forming

Flexible roll forming is one of the latest developed roll forming technologies. Compared with conventional roll forming, where a constant cross-section over the profile length is given, with flexible roll forming, it is possible to manufacture profiles with changing cross-sections over the profile length. Hence, profiles can be designed according to the occurring workload in the different profile sections. Through the combination of conventional and flexible roll forming an even greater number of different profile geometries can be manufactured. Figure 48 shows some flexible roll formed profile examples.

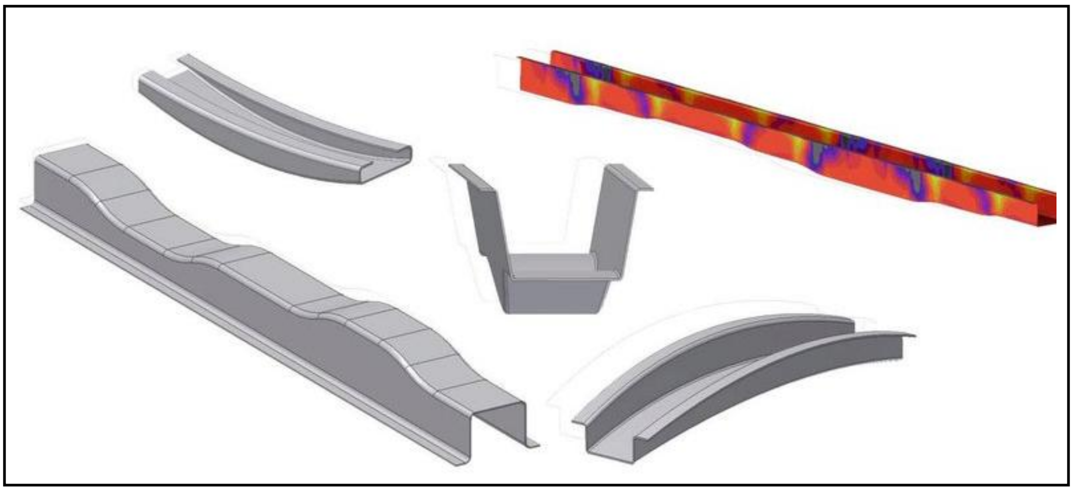


Figure 48: Profile examples manufactured with flexible roll forming [BBR13]

The flexible cross-sections are manufactured with the help of moveable rolls (transversely to the profile movement). The principle of flexible roll forming is shown in Figure 49 (left). It can also be seen that the construction of a roll forming plant with implemented flexible roll forming is getting more complex and more space is needed. Nevertheless with an accurate design it is possible to manufacture many different profile shapes with only one set of flexible rolls. The flexible rolls are usually computer-controlled. With such a computer-aided control it is possible to form the profile exactly according to the target shape seen in Figure 49 (right). [Zet07]

Similar to tailored blanks and tailored strips it can be necessary to pre-cut the semi-finished products depending on the desired profile end geometry.

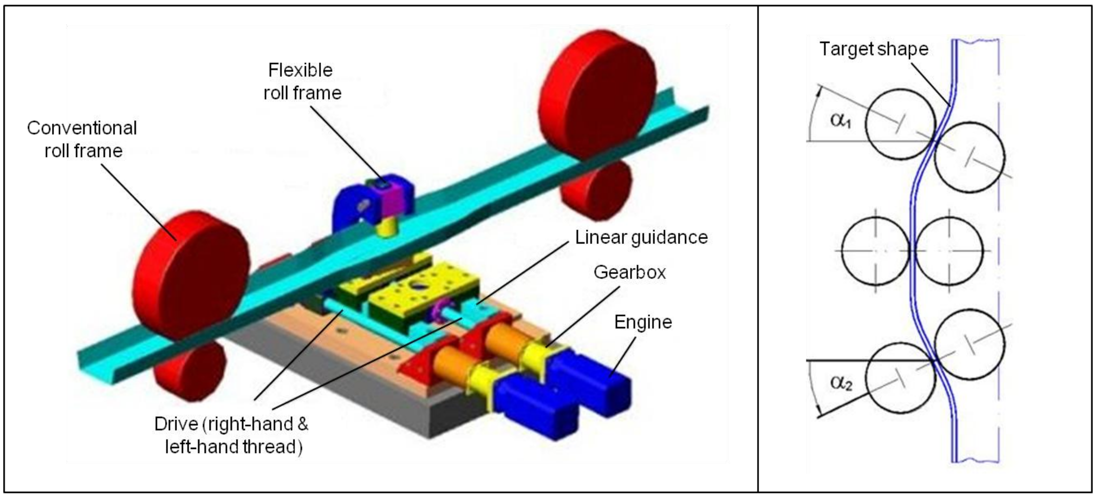


Figure 49: Left: Flexible roll forming principle [PTU132] ; right: Cross section of the flexible area [PTU133]

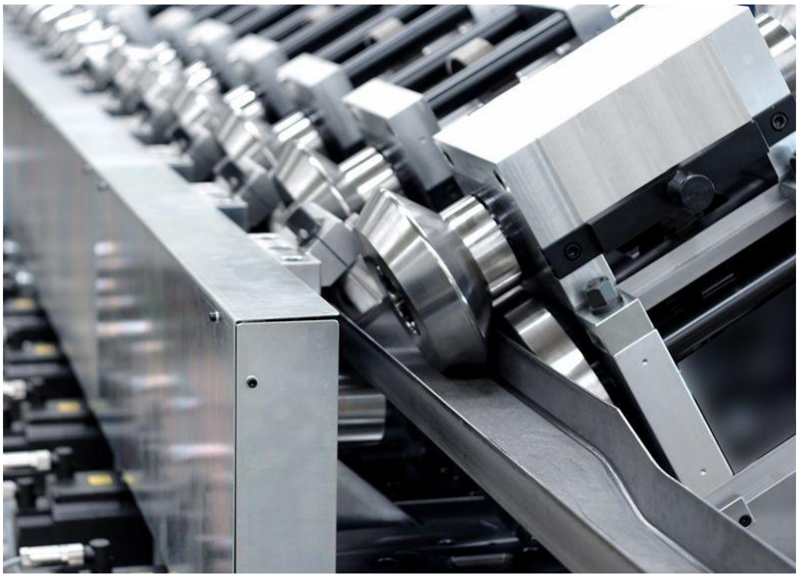


Figure 50: Flexible roll formed product [Sta131]

2.3 Structural Analysis of the Industry

The crucial part in defining a competitive strategy is to link the company with its environment. From the companies point of view the key aspect of environment is the industry in which it competes. The structure of the industry has a strong influence on the company's strategy, the competitive rules of the game as well as defining the entry barriers for newcomers. Michael E. Porter defined five basic competitive forces which will be shown in more detail in the following chapter.

2.3.1 Forces Driving Industry Competition

The state of competition in a branch is dependent on five individual forces (potential entrants, buyers, substitutes, suppliers and industry competitors) which are shown in Figure 51. The sum of these forces defines the ultimate profit potential a company can have in the industry. The potential depends on the combined power of the five forces. That also means that not all branches have the same profit potential.

A number of important technological and economical characteristics of an industry branch determine the strength of each individual competitive force. This chapter will identify these characteristics.

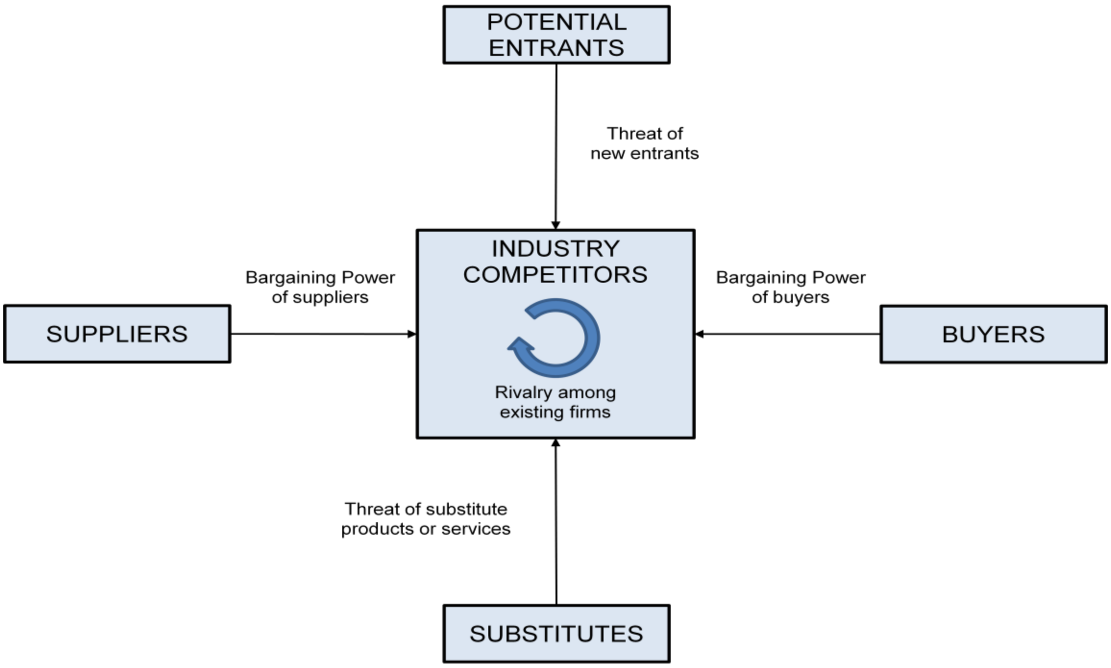


Figure 51: Forces driving industry competition [Mic04]

2.3.1.1 Threat of entry

New entrants into an existing industry provide new capacities. Price dumping, or increasing costs for already established companies can be a result of this. This can lead to a decrease in profitability. The threat of new entrants depends on existing entry barriers as well as on the reaction of existing competitors. If the barriers are high and/or the newcomer has to anticipate strong counteractions from entrenched competitors the threat of new entrants is low. In the following the seven essential entry barriers are discussed.

1. **Economies of scale (EOS):**
   Economies of Scale refer to a decrease in units costs of a product due to an increase of total volume produced per period. This forces the new entrant to either start the production with the same volume like an already established company, which can lead to strong reactions of already established companies, or to start with lower production volume and hence having higher production costs. Both are undesirable options. EOS can occur in almost every division of the business, including purchasing, R&D, manufacturing, marketing, etc.
   A similar type of an EOS entry barrier can occur when there are economies to vertical integration. That is, operating in consecutively stages of production or distribution. The new entrant has to enter vertically integrated otherwise he has to face a cost disadvantage, as well as possible locked markets or inputs for his products. The reason for this is, that most customers buy in-house units as well as the most suppliers sell their components in-house.
   The new entrant is facing two problems. First, it will be hard achieving comparable prices to competitors and second, the new entrant is running the risk of getting squeezed if integrated competitors (sellers and purchasers) offer different conditions compared to already established companies.
2. **Product differentiation:**
   Product differentiation means that established companies have a solid brand and customer loyalties that arise from customer service, product difference, advertisement or simply being the first in this industry sector. The new entrant is forced to spend a high amount of budget only for overcoming the existing brand and loyalties. This always leads to a start-up loss. Such investments are coming with a high risk, due to the reason that they have no salvage value if the entry fails.
3. **Capital requirements:**
   The need of a large financial investment in order to get into a specific market creates an entry barrier, particularly if the capital is needed for non-recoverable advertisements or research and development. Furthermore if the capital is not needed for e.g. production plants but for credits, inventory, to cover up entry losses, etc.
4. **Switching costs:**
   Switching costs are one-time costs that the buyer needs to be aware of when switching from one suppliers product to another’s. These costs may include product redesign, cost of new ancillary equipment, employee retraining costs, technical help, or time and costs

testing the new product source and product itself. If switching costs are high, the new entrant has to offer lower costs, increased product quality, or other additional performances. Otherwise the buyer will not switch.

5. **Access to distribution channels:**
   Existing distribution channels are normally saturated by the established companies. In order to secure the distribution of products of the new entrant, access to these channels is required. The access is difficult and in general can only be obtained by price reductions and advertisements. This leads to lower profit.
   Established competitors may have solid bonds between these channels based on long term relationships and high quality services. It happens that the entry barrier is so high that to overcome it the new entrant needs to create a completely new distribution channel.
6. **Cost disadvantages independent of scale:**
   Established companies may have cost advantages not reproducible for potential new entrants no matter what their economy of scale or size is. Factors that generate such an advantage are listed below:
   - Proprietary product technology (e.g. patents, know-how)
   - Favorable access to raw materials
   - Favorable locations
   - Government subsidies
   - Learning or experience curve

   If costs decrease with an increase of know-how in an industry, and if the experience is kept within the company, then this effect leads to an entry barrier. New entrants with no or hardly any experience will have higher costs then already existing companies in this sector.
7. **Government policy:**
   Government Policy can restrict or even prevent market entry by forcing licenses or limit the access to raw materials. Furthermore there can be governmental restrictions like controls of safety- and efficiency regulations, or environmental limits that cannot be exceeded. These reasons can not only lead to an increase of costs, but to delays of the market entry itself. This may give established competitors knowing about the potential entry and, under some circumstances, even knowledge of the potential product of the new entrants. With the help of this information they can formulate retaliation strategies, which can complicate the entry into the market even more.

Counteractions

There can be a lot of possible counteractions of already established competitors in the business. Below there is a short overview of conditions that signal potential high threats of competitors against new entrants.

- Strong counteraction against former new entrants
- Established companies possess power for substantial resources to fight back. (e.g. excess liquidity, unused capacities that can be used to cover upcoming market needs, unexploited creditability)
- Strong position and access to available distribution channels
- Slow market growth which restricts the market to establish potential new entrants, without reducing the revenue and financial performance of established companies.

2.3.1.2 Intensity of Rivalry among existing Competitors

Rivalry between existing companies is shown in a form of fighting over positions. This fighting is characterized by, price competition, new product introductions, advertisement battles, and increased customer services and guarantees. Rivalry occurs because one or more competitors feel crowded to improve their current market position. This action can have either a positive influence onto the market, or a negative. It can lead to price dumping for the whole branch. This leads to reduced revenue for the total industry sector. Advertisement battles, however, may also increase the demand and the product differentiation on the existing market. This causes a benefit for all companies within an industry.

Intensive rivalry is a result of combined structural factors listed below:

1. **Numerous or equally balanced competitors:**
   If the number of companies within a branch is high, there is the possibility that companies improve their position without being noticed by the competitors. Even with relatively few companies within a branch that are comparable in terms of perceived resources and size, instability is created because the affinity to fight each other and have resources for sustained retaliation is high. If the branch is dominated by a few or only one enterprise, such fighting over resources or rankings in the branch is usually not taking place. In this case the industry leader takes a coordinative role.
2. **Slow industry growth:**
   A slow industry growth normally results in intense fighting over market share. The competition over market share is much higher than in a situation of rapid industry growth. That's because only keeping up with the industry growth automatically results in an improvement of the company's financial results.
3. **High fixed or storage Costs:**
   High fixed costs force companies to fill capacity, which often leads to produce surplus. Surplus on the other hand, lead to rapidly price cutting when excess capacity is present. Various basic material producers like for example steel or paper industry suffer under these circumstances.
   A similar problematic occurs when the product is very cost intense or difficult to store. Companies therefore try to shade prices in order to insure sales. Thus, the profit gain is

kept small, for example, in the hazardous chemical manufacturer or lobster fishing industries.

4. **Lack of differentiation or switching costs:**
   In industries where the final product or service is an article of daily use the buying decision is mainly based on price and service. This leads to intense service and price competitions. Product differentiation, on the other hand, prevents such competition because it creates personal preferences and therefore loyalties of the buyers. Switching cost behave the same way.
5. **Capacity augmented in large increments:**
   Where EOS and a technological based minimum of company size prescribe that capacity must be added in large increments, a capacity increase can lead to disturbance in the equilibrium of supply and demand. The branch may face periods of price cutting and overcapacity.
6. **Diverse competitors:**
   Competitors within a branch diverse in strategies, personalities and origins. They may have different goals and strategies for how to compete against each other in order to increase market share. The variation in goals and plans can stand in conflict to each other. It can be hard to read each other's intentions and act accordingly to that. Thus, setting "rules of the game" can be rough. The right strategic choices for one competitor can be wrong for others. Foreign competitors often bring a large amount of diversity into the market
7. **High strategic stakes:**
   If companies try to be successful in a specific branch no matter the costs, rivalry can reach a high level. The financial effort is secondary if only the success is given. Such goals can destabilize the branch because there may be the willingness to sacrifice profitability in order to reach goals.
8. **High exit barriers:**
   High exit barriers can result in companies not leaving the branch even if earnings and profits are low or even negative. The barriers can consist of economic, strategic and/or emotional factors. Sources of such exit barriers are listed below:
   - Specialized assets
   - Fixed costs of exit
   - Strategic interrelationship
   - Emotional barriers
   - Government and social restrictions

   If entry barriers are high, small or weak companies are often forced to stay in the branch even against their will. This may lead to extreme actions of those companies in order to earn profit. As a consequence profitability of the branch is kept low.

Entry and exit barriers

An important aspect of the structural analysis of an industry is the connection between entry- and exit barriers and their connection to each other. Figure 52 shows the simplified case in which those two barriers can be either low or high.

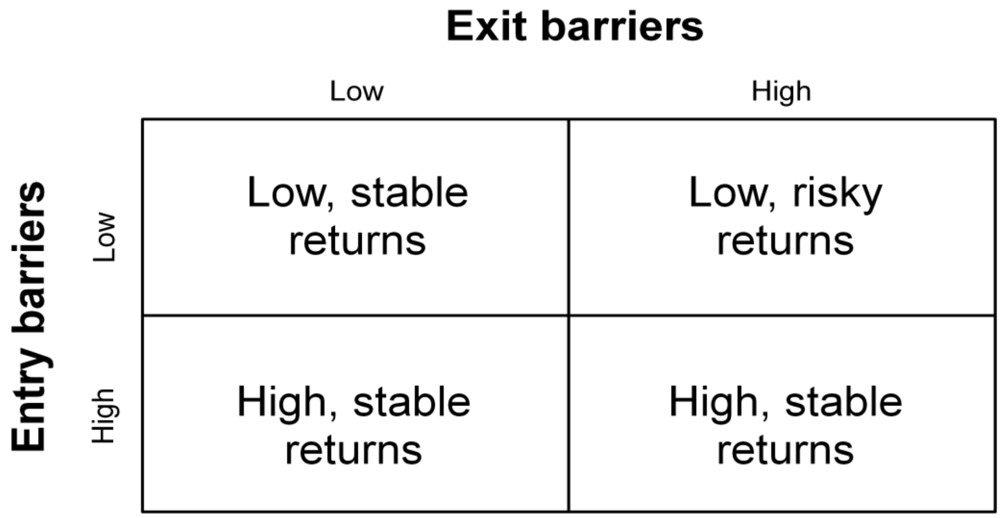


Figure 52: Barriers and profitability [Mic04]

On the point of view of profits for an already established company in a branch, the best case would be having high entry barriers, to lower the threat of new entrants but low exit barriers, to not have the risk of facing excessive actions of companies that are forced to stay in the branch.

The worst case for established companies would be the other way around. That means, having low entry barriers, so the branch gets saturated by new entrants, but having high exit barriers so the new entrants are not able to leave the branch if wanted to.

2.3.1.3 Pressure from Substitute Products

Companies not only compete against each other in their own field of interest, but also against branches in which substitutes are produced. Substitutes are products that have the same or similar benefit as the original product and hence can replace it on the market. Substitute products can be hard to identify. It is necessary to search for products that can perform similar functions like the original product. Sometimes this can lead to complete different business sectors.

They generate a threat within the branch because they lower the profit potential, especially the more attractive the price-performance ratio of substitutes is. Competing against substitute products can be a matter of collective industry actions. Advertisement from a single company for example may not be enough to strengthen the product. On the other hand, large and sustained advertisement by the whole industry may lead to an improved position of the branch.

2.3.1.4 Bargaining Power of Buyers

Buyers of products or services influence the profitability of a branch by forcing down prices, claiming better quality or more service, and playing off competitors against each other. The bargaining power of buyers depends on a number of characteristics of the market situation. If the following conditions prove true, a buyers group is considered powerful:

1. **Concentrated buyers:**
   If one buyer purchases almost all or at least a large portion of the sales in a branch, the importance and the power of the buyer rises. In branches with high fixed costs the bargaining power of such large-volume buyers rises even further.
2. **The products represent a high fraction of the buyers overall costs:**
   In order to reduce the overall costs, buyers are prone to extend the resources necessary to constantly search for alternative suppliers with lower prizes.
3. **Standardized products or no differentiation:**
   Within the branch, the products have no or less differentiation. The buyer knows that he can always find another seller and hence he may play one company against another, e.g. in steel production.
4. **Low switching costs:**
   Low switching costs for buyers increase their bargaining power because the obligation to a seller is low or not present.
5. **Low profits:**
   Low profits forces the buyers to tough product price negotiations with the supplier. As a result purchase costs are decreasing and the profit rises.
6. **Buyers pose threat of backward integration:**
   If buyers are partly integrated or pose threat of backward integration they have a good position to drive a hard bargain. Practicing partial integration, that means, producing some of the needed parts for their product in-house and purchasing the rest from suppliers, gives them not only creditability for further integration but also a detailed knowledge of costs and thus gives additional bargaining power.
7. **Industry product is unimportant to buyers product quality or services:**
   If the quality and services of the industry’s products are important for the buyer’s product, they are normally less price sensitive. If such a dependency is not given the bargaining power is higher.

8. **Buyer has full information:**
   The more information the buyer has about actual market prices, demand and supplier costs, the higher is his bargaining power compared to when information is poor.

A company's choice of buyer groups to sell to should always be an important strategic decision. To improve the position in the branch it is always favorable to find buyers with hardly any bargaining power. In other words, buyer selection is crucial.

2.3.1.5 Bargaining Power of Suppliers

Suppliers can show their bargaining power by threatening to reduce the quality of products and services or to raise prices. Powerful suppliers can thereby reduce the profit of an industry to such an extent that companies may not be able to withstand such a reduction of profitability. The conditions that have to be given to consider suppliers as powerful in terms of bargaining power have a tendency to mirror those making buyers powerful. The conditions are listed below.

1. **Concentrated supplier:**
   A concentrated suppliers group that delivers to a fragmented buyers group has higher influence on price and quality of the products. Furthermore, the suppliers may have the power to design delivery conditions in their favor.
2. **No threat of substitute products:**
   Substitute products have the ability to lower the bargaining power of suppliers because they can easily replace the original product. If there are no suitable substitutes, the supplier's power is high.
3. **Industry is less important for the supplier:**
   When suppliers sell to a number of different industries and their profit and sales are not dependent on a particular industry, their bargaining power is high. If an industry is an important customer and their turnovers are linked together, the supplier is forced to maintain a good relationship by helping in R&D activities and reasonable pricing.
4. **Suppliers products are an important input to the buyers business:**
   If the input of a supplier is important for the success of the buyer´s product quality or service the bargaining power rises. Especially when the input is not storable and the buyers are not able to build a stock.
5. **Differentiated products or high switching costs:**
   The bargaining power of the supplier is strong if buyers would have to face high switching costs and differentiated products when changing their suppliers.
6. **Threat of forward integration:**
   With a credible possibility of forward integration, suppliers are able to increase their bargaining power. Furthermore, the industry's ability to get terms and conditions in their favor is lowered.

2.3.2 General Competitive Strategies

Once the forces are diagnosed which are driving and influencing the level of competition within an industry are diagnosed, the company is able to identify their own strengths and weaknesses compared to the industry. From a strategic point of view the essential strengths and weaknesses are defined as the attitude of the company towards each competitive force.

An effective competitive strategy takes offensive and defensive actions in order to create a defendable position against the five competitive forces. Hence, the following global approaches are possible:

- Place the company in a way that its abilities provide the best possible defense against already existing competitive forces.
- Improve the company´s relative position by influencing the equilibrium of forces with strategic moves
- Anticipate future changes of the competitive forces and react accordingly by creating an appropriate strategy to the new competitive balance before rivals can do so.

2.3.3 Guideline to Conduct an Industry Analysis

At the beginning of an industry analysis it is important to know what kind of data is important and how to acquire it. Data is basically divided into published data and data gathered from interviews of branch participants and observers (field data). The focus is to identify, the important sources of both data categories, their strengths and weaknesses to each other and to generate the most effective strategy to advance with this information. Figure 53 gives an overview of the most important sources for gathering field data.

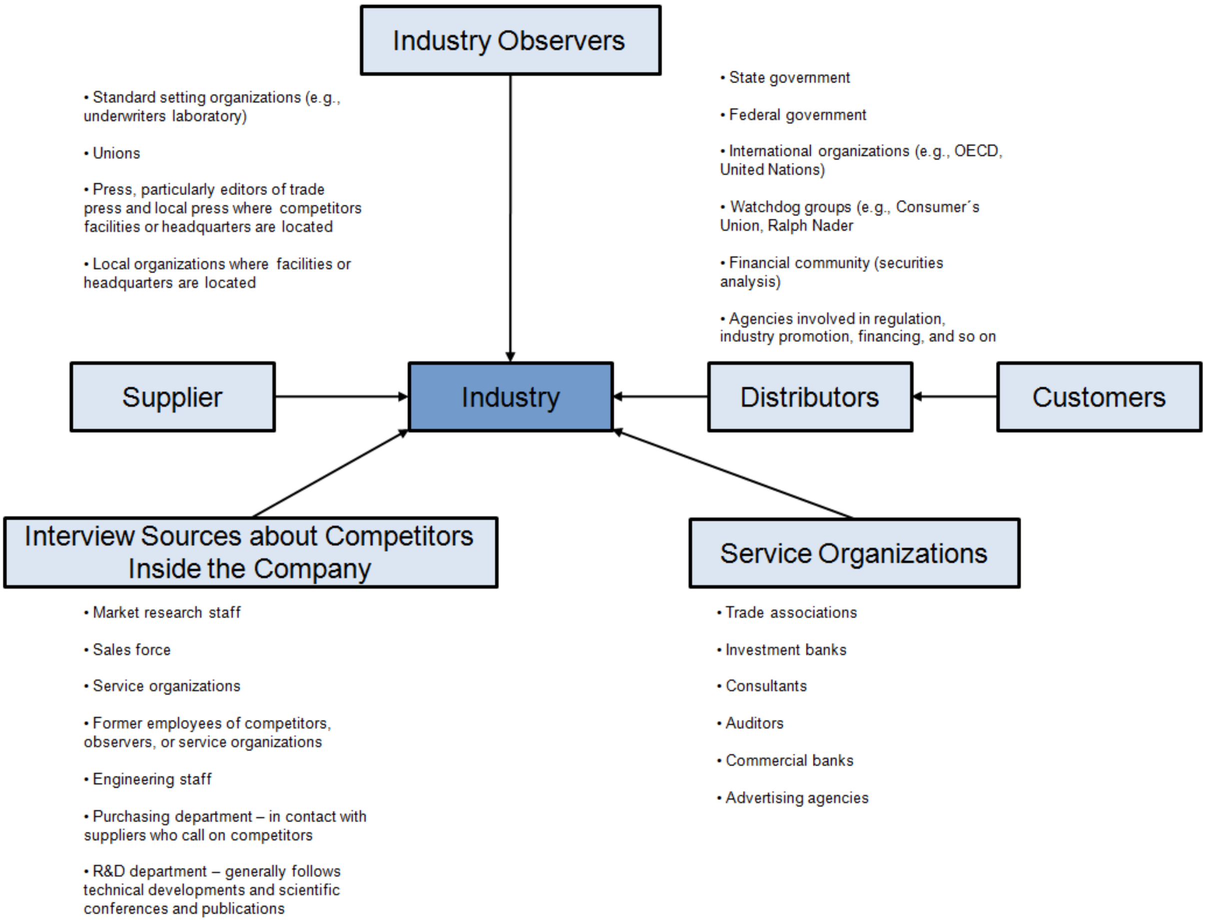


Figure 53: Sources of field data for industry analysis [Mic04]

The raw data storing needs to be done systematically in order to categorize the data. Thus, the follow-up analysis is simplified. A simple but efficient way to store data is to classify it according to the areas shown in Figure 54. The compilation of the raw data categories can be divided by **company**, **year** and **functional area**.

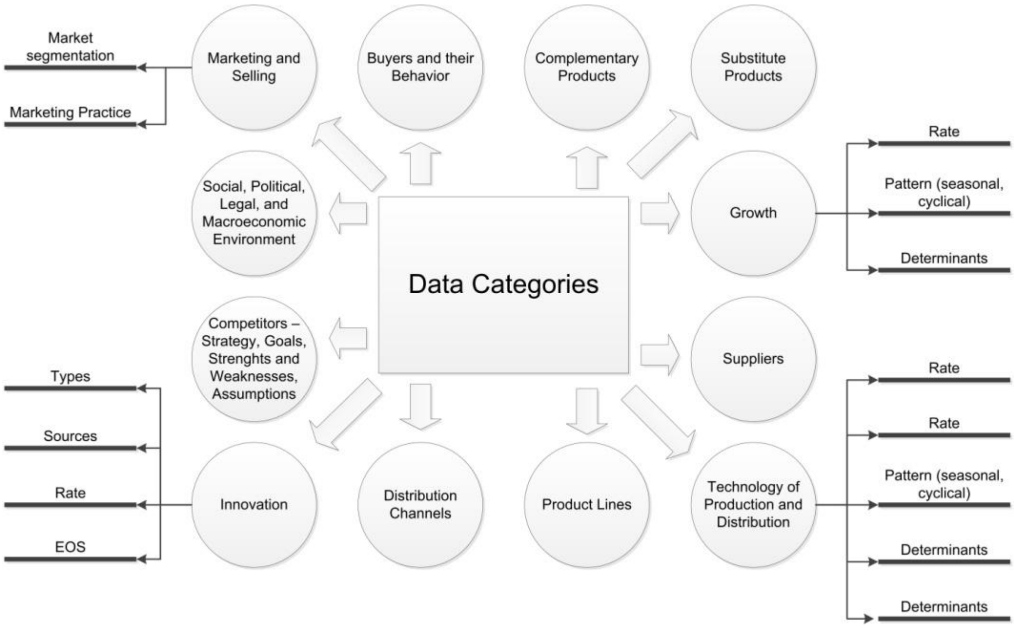


Figure 54: Raw data categories for industry analysis [Mic04]

After constructing a guideline it is important to get a general overview of the industry before focusing on details. Experience has shown that a broad understanding helps the researcher to be more effective in gathering important data. The following steps are a useful guideline to obtain this overview:

1. **Identification of industry´s participants:**
   It is useful to develop a rough list of the industry´s current participants and rank them according to their market share. Such a list helps to identify the major competitors. The *Standard Industrial Classification (SIC)* system classifies industry participants on a variety of different characteristics.
2. **Industry studies:**
   Already existing industry studies may be helpful for obtaining a general overview of the industry.
3. **Annual reports:**
   An overview of annual reports of a number of major participants over a period of ten to fifteen years is an excellent way to gather important information. However, having only access to a few reports may lead to a misunderstanding of the current situation in the industry.

2.4 Generic Competitive Strategies

Chapter 2.3 described offensive and defensive actions in order to create a stable position within the industry, to handle the five competitive forces and thereby earn a high return on investment (ROI). Many strategies were discovered in the past and the best solution for a specific company is always a unique construction. However, generally we can identify three independent generic competitive strategies that can be used separately but also in combination:

- Overall cost leadership
- Differentiation
- Focus

These strategies lead to a long term competitive advantage over companies within the industry. This chapter describes the three strategies and analyzes their benefits and risks. The basic differences among the strategies are shown in Figure 55.

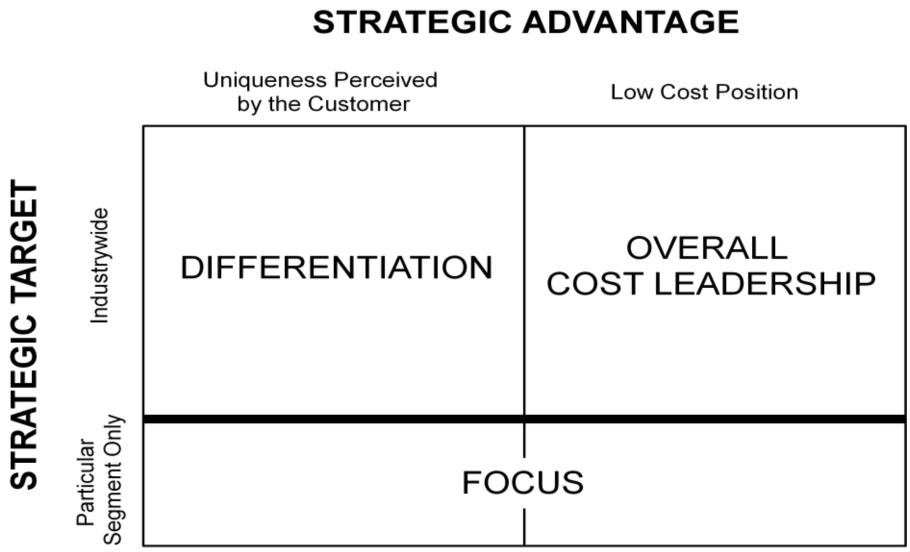


Figure 55: Three generic strategies [Mic04]

Usually a company focuses only on one approach as its primary target. Implementing those strategies into the company's vision and mission requires total commitment and support of the whole organization. Hence, it is not likely to have two different strategies at the same time, but it is theoretically possible.

2.4.1 Overall Cost Leadership

Based on the popularity of the experience curve the first strategy to obtain a competitive advantage and to solidify the market position is through overall cost leadership. A low cost position in relation to the competitors means that the company still earns profits after the competitors have competed away their profits through rivalry.

To acquire this position Robert M. Grant listed eight methods that are shown in Figure 56 and are explained below. [Rob02]

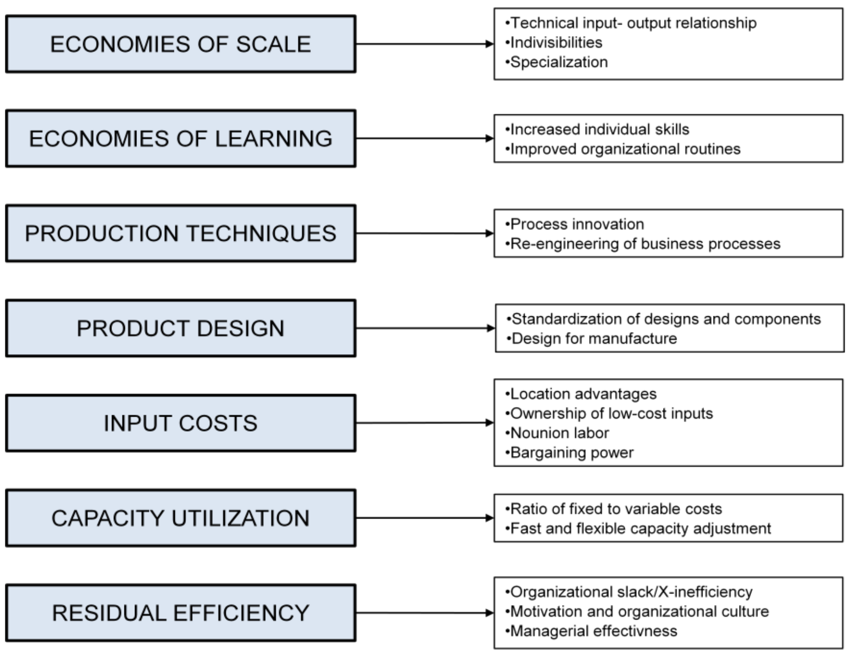


Figure 56: The drivers of cost advantage [Rob02]

1. **Economies of scale (EOS)**
   In almost every mass production industry EOS is a key determinant. The higher the sale volume is, the lower are the costs for R&D, advertisement, accounting per unit. With specialization, like Henry Ford`s automobile plants or the pin factory of Adam Smith, production costs can lowered even further. They broke down the production process into separate tasks. One worker was only doing one specific task. With this he got an expert in this field. This is connected to the economies of learning.
2. **Economies of learning**
   The basis of the experience curve is learning by doing. By repeating a process several times both, the individual skill and the routines necessary to the process are developing. For example, 1943 it took about 40.000 labor hours to build the B-24 liberation bomber. Two years later only 8.000 hours were needed. That is a reduction of 32.000 hours in total and a percentage reduction of 80%. [LRa65]
3. **Production techniques**

Process technology and process design are a huge cost economies source. With advanced technologies or a new innovative process design production time can be lowered and results in a cost advantage. A good example for a new process is the lean production process developed by Toyota.[JWo96]

4. **Product design**

   Designing a product with the focus not only on functionality and esthetics but also on an ease of production can lead to huge cost savings.

   Platform production as an example leads to a cost cutting because the company can use a production plant for different products.

5. **Input costs**

   Companies in the same industry do not automatically pay the same prices for identical inputs. Reasons for lower input costs can be location differences or an ownership of supply sources, especially in raw material intense industry. Further different labor unions can result in different payment levels. Last, bargaining power as discussed in chapter 2.3.1 can also lead to lower input costs compared to competitors.

6. **Capacity utilization**

   Plant capacity is normally fixed over short and medium terms. Capacity variation therefore is caused by a variation of output. Underutilization leads to higher unit costs. Fix costs have to be paid anyway and are now divided over less units. Overutilization can also lead to inefficiency in terms of overtime payments, premiums for weekend– and night shifts, and increased maintenance costs. Hence having the ability to adjust capacity to the right amount is a cost saver.

7. **Residual efficiency**

   Even after considering all six previously mentioned cost drivers, there can still be differences between companies. There is always a difference in personal motivation and skill of the employees as well as of the company's management.

The lowest cost position also protects the company from powerful buyers. Buyers are only able to dumb the prices to the second most efficient competitor and the company can cope better with input cost increases. The factors listed above normally also provide substantial entry barriers. This leads to a tough potential market entry for newcomers. Finally, the low cost position provides also a better position versus substitute products relative to other competitors.

“A low-cost position protects the firm against all five competitive forces because bargaining can only continue to erode profits until those of the next most efficient competitor are eliminated, and because the less efficient competitors will suffer first in the face of competitive pressures.”[Mic04]

2.4.2 Differentiation

A company’s ability to differentiate itself from the industry´s competitors is given “when it provides something unique that is valuable to buyers beyond simple offering a lower price”.[MEP85]

H. Mintzberg, B.J. Quinn and S. Ghoshal figured out the four main areas beside costs in which a company can differentiate itself from competitors. [Hen95]

- Image
- Support
- Design
- Quality

Being unique in at least one of these areas gives the company a differentiation advantage. Thus, the company is able to obtain a price premium in the industry´s market that exceeds the costs that are needed to provide the differentiation.

2.4.3 Focus

The last strategy is focusing on a specific geographical market, a product line or a buyers group. The requirement to successfully execute this strategy is to be able to serve the strategic target more efficiently or effectively than competitors who are competing more broadly. As seen in Figure 55 this can be achieved either with cost leadership or with differentiation, or both.

3 Objectives of the Master Thesis

The goal of this master thesis is divided into two independent parts. The first key aspect lies in a roll forming branch analysis. Thereby the entry potentials- and opportunities of this market are analyzed. Furthermore an outlook of future possibilities for roll formed high-and ultra high-strength profiles in the automotive industry is given. Press hardened parts in the automotive industry serve as a basis for this analysis.

The second part of the thesis deals with the acquisition of a complete roll forming line for the Institute Tools & Forming Graz University of Technology. Therefore roll forming know-how needs to be built up in the first place. With this fundamental knowledge of the roll forming technology, a specification catalogue is designed in order to request offers from roll forming line manufacturers. Subsequently, in cooperation with the project partner, an adequate roll forming line is chosen. This includes the line itself and also the design and number of the first roller sets needed to manufacture simple profile geometries for research and development purposes.

This line will be capable of manufacturing simple profile geometries out of high- and ultra high-strength materials and can be modified in a later stage of the project to manufacture more complex geometries.

4 Roll Forming Branch Analysis

In order to be able to successfully enter an existing market, it is crucial to have precise information about the current market situation. That includes the existing companies (**competitors**), their sales market (**buyers**), the company's **supplier**, **potential new entrants** and products that have the possibility to replace existing products on the market (**substitute products**).

The data in this chapter results mainly from internet research and expert interviews of roll forming line producers. As already mentioned in Chapter 3, offers of complete roll forming lines from different roll forming line producers, to gather additional data, were collected as well.

4.1 Rivalry among Existing Companies

Ten companies can be identified that are producing profiles with roll forming technology within the European market. The companies name and data can be seen in Figure 57. Before going more into detail about those specific companies it is important to note that there can be additional companies working with roll forming technology. Should that be the case, this technology is not their primary forming method. Profile manufacturing with different technologies will be explained in more detail in chapter 4.4.

Furthermore, as this thesis focuses on profile manufacturing of high- and ultra high-strength steels, it also has to be added that those companies are all capable of producing HSS and UHSS profiles, but forming these steel grades is not their primary focus. As it can be seen, it is hard to create a ranking for those companies in terms of competitiveness for HSS and UHSS profile production.

Welser Profiles Austria GmbH is by far the market leader in this branch. The company has about 1800 employees and more than 60 roll forming lines. They have the longest company's history as well as the highest budget. Therefore it can also be assumed that this company also invests the highest amount of financial interests in research and development compared to the other industry competitors. Hence, they are most likely not only the market leader, but also the main competitor for producing profiles with high – and ultra high-strength steels.

The second biggest company is Protektorwerk GmbH with about 400 employee´s. Though, the main focus lies in the construction industry. Hesse Kaltprofile GmbH and König GmbH also have their main focus in the construction industry. Hadley Profiliertechnik GmbH has a wide product range for different industry branches. They have an "Ultra Steel" product. This ia new method of producing the semi-finished product for further profile manufacturing. With this method the steel sheet or steel coil is getting stiffer and hence a weight reduction of the end product is possible. The advantages are similar to roll formed products made of HSS and UHSS materials, but to a lesser extent.

A company worth mentioning is *Profilmetall GmbH*. Over the last years, they became an upcoming company not only in producing profiles, but also in producing whole roll forming lines. They have big invests in research and development and they are also researching in the field of forming HSS and UHSS materials. The company currently employs about 100 people and is still expanding. In the end of year 2012 they bought *Nagel Profiliertechnik GmbH*. They can also be considered as a primary competitor in the field of forming high- and ultra high-strength steels.

The other companies in Figure 57 that were not mentioned above are small to mid-sized companies that should not create a large competitive force against a potential new entrance in the roll forming industry.

The rivalry among the existing industry competitors is considered small because the predominant selling market for roll formed products is huge. Additionally, having a clearly defined market leader also prevents huge market share fights.

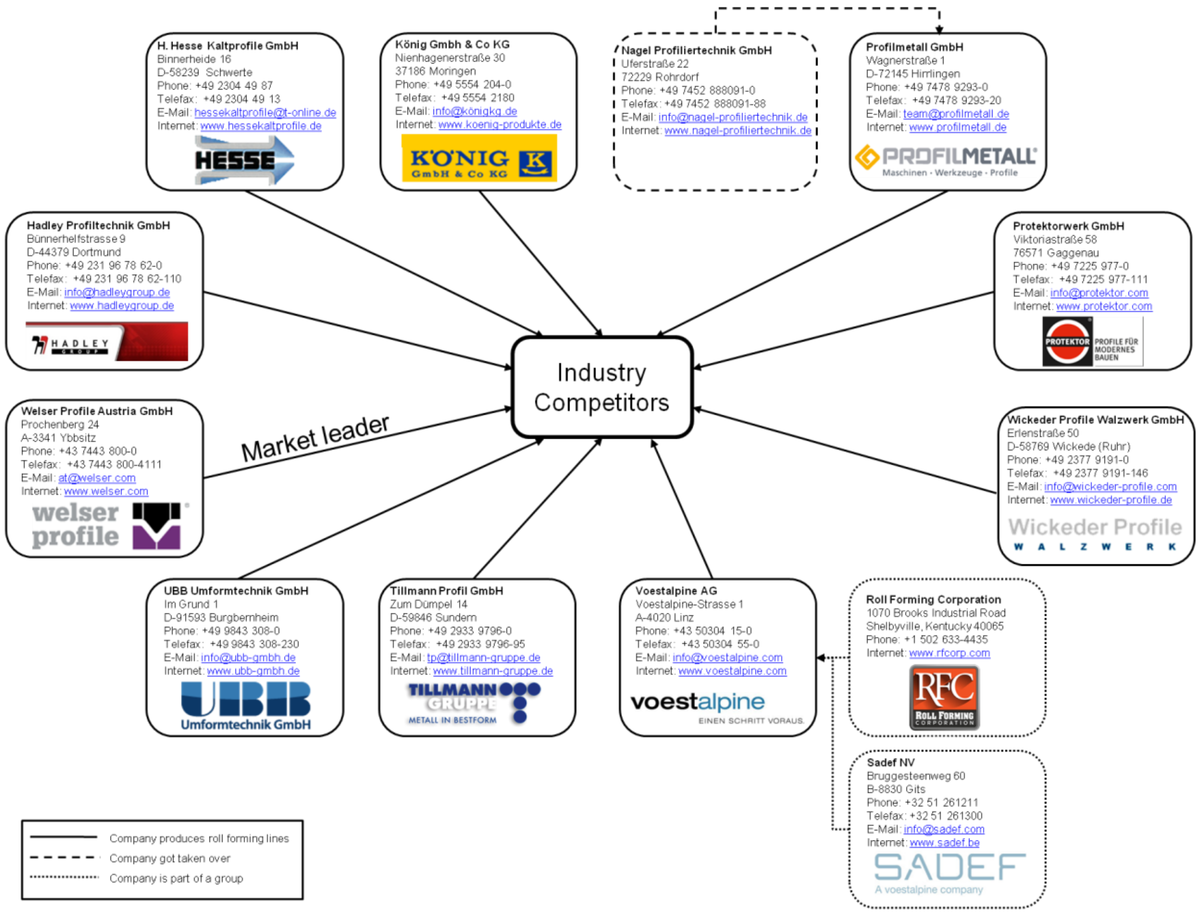


Figure 57: Roll forming industry competitors

4.2 Buyers

The buyers of roll formed products can be found in many industries. Though, after a research of the product range of the companies listed in Figure 57 the four industries shown in Figure 58 are the ones with the highest sales. Not only because these industries are huge comparatively to others, but also because the number of profiled products needed in those branches is immense.

In reference to the selling potentials of roll formed high- and ultra high-strength steels, industry sectors in which light weight design and constructions are crucial, e.g. passenger transport and skyscrapers, should be the focused targets. Not only the increasing raw material costs but also follow- up costs like fuel consumption and CO_2 emissions are leading to a more and more increased demand of substantial product design.

With roll forming of high- and ultra high-strength steels, such substantial product design is possible and the selling numbers in the mentioned industries will rise even further. Hence, it can be assumed that the bargaining power of buyers is small because they will have a huge need of such light weight, but high stiffness products.

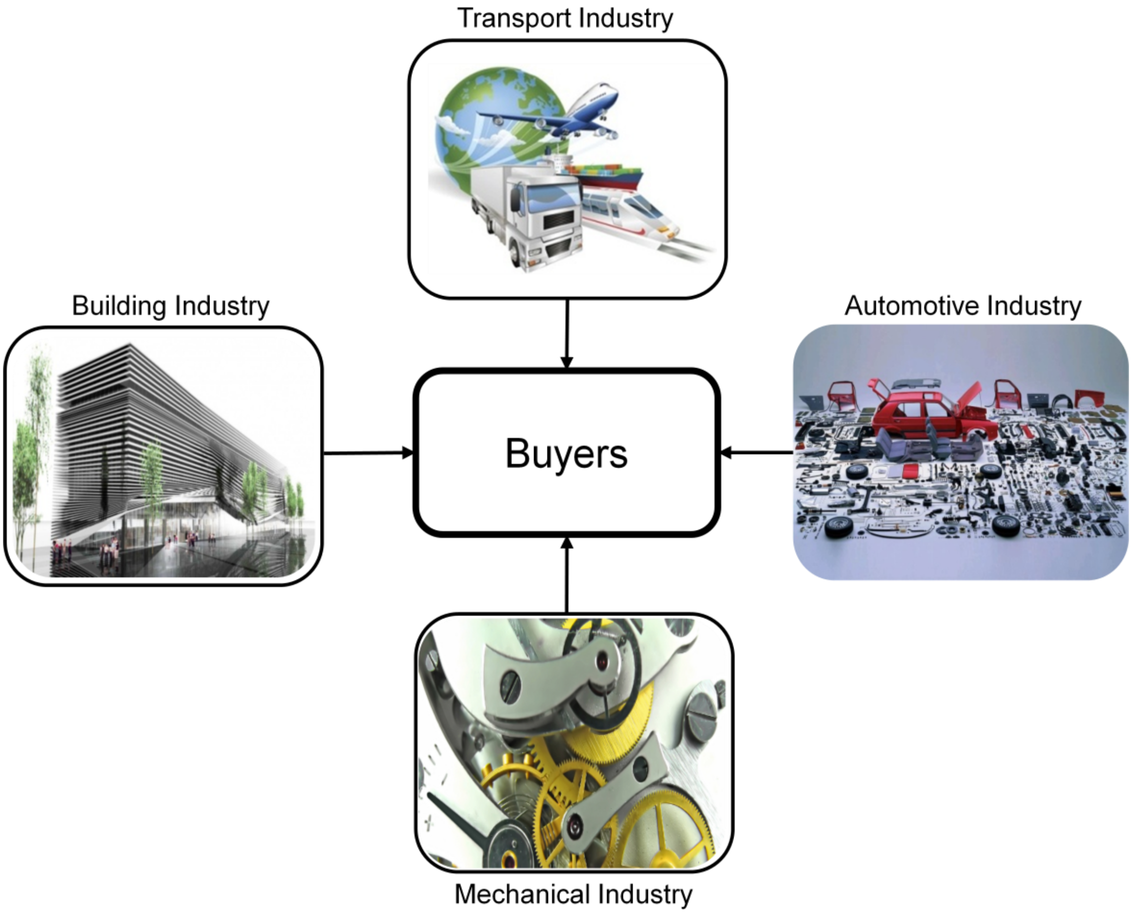


Figure 58: Delivery markets for roll forming products

4.3 Suppliers

Roll forming industries suppliers can be divided into three major sections (Figure 59).

The needed software to model the roll forming process is supplied by only two companies, *Ubeco GmbH* and *Data M Sheet Metal Solution GmbH*.

Data M Sheet Metal Solution GmbH sells a product named COPRA RF and covers all needed areas for modeling every possible way to form a material in a roll forming line. They also developed a simulation tool for simulating flexible roll forming. In the past ten years, COPRA RF was developed to an accepted worldwide standard in the roll forming industry. The software is available in ten different languages and is sold in more than fifty countries worldwide. [Dat13]

Ubeco GmbH is also covering vital roll forming simulation tools but is not as much experienced as their competitor. Hence, the bargaining power of Data M is huge. The license costs for COPRA RF are about € 65.000 with additional maintenance costs of 12% per year based on the acquisition costs. [Alb13]

The second big supplier group is made up of hardware producers. As shown in Figure 59 this sector is divided into manufacturers of complete lines and in those who are only producing parts of a roll forming line, or in some cases additionally needed equipment like a welding unit or a straightening unit for example. The manufacturers of complete roll forming lines are pictured in Figure 60. The bargaining power of complete line producers can be considered as low, because most of the manufacturers are only operating in this specific field and have no other technologies in their product range. However, for those companies only producing parts needed for the line it is the opposite. The roll forming branch is not that important, because they are also selling their products to different industries.

The third big supplier group is made up of the semi-finished product manufacturers. Figure 59 shows the two biggest strips and coil producers on the European market. It is the *Bilstein Kaltband GmbH* and the *Thyssen Materials GmbH*. There are others, but those two are holding the biggest market share. The material producers are listed as well because they can have a huge impact on the coil and strip producers and therefore also on the roll forming market. Though, our project partner is one of the leading companies in terms of cold rolled materials, we don’t have to expect a huge bargaining power in this sector of suppliers.

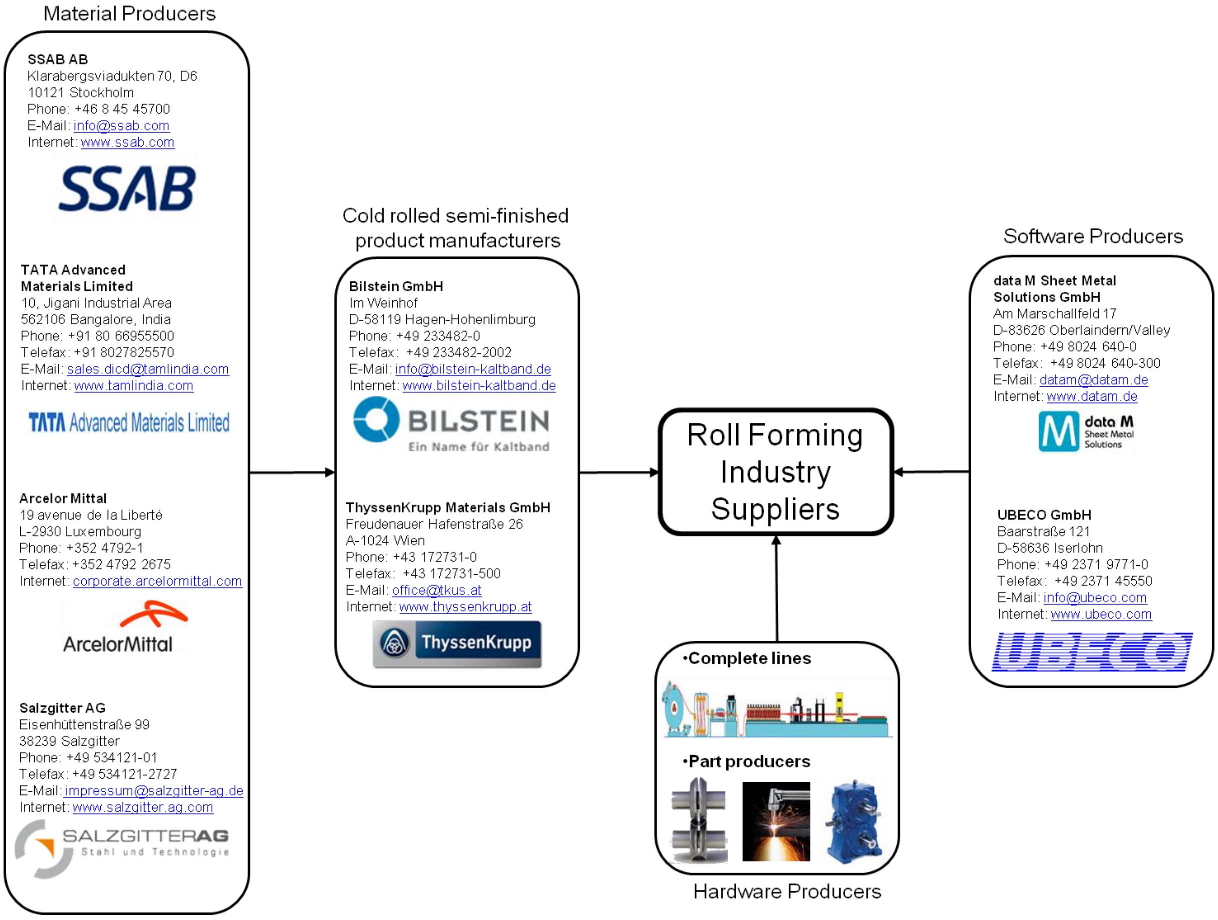


Figure 59: Roll forming industry suppliers

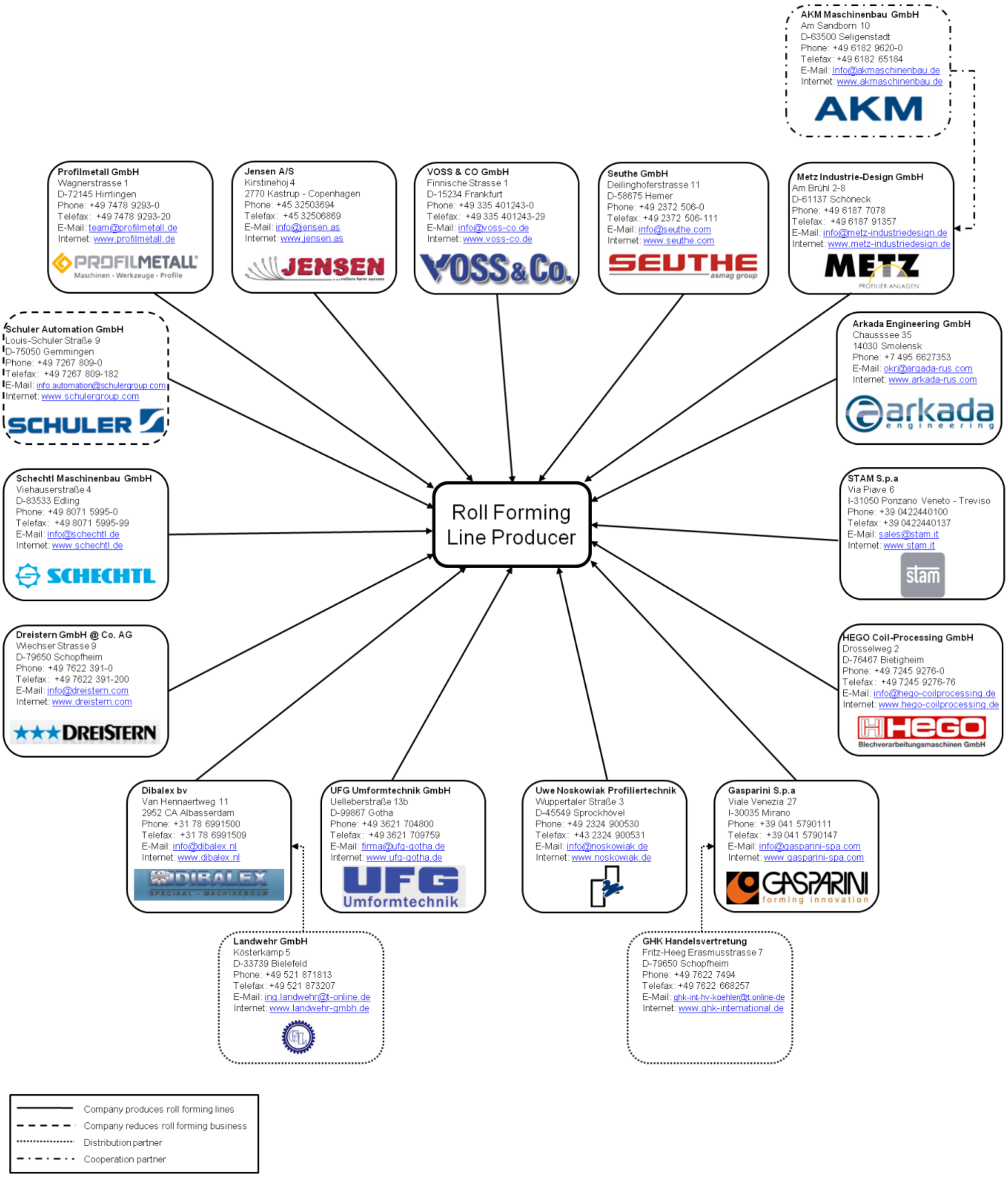


Figure 60: Roll forming line producers

4.4 Substitute Production Methods

Although Micheal E. Porter is talking about substitute products in his “Porter Five Forces Model” in this case it is more accurate to talk about substitute production methods because entering the roll forming market not only offers the possibility to produce a single product, but a complete range of different products for several different market industries. Hence, the bargaining power of substitutes is also replaced by substitute production methods of profile manufacturing. Figure 61 shows the four most common ways of producing all different kinds of profiles for different purposes. The force of substitute production methods is supposed to be the strongest competitive force among the “Porter Five Forces”. Compared to those forming methods, roll forming is a young technology where not all aspects and possibilities are discovered yet. It is an upcoming and rising technology with a huge potential, especially in the field of forming high- and ultra high-strength steels, because that is where conventional forming methods are having a deficit.

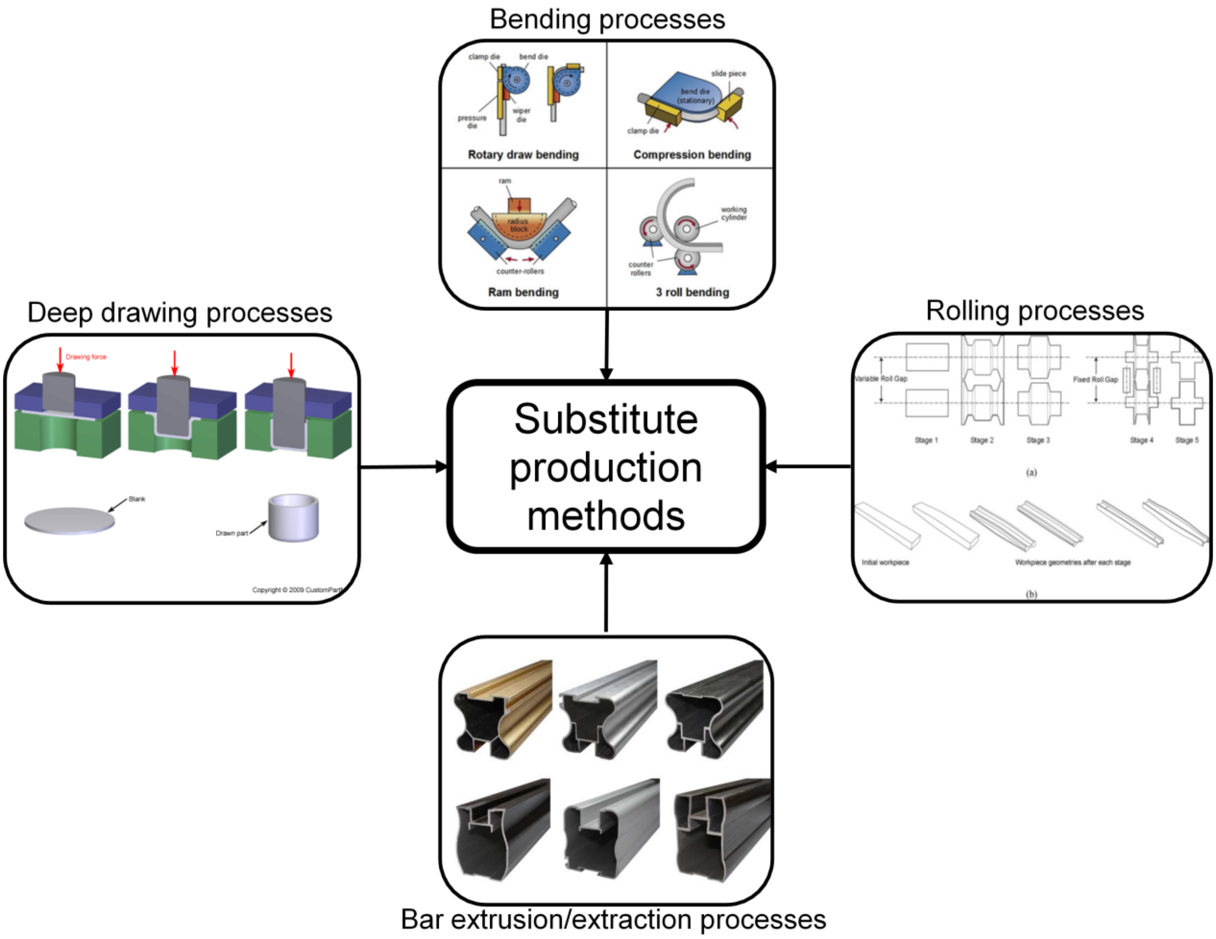


Figure 61: Substitute production methods

4.5 Potential New Entrants

It can be assumed that the market for profiles of different materials is not overall increasing, but within this market the demand of high- and ultra high-strength profiles is increasing while at the same time the amount of low strength material profiles is decreasing. This happens because of the already mentioned change of production culture where lightweight design, environmentally friendly- and substantial production is getting more and more important. With the overall better formability of high- and ultra high-strength steels with roll forming technology compared to the technologies seen in Figure 61 the roll forming market will increase even further in the future. Hence, also the interest in this technology will rise further. For companies with no or almost no knowledge of forming basics it will be hard to enter this market.

Thus, it can be assumed that only companies or industry branches that are already working in that field have the potential to successfully enter the roll forming market. Those can be divided into companies that are already working with substitute production methods as shown in Figure 61 and companies that are supplying the current roll forming market as shown in Figure 59.

Overall the bargaining power of potential new entrants is set low, because building up a proper knowledge and get the needed facilities is a huge time and money consuming business that only big companies can afford.

5 Process Operation of Plant Acquisition

As already slightly discussed in Chapter 3, one of the main purposes of the thesis is to acquire a roll forming line for the Institute Tools & Forming Graz University of Technology. The primary function of this roll forming plant lies in the field of research and development with the goal to build up know-how by manufacturing simple profile geometries. But it also has to be possible to modify the line in a way that it is able to manufacture more complex profiles in the future without the need of much invests.

5.1 Plant Specification

In the following the plant specifications will be discussed in more detail, as well as the finished specification catalog is shown in the Appendix (Part A).

General data:

The roll forming line mainly needs to serve as a research and development facility, but also needs to be capable to produce more complex parts with little modifications. Therefore the frame needs to be designed in a way that it is possible to enlarge the complete line. Thus place for additional roll forming stages is created. The roll forming stages need to be adjustable in height so different material thicknesses are possible to handle. The forming speed needs to be adjustable. Overall the roll forming line should be built as simple and as flexible as possible to ensure easy modifications.

Material data:

The basic raw material is a blank with about 160mm width, a length of ~1 meter and a maximal material thickness of 1.5mm. The line needs to be capable of forming high- and ultra high-strength steels. Hence, the line needs to be able to form materials with a tensile strength of up to 1000MPa.

Profile data:

The possible profile geometries should be L-, U-, V-, C-, and O-profiles. Examples of their dimensions are shown in the Appendix.

Additional equipment:

Figure 5 shows an example of a roll forming line. In the first stage no additional equipment such as welding, straightening or cutting units are needed. However, a later mounting of these units should be possible and considered in the line layout.

Figure 62 gives an overview of the offers gathered with the specification catalog seen in the Appendix. A remarkable variation in price is recognizable. A closer look into the offers shows that the price difference is partly achieved by additional equipment offered that was not part of the initial request. But also huge price differences for the different forming stages can be identified.

The roll forming line budget was set to a total of € 140.000. Only two offers are below that price limit and both are second hand products.

The plant specification and the simple profile geometries were mainly set to get a better feeling for the prevalent market prices and to get in first contact with the roll forming line manufacturer. The second step includes personal meetings with the manufacturing companies and defining the first profile geometries with the project partner.

The goal is, to be able to manufacture simple, but useful profile geometry. Firstly, the more complex the profile geometry, the higher the price for the plant is going to be because the number of roller stages is increasing. Secondly, if the profile geometry is too simple, no valuable research output is gathered by manufacturing it. The goal is to find the right balance between complexity and price.

	O-profile	C-profile	L-profile	V-profile	U-Profile	Plant
Hego-Coilprocessing POS.1	18.300	29.900	15.300	15.300	15.300	72.000
Hego-Coilprocessing POS.2						145.000
Hego-Coilprocessing POS.3						99.000
Hego-Coilprocessing POS.4						180.000
Arkada - RUS		130.000	90.000	95.000	115.000	170.000
VOSS & CO			9.000	9.000		145.000
Noskowiak Profilier-technik		32.500	10.200	10.600	48.500	182.250
Schuler Automation GmbH		55.000	45.000	55.000	55.000	356.500
Dibalex		35.000	37.500	37.500	35.000	375.000
METZ Industrie-Design			10.500	10.500		59.000
Seuthe GmbH						250.000
STAM S.p.A		26.000	18.000	18.000	26.000	162.000
Gasparini					30.000	120.000

Figure 62: Roll forming line offers

5.2 Value Benefit Analysis

In order to value the roll forming line offers and the companies behind the offers it is important to find an accurate analysis tool. The value benefit analysis is a quantitative, non-monetary analysis method that serves the purpose to rate different offers in order to find the best solution for a specific purpose.

The main goal of this evaluation is to get an overview of which companies and offers should be further investigated. Therefore it is important to visit the company, set up personal meetings, discuss about the project in more detail, specify a second offer, etc. The procedure and the needed data for a value benefit analysis are explained below.

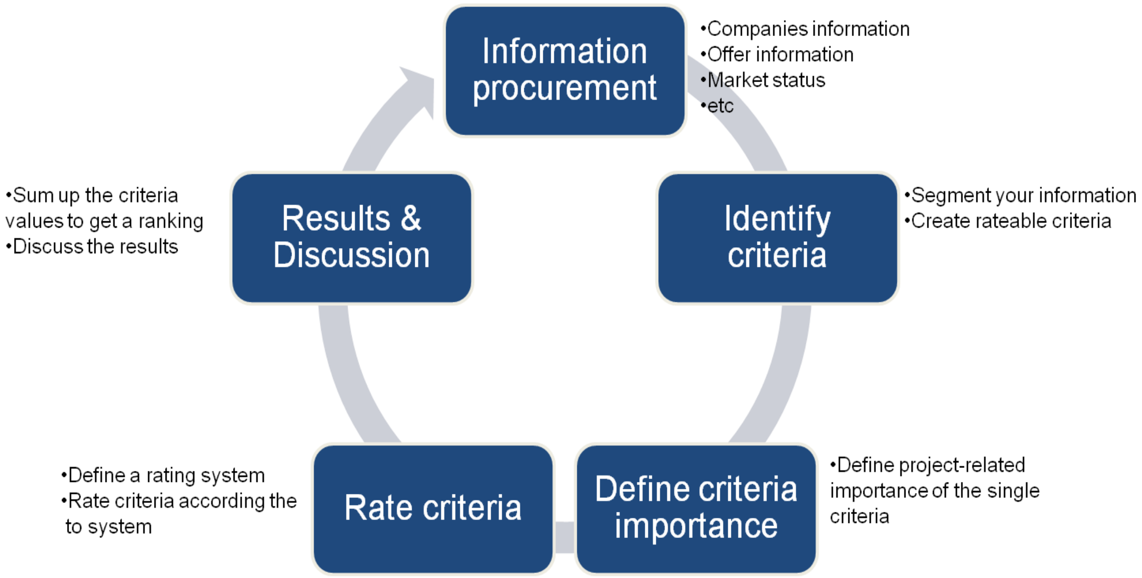


Figure 63: Value benefit analysis procedure

Criteria identification

As a first step evaluation criteria need to be defined. These criteria are specific and need to be defined particularly for every new value benefit analysis. In this case the criteria are further divided into two separate parts. The first part of the evaluation consists of knock-out criteria, which have to be reached by the offers before they can continue in the evaluation process. The second part contains the criteria by which the offers are evaluated in the value benefit analysis. Although, the used analysis tool is a quantitative evaluation method it is important to give a short description of every single criterion and a reason why it needs to be considered in the analysis.

Personal importance of the criteria

After setting up all needed criteria, their importance for the Institute for Tools & Forming needs to be evaluated. In this case, main criteria groups are defined which are segmented into sub-criteria. At first, the personal significance for the main groups needs to be set and second, the sub criteria are rated among each other. Both have a total importance value of 100%.

Criteria rating

There are two different rating systems which can be seen in Figure 64. In this case, mainly the quantitative rating system is used because most criteria cannot be divided into specific numbers. The used scale for both systems is going from 1 to 6. Thus it is avoided to rate exactly the middle and also the number of steps is sufficient for this first evaluation. It has to be kept in mind, that there is no right or wrong in setting the amount of evaluation steps. It needs to be adapted for every single value benefit analysis.

Qualitative Method (fuel consumption example)	**Quantitative Method**	**Grade**
specific degree of fulfillment (l/100km)	*verbal degree of fulfillment*	
<4	very good	6
4-6	good	5
6-8	moderate	4
8-10	low	3
10-12	very low	2
>12	insufficient	1

Figure 64: Rating systems for the value benefit analysis

5.2.1 Criteria for rating

In the following the criteria are explained in more detail. The criteria that are rated quantitatively reached the degree of fulfillment according to Figure 64. The criteria that are possible to be rated qualitatively have degree of fulfillment explained in the specific chapter.

Knock-out criteria

Two knock-out criteria are defined which the offers need to surpass in order to get further evaluated. The first is the **cost criterion**. Roll forming offers, where the price for a line without roller set plus the average tool costs for one profile, is two times higher than the available budget costs, will not be further investigated. All offers are shown in Figure 62.

Three companies, the *Arkada Engineering GmbH, Schuler Automation GmbH* and *Dibalex bv* fail to pass this criterion. The second necessary criterion is the **profile producibility**. Offered roll forming lines that are not capable of fulfilling the needed profile geometries will also not be further investigated. *Hego Coilprocessing Pos2-4* and *METZ Industrie-Design* fail to pass the second criterion.

This results in six offers which are further investigated in the value benefit analysis.

1. Information on companies

This main group criterion includes general informations about the company. This criterion serves to get a better overview about the company and how likely they are interested in a future cooperation.

1.1 Location (qualitative)

The company's location is an important criterion because it defines the time and the money needed to make a visit. Especially future project cooperation's with the company and the Institute for Tools & Forming can become a burden and therefore need to be investigated. Figure 65 shows the distance grading and Figure 66 shows the distances between the different companies and the Institute of Tools & Forming.

Qualitative Method	**Grade**
specific degree of fulfillment (km)	
<200	6
200-400	5
400-600	4
600-800	3
800-1000	2
>1000	1

Figure 65: Location degree of fulfillment

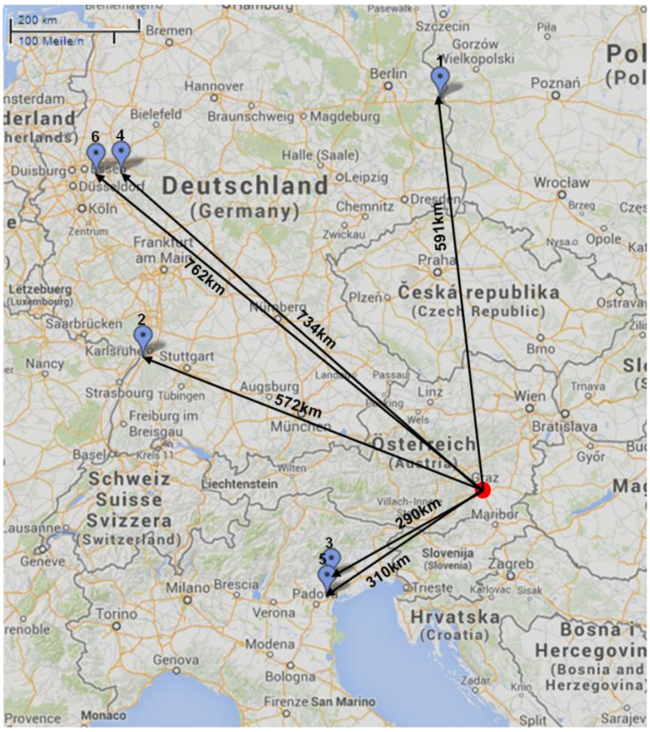


Figure 66: Distances between home location and companies

1.2 Language (quantitative)

In order to have a smooth clear communication the negotiation language is important. The grading will be done with the company’s language proficient in **German (very good)**, in **English (good)**, **none** of these two **(insufficient)**.

1.3 Size of the company (qualitative)

The Institute for Tools & Forming is looking for a small or medium-sized company because in this case the chance of future projects and a long term partnership is expected the highest.

Qualitative Method *specific degree of fulfillment (number of employees)*	**Grade**
20-50	6
10-20 or 50-80	5
<10 or 80-100	4
100-150	3
150-200	2
<5 or >250	1

Figure 67: Employee degree of fulfillment

1.4 References and experiences in the field of HSS+ materials (quantitative)

The Institute for Tools & Forming is searching for a company that is not only capable of fulfilling the roll forming line requirements, but is also interested in future projects and a possible long term partnership. Therefore a company that has already built up know-how in the field of forming high- and ultra high-strength materials is preferred. The information to rate this criterion is mainly out of internet research and expert talks with the company's members.

2. Offered roll forming lines

This main group provides criteria regarding the offered roll forming line. General information about the lines is evaluated in order to be able to rate the offers among each other. This group of criteria is very important for the Institute for Tools & Forming because it not only rates the offers of the different companies. It also gives a very good overview of the state of the art of the roll forming technology because the companies offered very different solutions.

2.1 Compactness (qualitative)

A main requirement for the roll forming line was to be as compact as possible. With this criterion the dimensions of the offered line are evaluated. The important values are the length and the width of the lines. The total area needed to set up the line is used as the measurement unit.

Qualitative Method	**Grade**
specific degree of fulfillment (m^2)	
<5	6
5-10	5
10-15	4
15-20	3
20-25	2
>25	1

Figure 68: Compactness degree of fulfillment

2.2 Set-up times (quantitative)

The set-up times specify the amount of time needed to change the set of rolls in order to be able to manufacture a different profile. The set-up times are dependent on the offered system to change the roller sets.

2.3 Flexibility (quantitative)

The flexibility is a reference value of how flexible the whole roll forming line is in general. That includes the design of the line in terms of possible additional adjustments and also the manufacturing speed variation during forming.

2.4 Expandability (quantitative)

The expandability is a really important criterion for the Institute for Tools & Forming because at first only simple geometries need to be manufactured in order to get a feeling for the technology itself and also to build up know-how. However, it should be possible to expand the line to be able to manufacture more complex and market-oriented geometries in order to get into the roll forming market. The expandability criterion is a value of how easy and fast the line can be expanded and also how little money the adoptions cost.

2.5 Additional equipment (quantitative)

This includes units like for example a straightening unit, a transport unit after the roll forming process or a cutting unit mounted at the end of the line. Although it was written in the specification catalog that no additional equipment is needed, the roll forming line manufacturers offered it partly. These equipments increase the price of the offer itself and therefore need to be evaluated somehow.

2.6 Requirement catalog compliance (quantitative)

This evaluation criterion rates the compliance of the specification catalog with the single roll forming offers from the different companies. It gives an overview of how precise the companies or at least the sales department is working.

3. Times

The “time” criterion gives an overview of the communication and the processing times of the different companies. In some cases it serves also as an indicator of engagement of the company and their motivation to make the contract.

3.1 Time for first response (qualitative)

The time gap between sending out the specification catalog and the companies’ first response is measured.

Qualitative Method *specific degree of fulfillment (days)*	Grade
<1	6
1-5	5
5-10	4
10-20	3
20-30	2
>30	1

Figure 69: Response time degree of fulfillment

3.2 Offer processing (quantitative)

The offer processing is the time elapsed from sending out the specification catalog till the offer was received. In this case it can only be measured quantitatively because there were partly some miscommunications and adoptions regarding the specification catalog and the intended information out of it.

3.3 Delivery Times (qualitative)

The criterion “delivery times” gives an overview of how fast the different companies can manufacture the roll forming line and delivery it to the Institute for Tools & Forming.

Qualitative Method *specific degree of fulfillment (months)*	Grade
<3	6
3-4	5
4-5	4
5-6	3
6-7	2
>7	1

Figure 70: Delivery time degree of fulfillment

3.4 General response times (quantitative)

This criterion gives an overview of how smooth the communication between the companies and the Institute for Tools & Forming in general was working in general.

4. Costs

The main criterion "costs" includes all arising costs during the project processing. This not only includes the actual roll forming line costs and the costs for the roller sets needed for the different profiles, but also the set-up and calibration costs for the line.

4.1 Roll forming line costs (qualitative)

With this criterion it gets evaluated how much the whole roll forming line, without the roller sets for the profiles, costs. The costs will get rated according to Figure 71.

Qualitative Method *specific degree of fulfillment (€)*	**Grade**
<100.000	6
100.000-130.000	5
130.000-160.000	4
160.000-190.000	3
190.000-220.000	2
>220.000	1

Figure 71: Roll forming line costs degree of fulfillment

(Remark: The offer from Seuthe GmbH seen in Figure 62 includes the base roll forming line as well as the stands needed for the rolls, but excludes the rolls for the different profile; The rest of the offers are divided into base roll forming lines (blue marked) and complete roller sets, including the stands and the rolls. A slight distortion in this rating is given.)

4.2 Tool costs (qualitative)

Although the specification catalog required the tooling costs for all five profile geometries, not every company has offered tool costs for all profile geometries. In order to be able to make an accurate rating, the average tool costs of the single companies are used as a base to compare them.

Qualitative Method	**Grade**
specific degree of fulfillment (€)	
<10.000	6
10.000-15.000	5
15.000-20.000	4
20.000-25.000	3
25.000-30.000	2
>30.000	1

Figure 72: Tooling costs degree of fulfillment

4.3 Additional costs (quantitative)

Other costs which are mentioned in the offer or may arise during the project process are rated with this criterion. This can be for example, set-up costs, calibration costs, travel costs for the companies' specialists', etc.

5. Personal judgment

The criteria assigned to the main criterion "personal judgment" are a compendium of personal feelings, estimations and assumptions gathered from all persons involved in this project so far. Future projects and cooperation's with the final chosen company are intended and therefore these criteria are very important.

5.3 Value Benefit Analysis Ranking

The results of the analysis can be seen in Figure 73. A clear leader can be identified at the moment. *Voss & CO* do not offer the cheapest line, but just like *Seuthe GmbH* and *Gasparini S.p.A.* the motivation and willingness to get the contract can be seen and in addition the company is, in terms of personal judgment, the most suitable one. Nevertheless, further meetings and discussions will not only be held with the leading company, but also with the other companies, that were not dropped out due to the knock-out criteria. This will show if there is a future change in rankings.

Criterion		Tier I	Tier II	Value	Voss & Co Grade 1 - 6	Voss & Co Value	Hego Coil Processing Note 1 - 6	Hego Coil Processing Value	Stam S.p.A Note 1 - 6	Stam S.p.A Value	Seuthe GmbH Grade 1 - 6	Seuthe GmbH Value	Gasparini S.p.A Note 1 - 6	Gasparini S.p.A Value	Noskowiak Note 1 - 6	Noskowiak Value
1 Company		10%														
1.1	Location		30%	3,00%	4	12	4	12	5	15	3	9	5	15	3	9
1.2	Language		10%	1,00%	6	6	6	6	5	5	6	6	5	5	6	6
1.3	Size (employees)		10%	1,00%	6	6	5	5	3	3	5	5	3	3	[redacted]	0
1.4	References- & experiences HSS+		50%	5,00%	4	20	2	10	3	15	3	15	5	25	2	10
						44		**33**		**38**		**35**		**48**		**25**
2 Offered roll forming line		20%														
2.1	Compactness (dimensions)		30%	6,00%	5	30	[redacted]	0	[redacted]	0	4	24	5	30	[redacted]	0
2.2	Set-up times		5%	1,00%	3	3	[redacted]	0	[redacted]	0	6	6	4	4	5	5
2.3	Flexibility		20%	4,00%	5	20	4	16	4	16	5	20	6	24	3	12
2.4	Expandability		30%	6,00%	6	36	3	18	4	24	4	24	6	36	3	18
2.5	Additional equipment		5%	1,00%	0	0	0	0	3	3	4	4	0	0	3	3
2.6	Requirement catalog compliance		10%	2,00%	6	12	3	6	3	6	6	12	5	10	4	8
						101		**40**		**49**		**90**		**104**		**46**
3 Times		10%														
3.1	First response		10%	1,00%	6	6	4	4	3	3	5	5	5	5	5	5
3.2	Offer processing		10%	1,00%	3	3	5	5	2	2	4	4	5	5	3	3
3.3	Delivery time		50%	5,00%	6	30	4	20	1	5	2	10	4	20	4	20
3.4	general response times		30%	3,00%	6	18	6	18	5	15	5	15	3	9	3	9
						57		**47**		**25**		**34**		**39**		**37**
4 Offer / costs		30%														
4.1	Roll forming line costs		70%	21,00%	4	84	6	126	3	63	2	42	5	105	3	63
4.2	Tooling costs		20%	6,00%	6	36	4	24	3	18	[redacted]	0	2	12	2	12
4.3	Additional costs		10%	3,00%	5	15	5	15	2	6	2	6	3	9	4	12
						135		**165**		**87**		**48**		**126**		**87**
5 Personal judgement		30%														
5.1	Motivation in HSS & UHSS		10%	3,00%	6	18	2	6	3	9	4	12	6	18	3	9
5.2	Experience in technology		10%	3,00%	4	12	3	9	5	15	5	15	6	18	3	9
5.3	Cooperativeness		20%	6,00%	6	36	3	18	3	18	5	30	6	36	2	12
5.4	Companies establishment		10%	3,00%	4	12	3	9	6	18	5	15	6	18	2	6
5.5	Sympathy		20%	6,00%	6	36	1	6	3	18	4	24	5	30	2	12
5.6	Budget adaption		10%	3,00%	6	18	3	9	3	9	5	15	6	18	2	6
5.7	Client service		20%	6,00%	6	36	2	12	3	18	5	30	5	30	1	6
						168		**69**		**105**		**141**		**168**		**60**
Total		**100%**				**505**		**354**		**304**		**348**		**485**		**255**

Figure 73: Value benefit analysis

6 Market Potential – High- and Ultra high- Strength Roll Formed Profiles in the Automotive Industry

This chapter provides information about the market potentials for high- and ultra high-strength roll formed products in the automotive industry. It gives an outlook of possible sales figures, already produced roll formed products and potential car body parts that can be manufactured with roll forming technology. For example, Figure 74 shows the material distribution in the car body frame of the new Audi A3. It can be seen that only 30% of the car body is still produced with low strength steels. So there is a huge potential market that makes it worth trying to get into this industry with the combination of roll forming technology and the mentioned materials.

Below, it will be shown that the used material mix in car bodies is different depending on the car manufacturers and their own philosophies. However, light-weight design is a huge growing trend and it will be seen that every manufacturer is trying to jump onto this hype. The current competition about the lightest and most efficient cars in the market is steadily growing.

In order to give an outlook of the future potentials it is necessary to have precise knowledge of the world wide car production and the future car production trends as well as the design trends in the automotive industry. Both will be explained in detail in the following chapters.

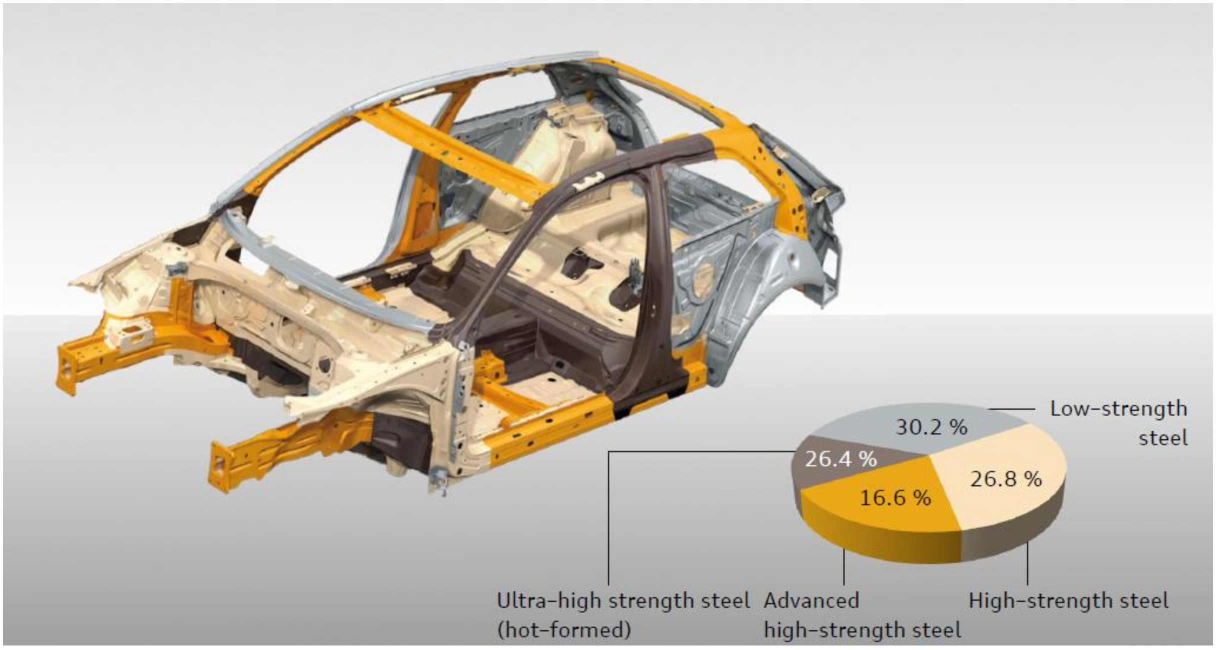


Figure 74: Car body material mix of the new Audi A3 [Pil12]

6.1 Worldwide Car Production and Future Trends

Monitoring the worldwide car production over the recent years is an inevitable task to be able to predict the future trends. Figure 75 shows a steady growth over the years, with only one big downturn in production numbers in the year 2009 during a big worldwide crisis.

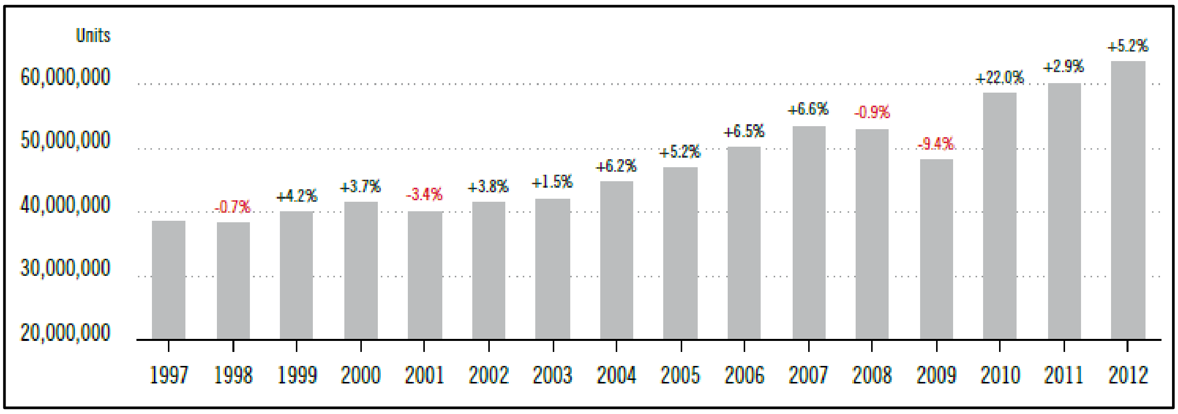


Figure 75: Passenger car production 1997–2012 [OIC13]

Future trends are showing that the number of cars produced per year will still increase. Figure 76 shows trends form three different sources that are pretty much congruent. The slight difference in numbers between Figure 75 and Figure 76 originates because the past car production only includes passenger cars and all three future trends are including not only passenger cars but also light commercial vehicles. The average increase of the yearly car production according to Figure 76 is about 4% beginning in 2013. The more into detail sources of Figure 76 are added in the Appendix (Part B – car production trends).

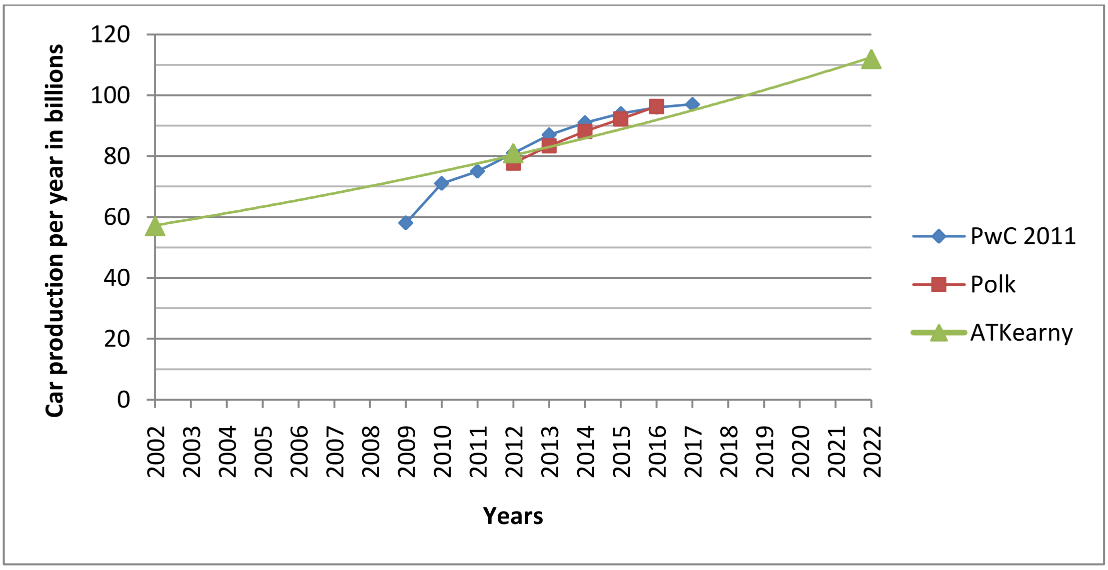


Figure 76: Future trends in car production [PwC11] , [Pol12] , [ATK12]

6.2 Material Mix in the Automotive Industry

As already mentioned, it is not only crucial to observe the future car production trends, but also the design trends in automotive industry. This chapter will focus on the material mix in the car body frame with the focus on high- and ultra high- strength steels.

Based on the “car body benchmark data summary”, which every car manufacturer has to provide for a specific car type, in order to be allowed to participate at the annual Euro Car Body, the data for this chapter is gathered. The analyzed data is gathered from the 12th till the 14th International Car Body Benchmark Conference. They took place in between 2010 and 2012.

Figure 77 shows the data processing on an example of the BMW 3 Series. It was presented on the 13th International Car Body Benchmark Conference. Figure 77 (top) gives an overview of the build-in parts in the car body frame, while Figure 77: Extract of the data gathering for the car body material mix trends 2010-2012 Figure 77 (bottom) shows the percentage distribution of the different material types used to manufacture the car body frame. Figure 78 and Figure 79 give an overview of the classification system used for the Benchmark Conference. They also show which steel subsection types are gathered together and form the main steel types and their range in terms of tensile- and yield strength.

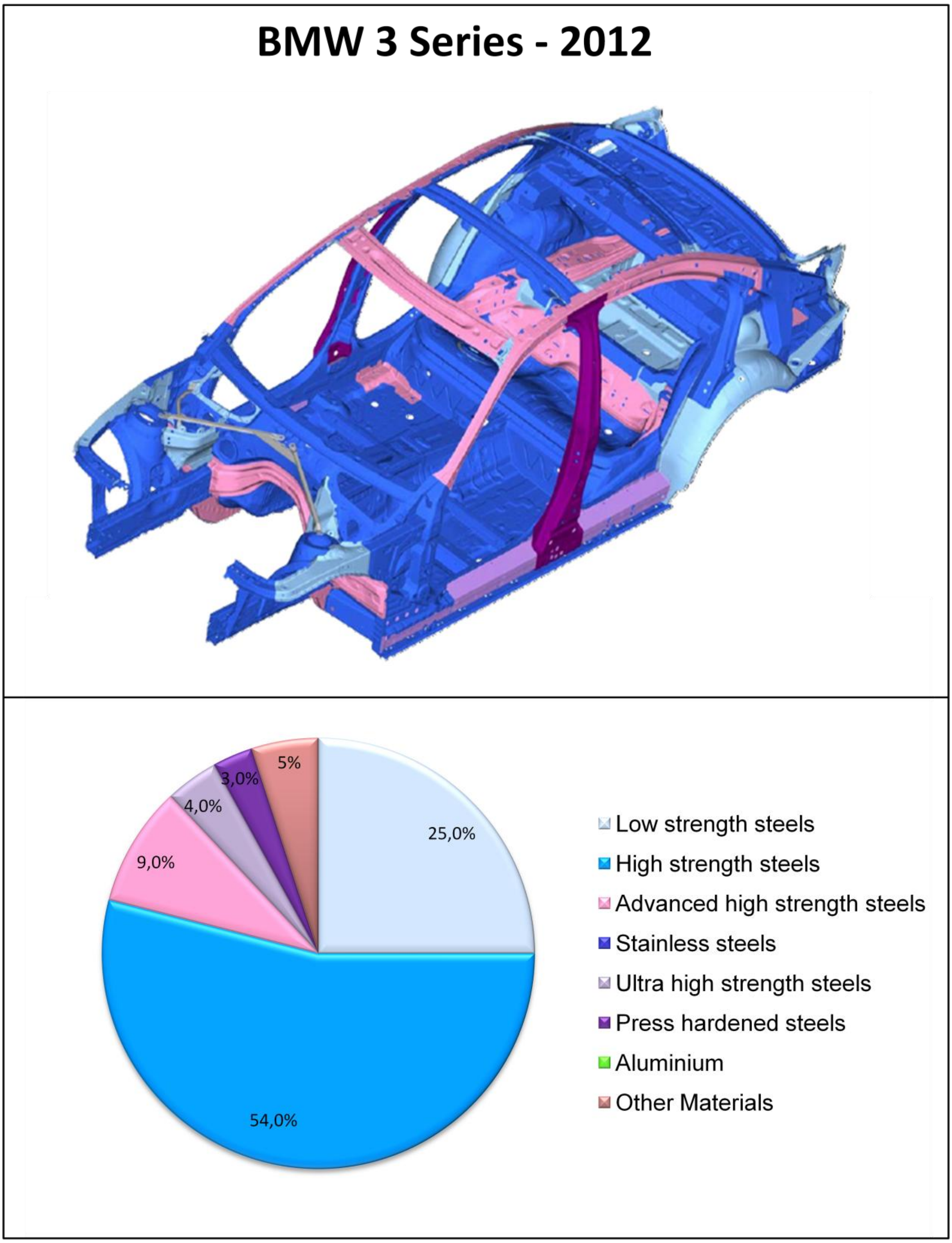


Figure 77: Extract of the data gathering for the car body material mix trends 2010-2012 [Eur12]

	Materials: corresponding metallurgical classes	**RGB colour code**
	Low Strength Steels: Mild steels	R 153, G 204, B 255
Steels	**High Strength Steels (HSS):** High Strength Interstitial-free Steels (HSIF), Bake Hardening Steels (BH), High Strength Low Alloy Steels (HSLA)	R 051, G 102, B 255
Steels	**Advanced High Strength Steels (AHSS):** Dual Phase Steels (DP), Transformation Induced Plasticity Steels (TRIP)	R 255, G 153, B 204
Steels	**Stainless steels:** Austenitic stainless steels	R 051, G 051, B 153
Steels	**Ultra High Strength Steels (UHSS):** Complex Phase Steels (CP), Martensitic Steels (MS)	R 204, G 153, B 255
Steels	**Press Hardened Steels (PHS)**	R 128, G 000, B 128
Aluminium	**Aluminium sheets:** 7xxx series	R 051, G 204, B 153
Aluminium	**Aluminium sheets:** 6xxx series	R 000, G 255, B 000
Aluminium	**Aluminium sheets:** 5xxx series	R 204, G 255, B 204
Aluminium	**Aluminium extrusion profiles**	R 153, G 204, B 000
Aluminium	**Cast aluminium**	R 051, G 153, B 102
	Magnesium	R 255, G 255, B 000
Plastics	**Fibre reinforced plastics**	R 255, G 000, B 000
Plastics	**Duroplastics, including Sheet Molding Compound (SMC)**	R 255, G 153, B 000
Plastics	**Thermoplastics**	R 153, G 051, B 000
	Other materials, namely:____________________	R 192, G 192, B 192

Figure 78: Euro car body material- and color code classification [Eur10]

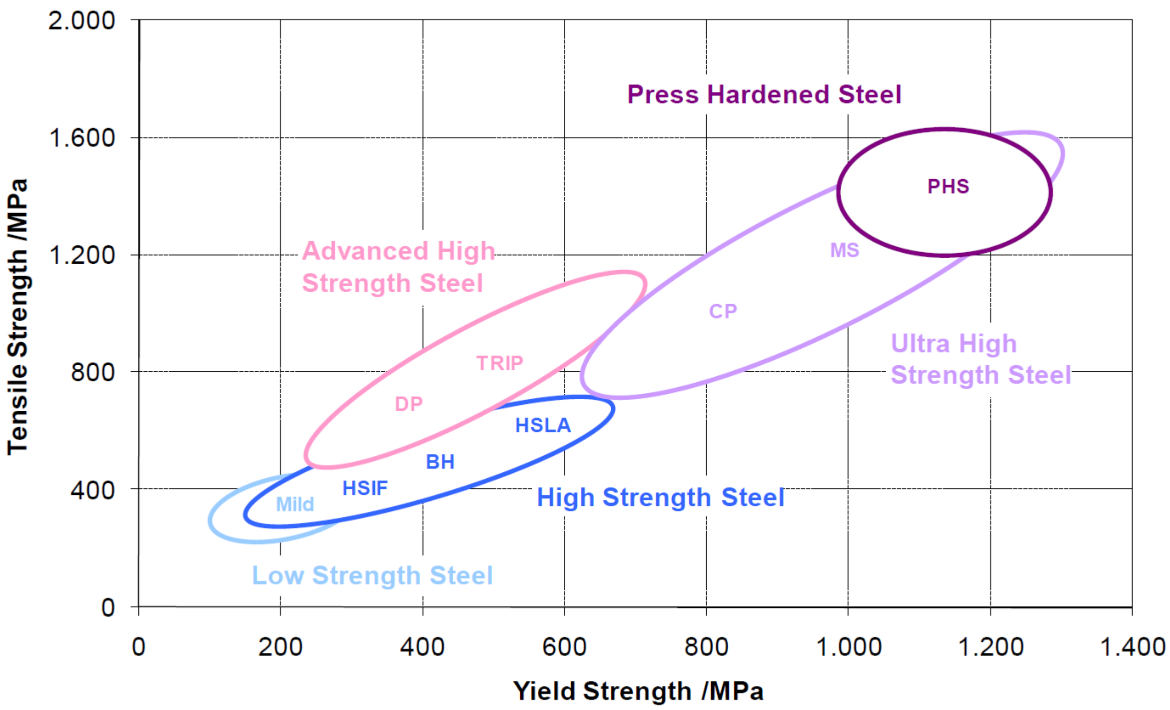


Figure 79: Euro car body material strength classification [Eur10]

Based on the International Car Body Benchmark Conferences, data regarding the material mix of 27 different car body types and manufacturing companies were gathered. Figure 80 shows the average material mix for the separate years 2010 till 2012. As it can be seen, only in the past two years the design concepts are more and more shifted in the direction of high- and ultra high-strength material types. A linear decrease of low strength steel usage of about 3.2% per anno is identified as well. The assumption is near, that by going further into the past, an even greater increase of high- and ultra high-strength material usage in the automotive industry happened and this increase will still go on.

The more into detail sources of Figure 80 are added in the appendix (Part C – Material mix in the automotive industry).

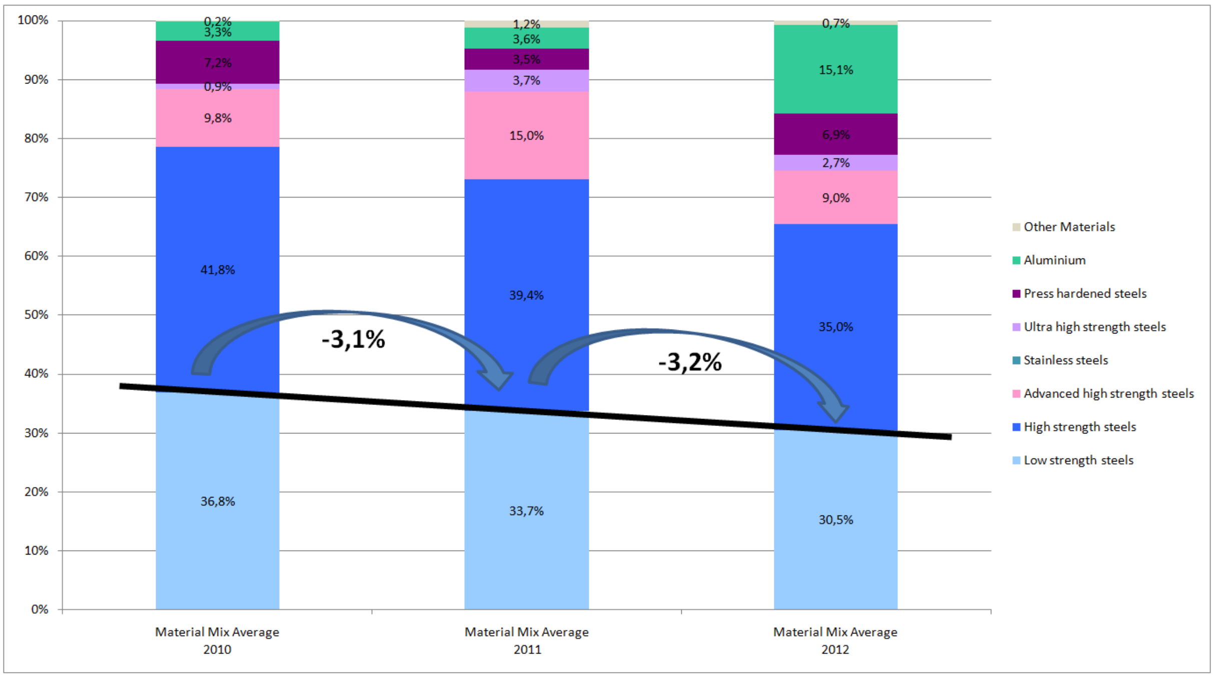


Figure 80: Material mix trend 2010-2012

6.3 Roll Formed Product Potentials in the Automotive Industry

This chapter focuses on the possibilities and potentials of roll formed products in the automotive industry. Chapter 6.2 gave an outlook on the material mix in different car bodies and it proved that the focus shifts more and more into the direction of manufacturing with high- and ultra high-strength materials.

It is essential to know which car body parts are already manufactured with roll forming technology, but also which parts can additionally be manufactured with this technology in order to get an overview of the future potentials for the roll forming market.

The information and data in this chapter is mainly aggregated from expert interviews with roll forming line manufacturers and profile manufacturers. These companies' data is shown in Figure 57 and Figure 60.

On the example of a middle class car body frame seen in Figure 81, the number of possible manufacturable parts needs to be identified in order to evaluate the roll forming potentials in the automotive industry.

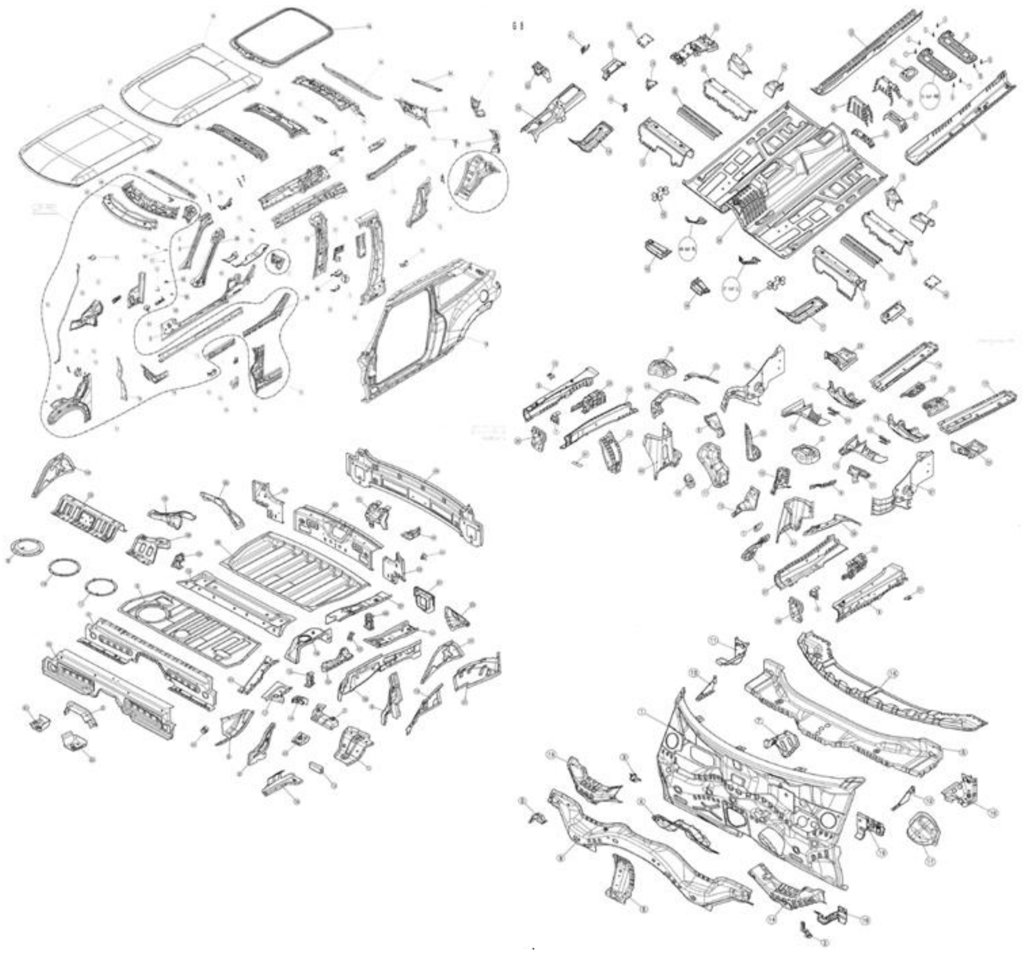


Figure 81: Exploded view of a middle class car body frame

As a first step the number of built-in parts made of high- and ultra high- strength steel must be identified. According to Figure 25 material with a yield strength of 210 MPa or higher is classified as high- or ultra high-strength material and therefore need to be found.

The number of parts resulting from this material breakdown need to be further investigated according to their producibility with roll forming technology. With roll forming technology manufacturable parts are normally classified as parts with a constant or almost constant cross-section over the part´s length.

The outcome of this analysis is the number of parts, within a car body frame, that is made of HSS or higher and can be manufactured with roll forming technology. Figure 82 shows the needed process steps and the potential car body frame parts of the above seen car body frame.

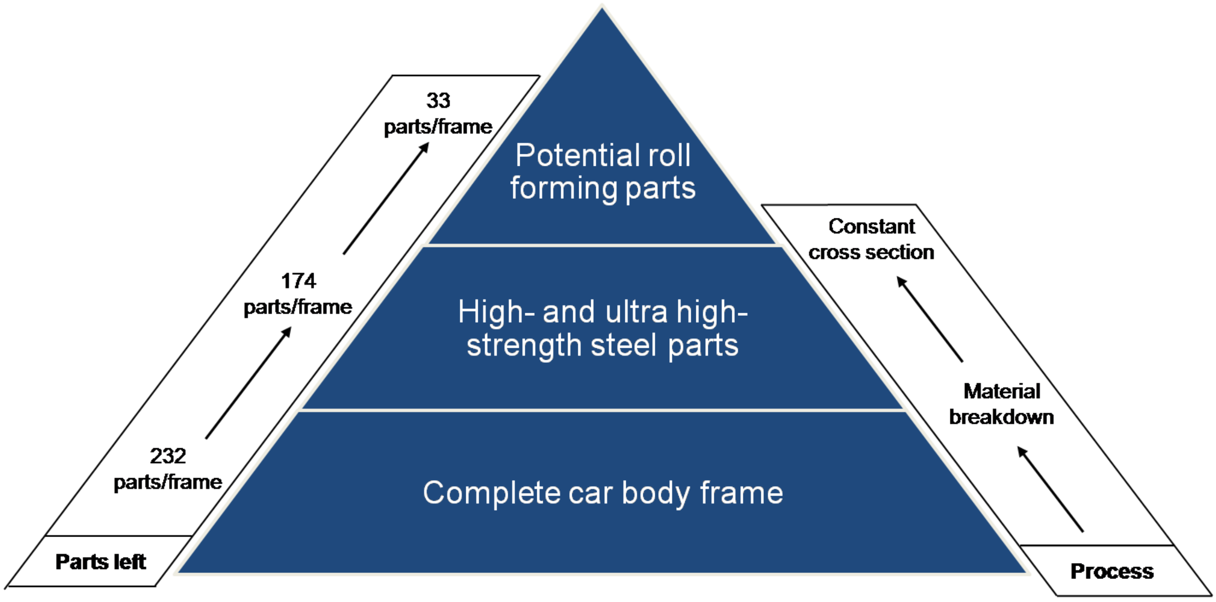


Figure 82: Roll forming part potential in a car body frame

The frame consists of 232 parts in total, 33 parts are identified that have yield strengths above 210 MPa and an almost constant cross-section. In other words, with a decent roll forming know-how and the necessary equipment it is possible to manufacture 14.22% of the total car body frame with roll forming high- and ultra high-strength materials. These 33 parts have a total weight of 39.625kg. The complete frame with the potential roll forming parts can be seen in Figure 83. The 174 high- and ultra high- strength parts are marked black, while the resulting 33 potential roll formed parts are additionally red-rimmed. Detailed information about the parts is listed in the Appendix (Part D).

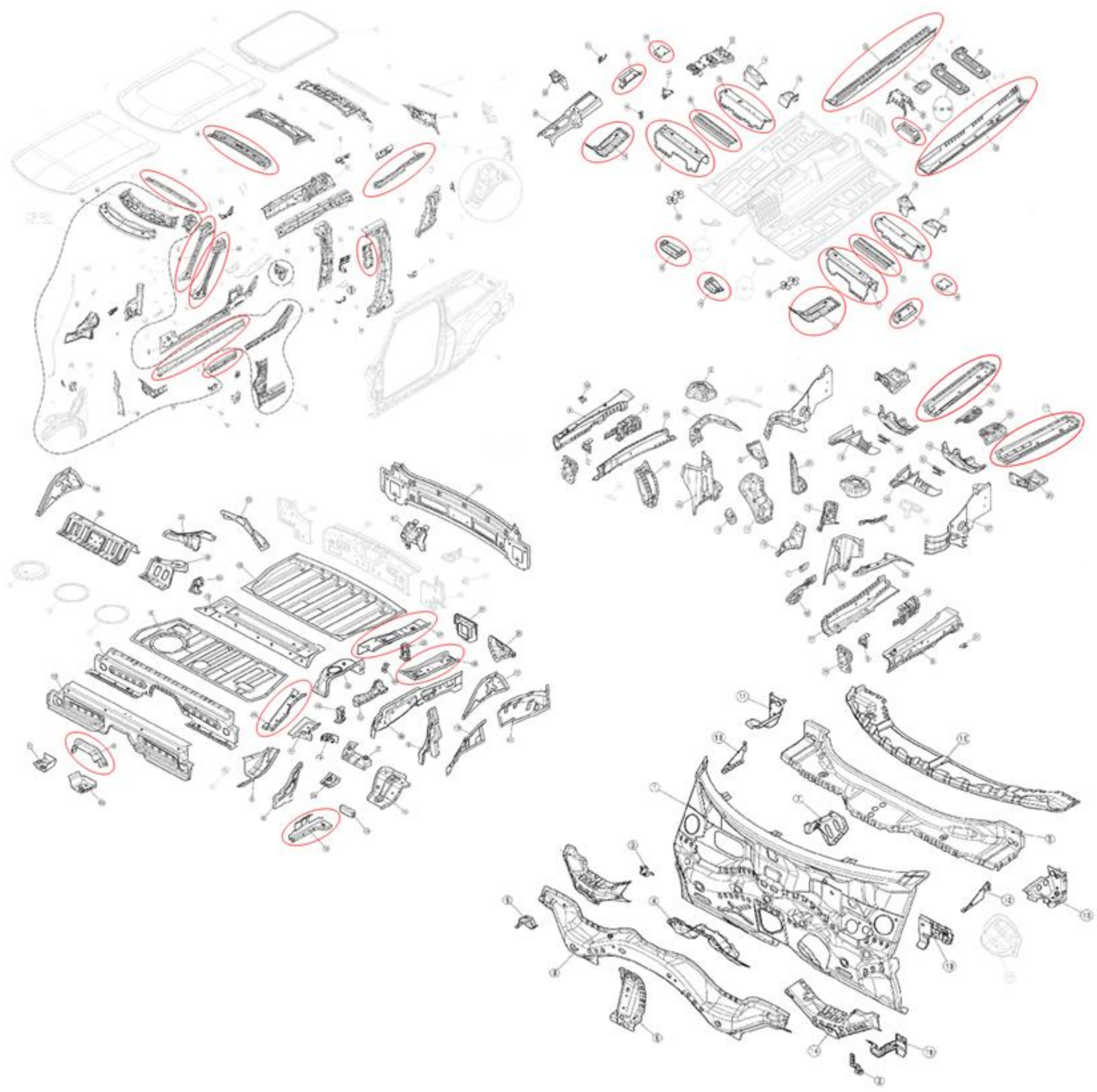


Figure 83: Highlighted potential roll formed car body parts

It is necessary to keep in mind that these 33 parts can be produced with roll forming technology, but that doesn´t mean that the production costs are cheaper. This always depends on the complexity of the part, the additional needed processing steps till the part is finished and the joining requirements.

6.4 Market Potential Results

With the informations gathered in Chapter 6 it is possible to give an outlook on roll forming potentials over the next years. Figure 84 shows the combination of car production trends, the material mix trends and also the manufacturing potential of roll formed parts in a car body frame. It can be seen that the increase of high-and ultra high-strength materials in a car body frame will lead to a potential build in roll formed parts of about 45 in the next twenty years. This results in 4.871.985 tons of high- and ultra high-strength material that can be manufactured worldwide with roll forming technology for the automotive industry.

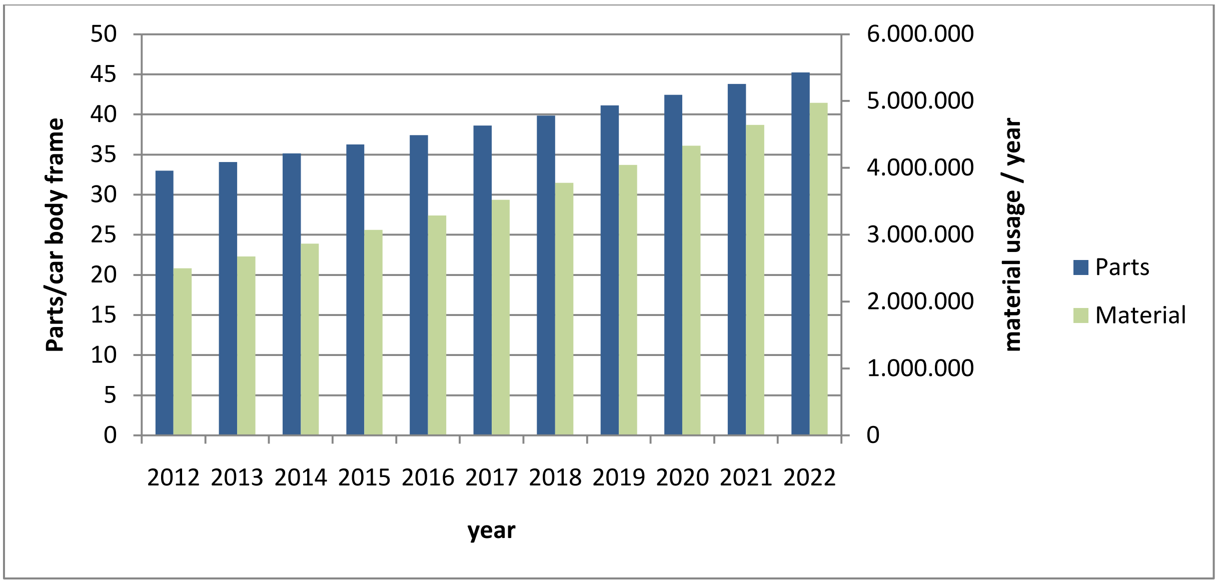


Figure 84: Roll forming potential with high- and ultra high-strength materials in the automotive industry

7 Summary and Outlook

The analysis of the roll forming branch market that was developed within this thesis shows a clear market leader: the *Welser Profile Austria GmbH* located in Austria. As Chapter 4.1 shows, it can be assumed that they are not only the market leader but also the main competitor for producing high- and ultra high-strength steel products with roll forming technology. Nevertheless it can be assumed that the competitive threats coming from substitute production methods, like for instance deep drawing, are even higher when thinking about the automobile industry. Companies that are already supplying the automobile industry with products have more bargaining power due to long-lasting partnerships and possess well-grounded advanced know-how. Roll formed products may be cheaper in production and also have a higher production efficiency, but OEM´s have to keep in mind that not the exact same designs can be obtained. Due to this reason consequential costs for modifications in the assembling process may arise.

As one of the main material suppliers in Europe, our project partner has no need to fear bargaining power from this field. It might even be considered to be an advantage, because synergies between roll forming and the used materials can be easier identified and improved.

Within the project budget € 140.000 are provided for the roll forming plant itself. After sending out the plant specification catalog and receiving the offers from roll forming line manufacturers it became clear that adoptions regarding the catalog need to be done. The next step is to define a valid profile geometry. This geometry should at the one hand be able to provide significant research data concerning the manufacturing process and on the other hand needs to be as cheap as possible to remain within the roll forming plant budget. A suggestion regarding the profile geometry is a C-profile or a hat-profile. These profiles have multiple purposes within the industry. The costs for the roller stands primarily depend on the dimensions of the profile itself and only secondarily on the profile shape.

The market potential is calculated on the basis of data regarding the car production trends for the next ten years, the material mix trend in car body frames and the potential roll formed build-in parts within a car body frame. This results in an increase of roll formed parts in the cars body frame of 37% in the next ten years, resulting in an estimated amount of approximately 5,000,000 tons of high-strength material manufactured with roll forming technology in the year 2022. This indicates that the automobile industry on its own will double its need for high-strength materials within the next ten years.

If synergies between the roll forming process and the used material can be identified in the near future, investments in this market idea will become highly advisable due to its high potential profits.

Investigations regarding roll forming potentials in other sales markets, as mentioned in Chapter 4.2, should also be started.

Appendix

A. Specification Catalog

TU Graz
Graz University of Technology

Institute Tools & Forming
Member of Frank Stronach Institute

Univ.-Prof. Dr.-Ing. Ralf Kolleck
Institutsvorstand

Telefon: +43(0)316/873-9452
Telefax: +43(0)316/873-9442

Inffeldgasse 11/I
A-8010 Graz

DVR: 008 1868 UID: ATU 574 77 929

Requirement Catalog

Roll forming plant

Graz University of Technology
Institute Tools & Forming
Inffeldgasse 11/I
8010 Graz

Table of Content

2

1 Initial Situation

In cooperation with the project partner the Tools & Forming Institute is ordered to acquire a roll forming plant. The usage of the plant is mainly for research and development activities. It is not used for mass production. Therefore the plant has specific requirements to fulfill, which are discussed in the following.

2 Roll Forming Plant Requirements

In the following the specific requirements needed for the plant are designed.

2.1 General Data

- The replacement of the forming stages should be simple
- Height adjustable forming stages are needed. Preferable upper- and lower shaft
- The plant in general should be as compact, simple and flexible as possible because we are limited with space.
- Planned length of the finished part ~1 meter
- Forward speed adjustable between 0 - 10m/min

2.2 Material Data

- No Coils; Feed with blank.
- Blank width: ~160mm
- Blank thickness: 1,5mm at max.
- Material: high strength steel or lower (tensile strength ~1000MPa)

2.3 Profile Data

L - U - V - C - and O- Profiles. The specific profile data is added in the appendix. O-Profile is not part in the appendix. A blank width of 160mm results in a diameter of the O- Profile of ~51mm.

2.4 Additional Equipment

In the first steps of the plant acquisition no additional equipment like, straightening units, stamp units or cutting units are needed. But the later addition of these tools should be considered in the construction.

4

3 Required Additional Information

Add these data please to your offer, when not added anyhow.

3.1 Roll Forming Plant

- Dimensions
- Value of the possible height adjustment
- Diameter of the profile rolls
- Art of the drive
- Plant structure: Lower- and/or upper shaft adjustable
- Electric devices
- Engine specifications

3.2 Forming Stages

- Number of needed forming stages for the various profiles. How is this connected to the length change of the whole plant?
- Which material is used for the profile rolls?
- How are the forming rolls changed? Construction with cassettes or fixed rack for manual alteration of the forming rolls?

3.3 Costs

- Please list the Costs for the whole plant and in addition the separate costs of the roll forming stages needed for the different profiles

3.4 Further Remarks

- Security facilities
- Entry- and exit tables

5

4 Contact Data

Reischl Philipp

Institute Tools & Forming

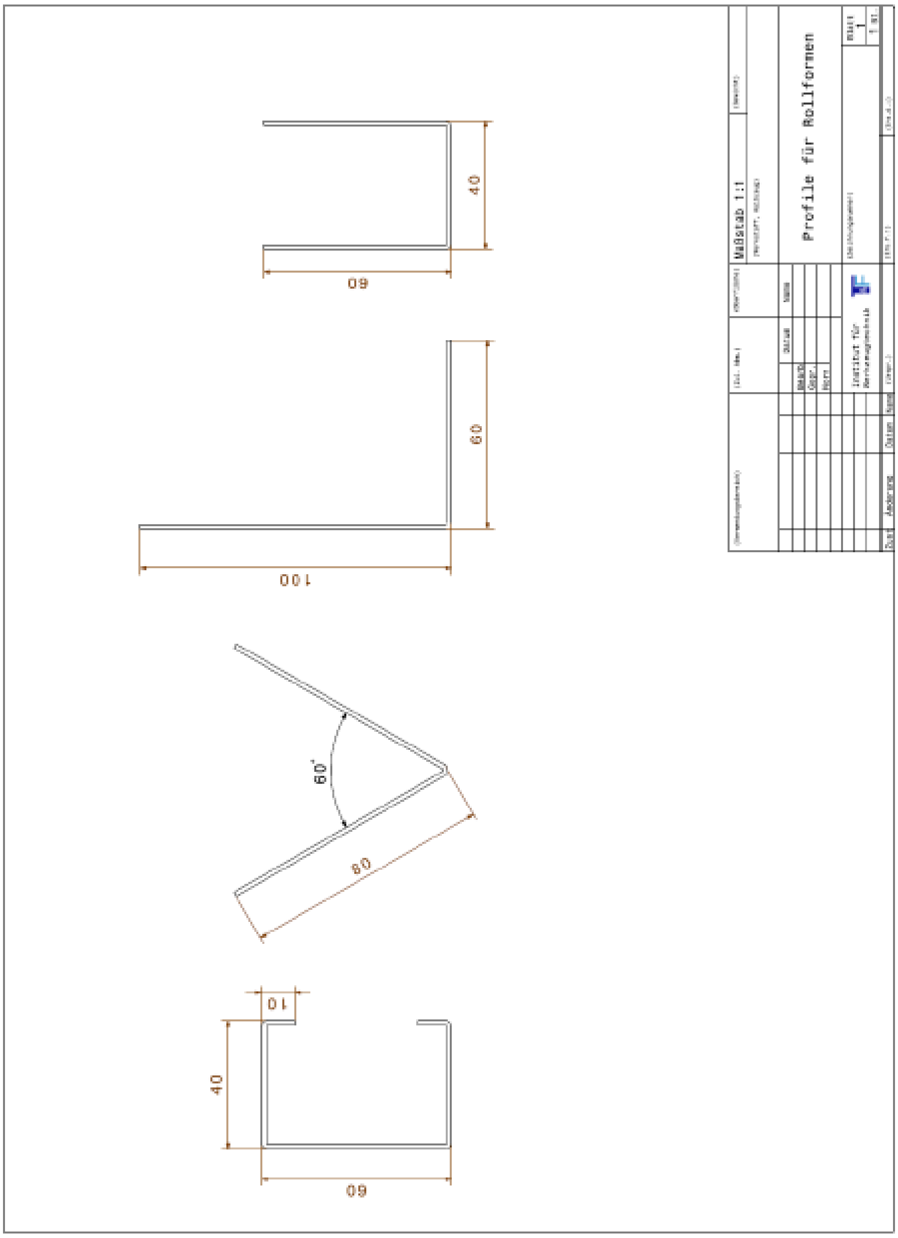
Infeldgasse 11/I

A-8010 Graz

E-Mail: philipp.reischl@tugraz.at

6

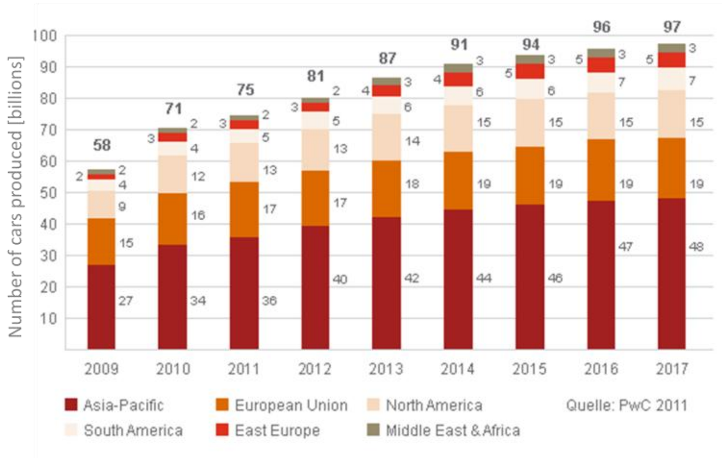
Appendix



7

B. Car Production Trends

PwC:

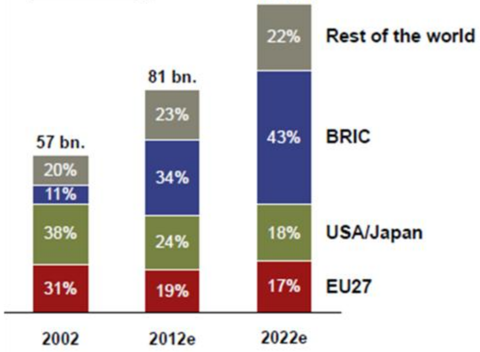


L.Polk:

	2012	2013	2014	2015	2016
Global	77.7	83.4	88.1	92.2	96.3
Europe	19.0	20.3	21.5	22.7	23.7
United States	13.7	14.9	15.6	16.0	16.3
Brazil	3.6	3.8	3.9	4.1	4.3
China	17.9	19.4	20.6	22.0	23.6
Japan	4.5	4.8	4.9	4.8	4.8

Number of cars produced [billions]

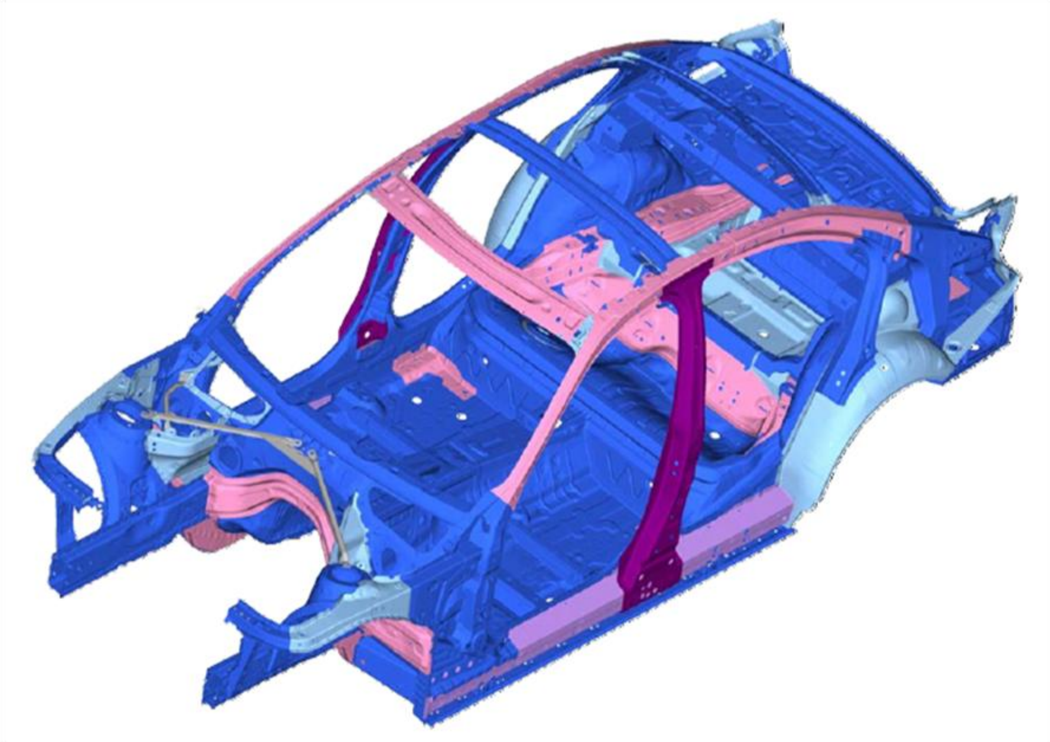
ATKearney:

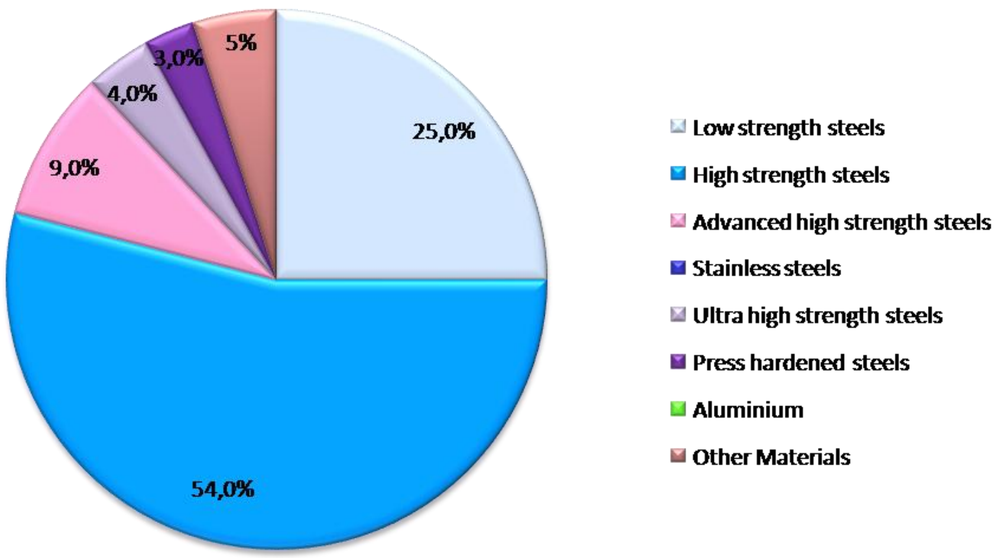


C. Material Mix in the Automotive Industry – Car Body Frame Data Sheets

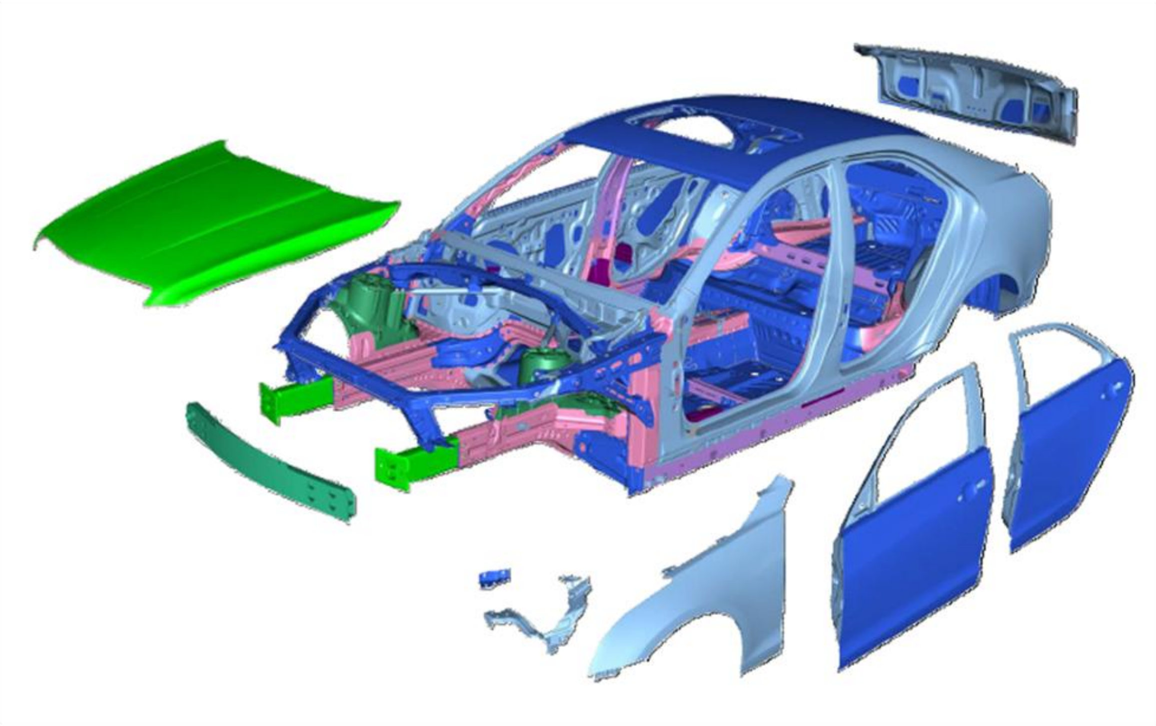
Euro Car Body 2012:

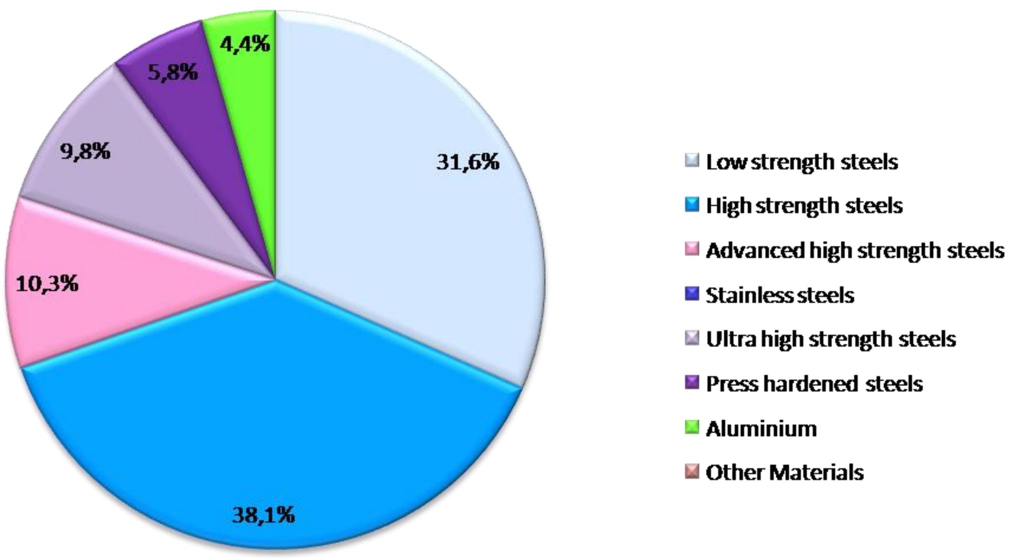
BMW 3 Series



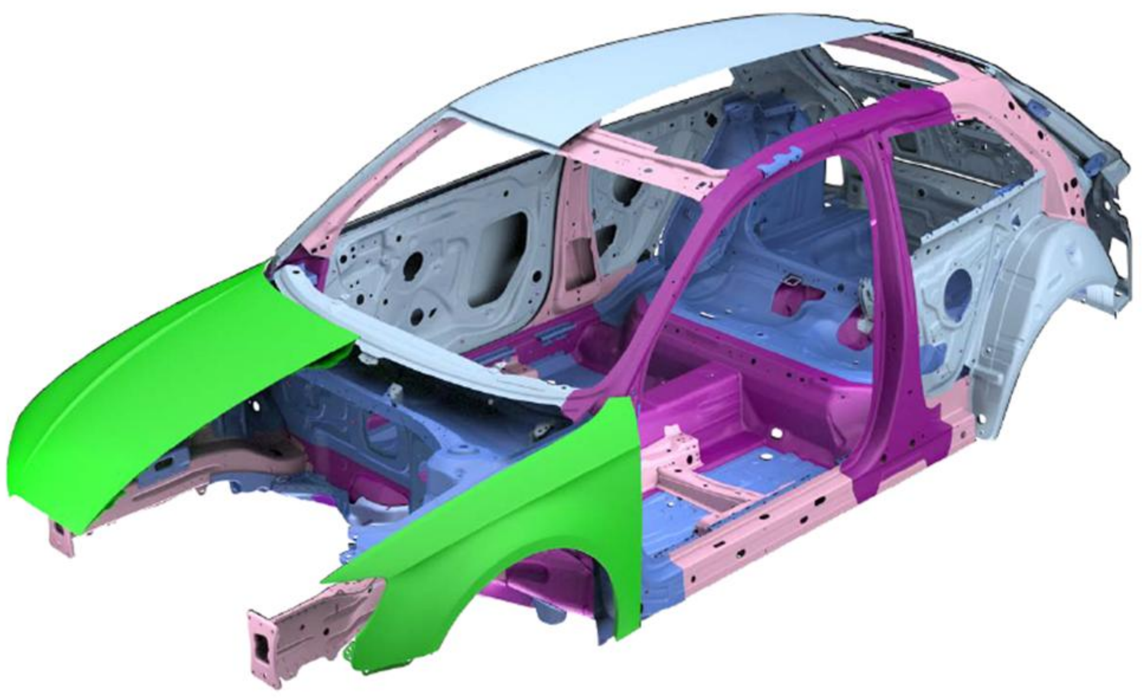


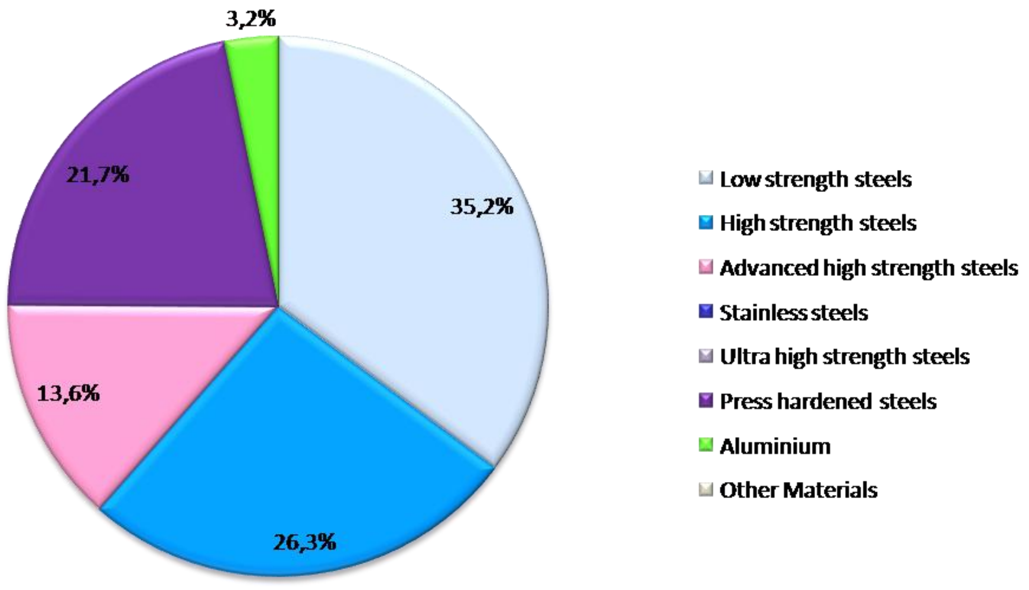
Cadillac ATS



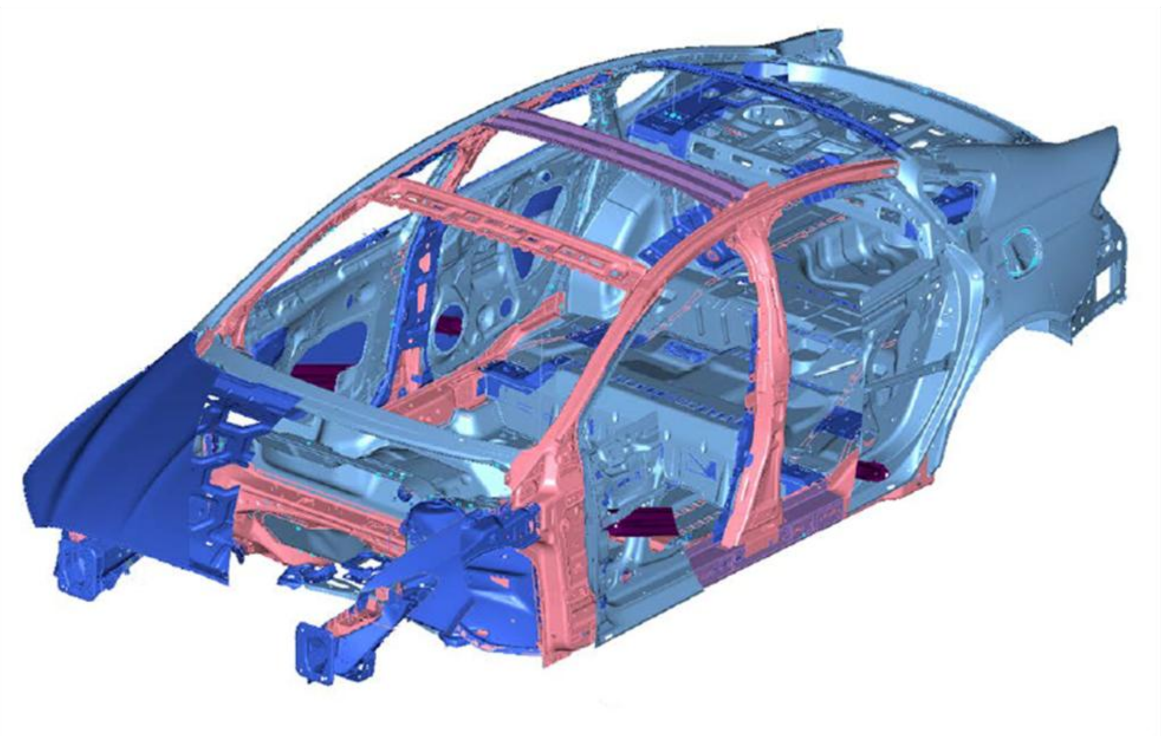


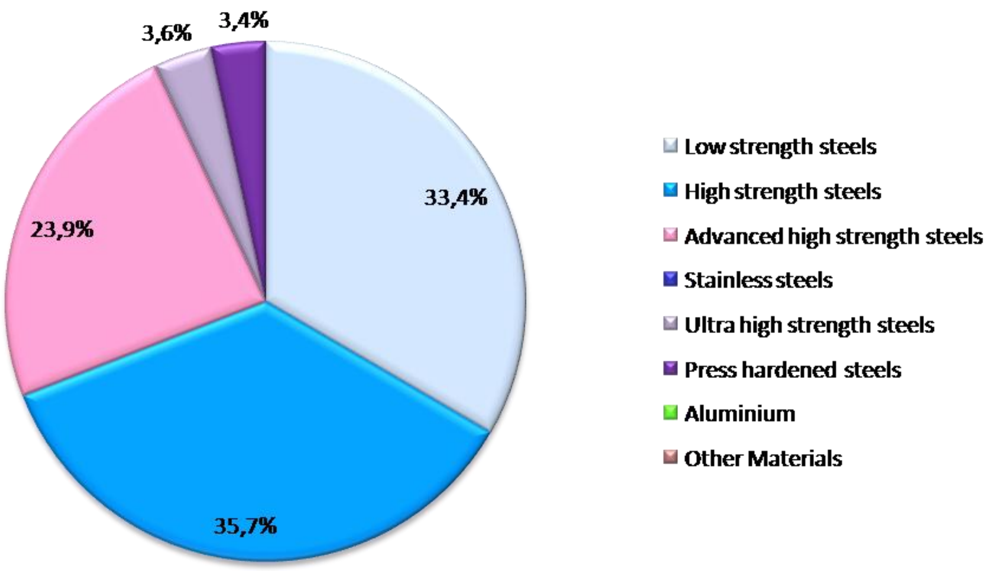
Audi A3



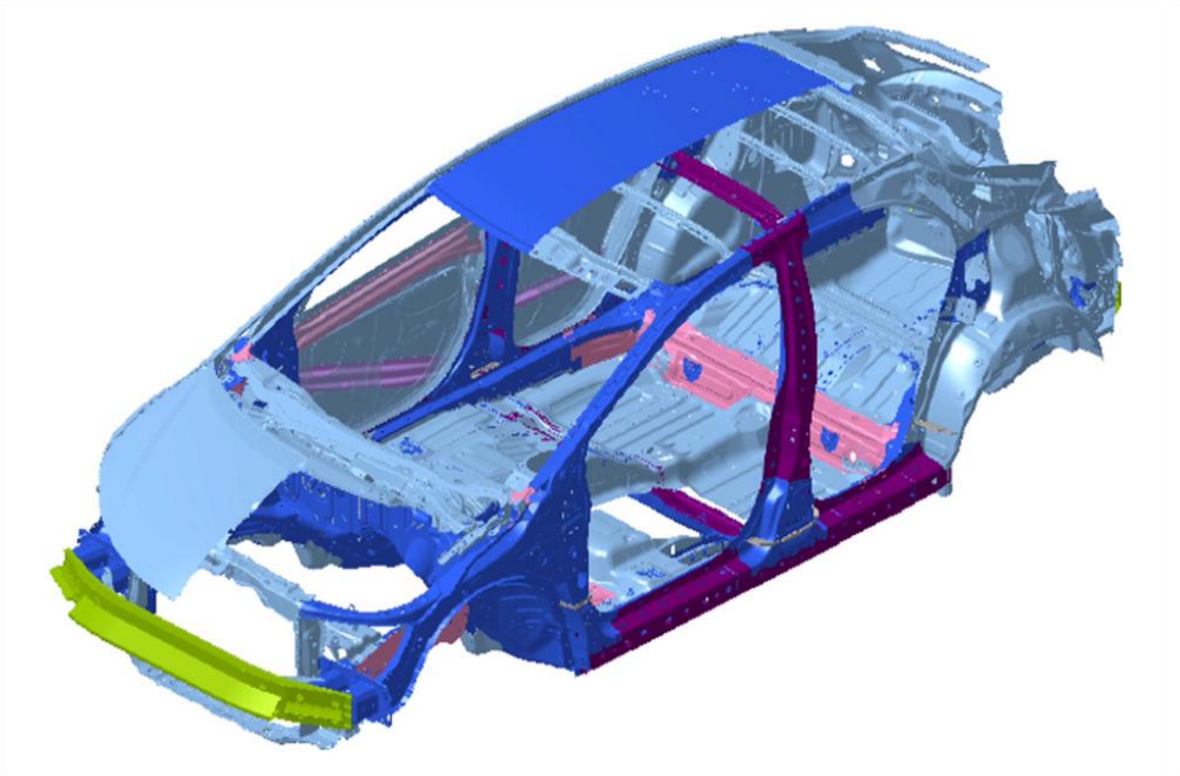

3,2%
35,2%
21,7%
13,6%
26,3%
Low strength steels
High strength steels
Advanced high strength steels
Stainless steels
Ultra high strength steels
Press hardened steels
Aluminium
Other Materials

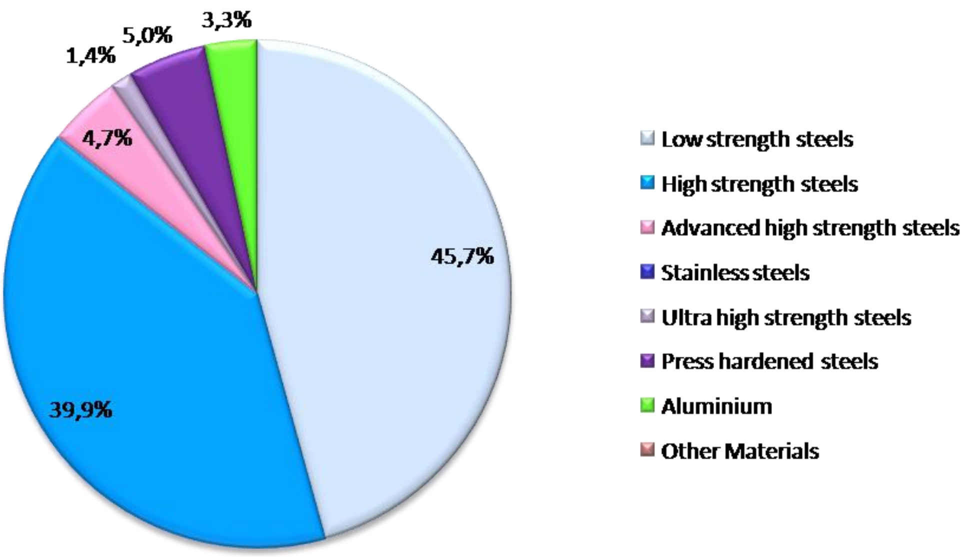
Ford Fusion/Mondeo



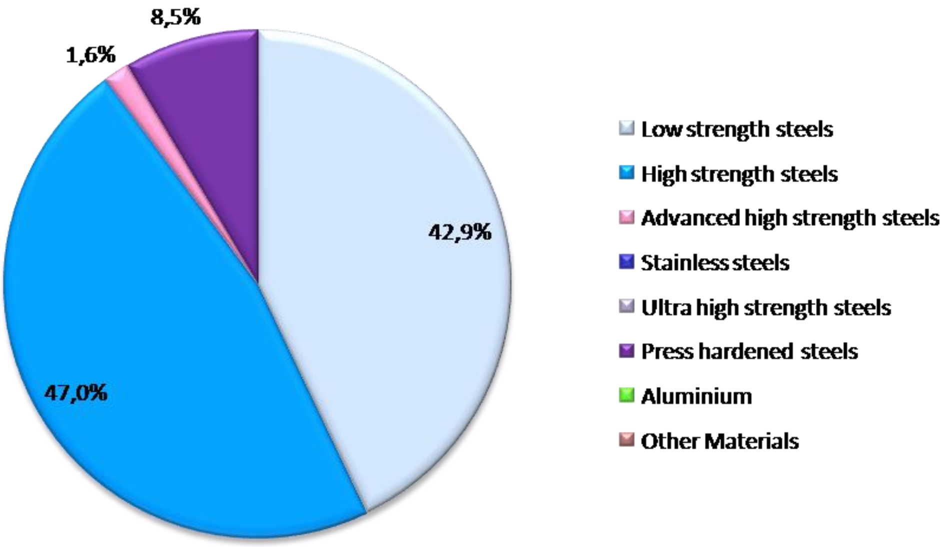


Honda Civic

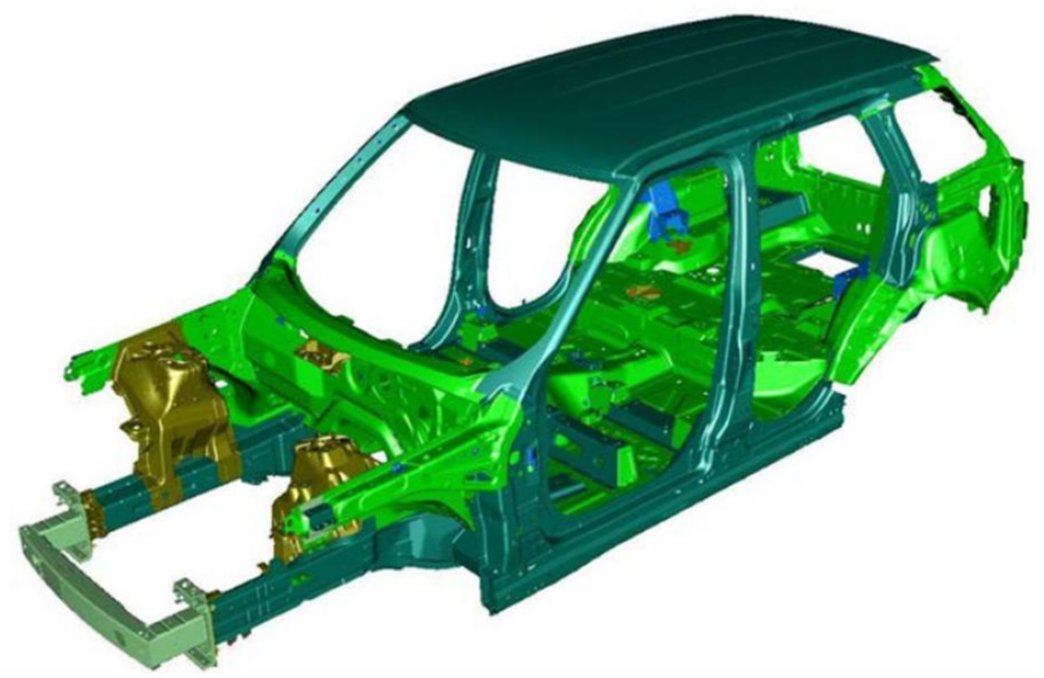


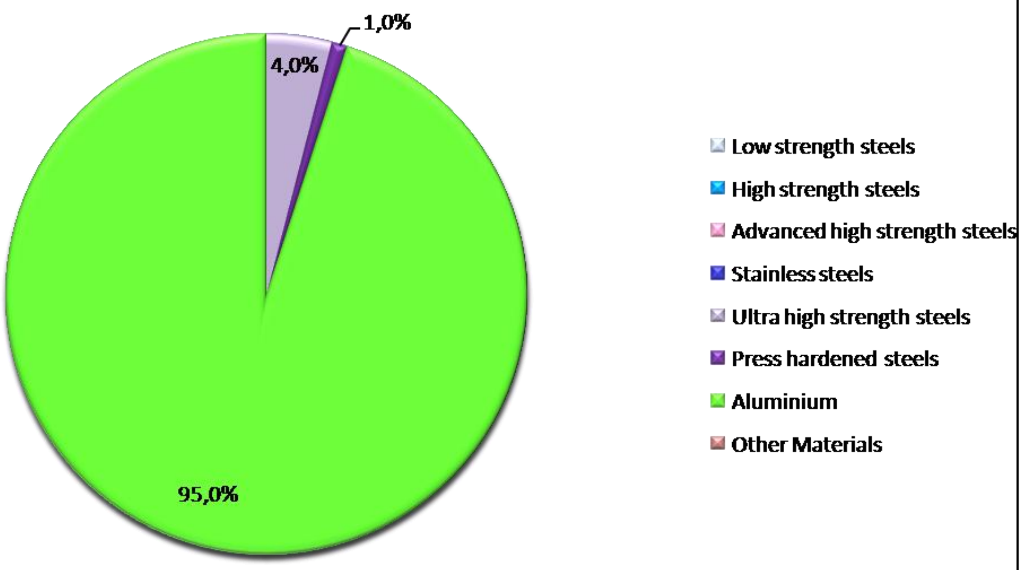

3,3%
5,0%
1,4%
4,7%
45,7%
39,9%
Low strength steels
High strength steels
Advanced high strength steels
Stainless steels
Ultra high strength steels
Press hardened steels
Aluminium
Other Materials

Skoda Rapid


8,5%
1,6%
42,9%
47,0%
Low strength steels
High strength steels
Advanced high strength steels
Stainless steels
Ultra high strength steels
Press hardened steels
Aluminium
Other Materials

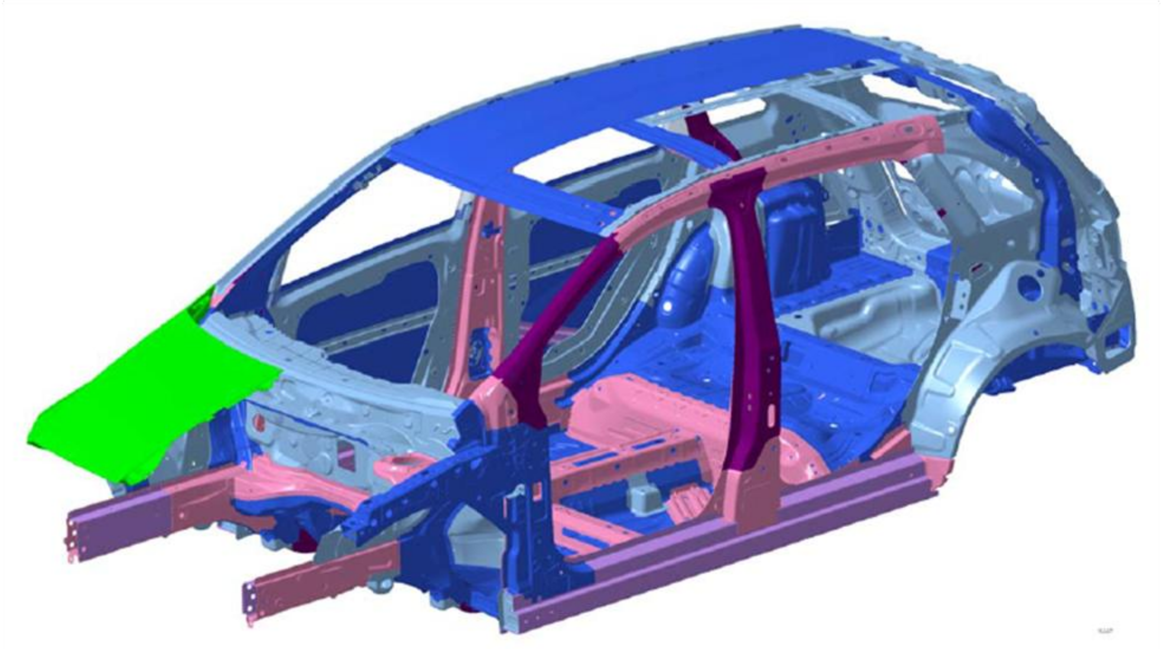
Jaguar Range Rover

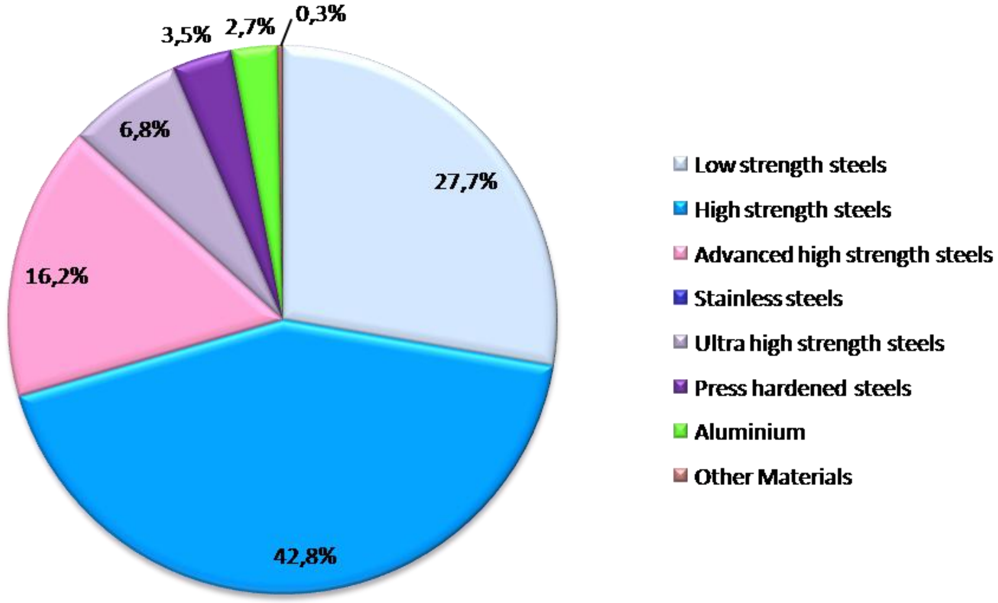




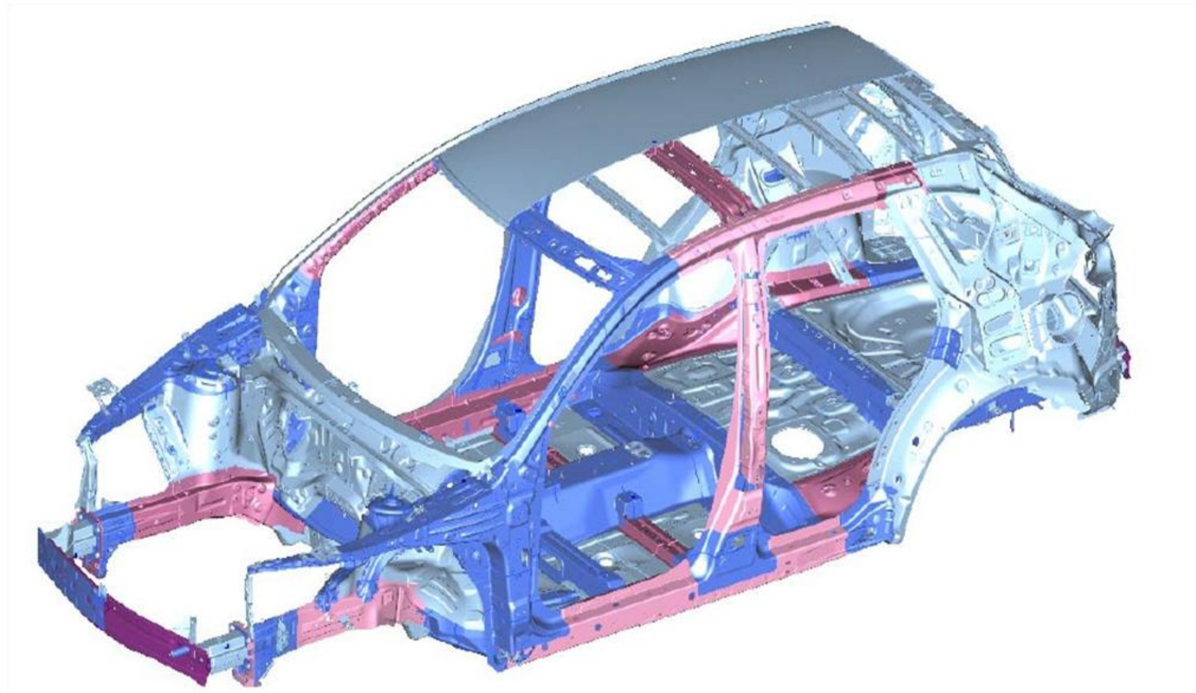
Euro Car Body 2011:

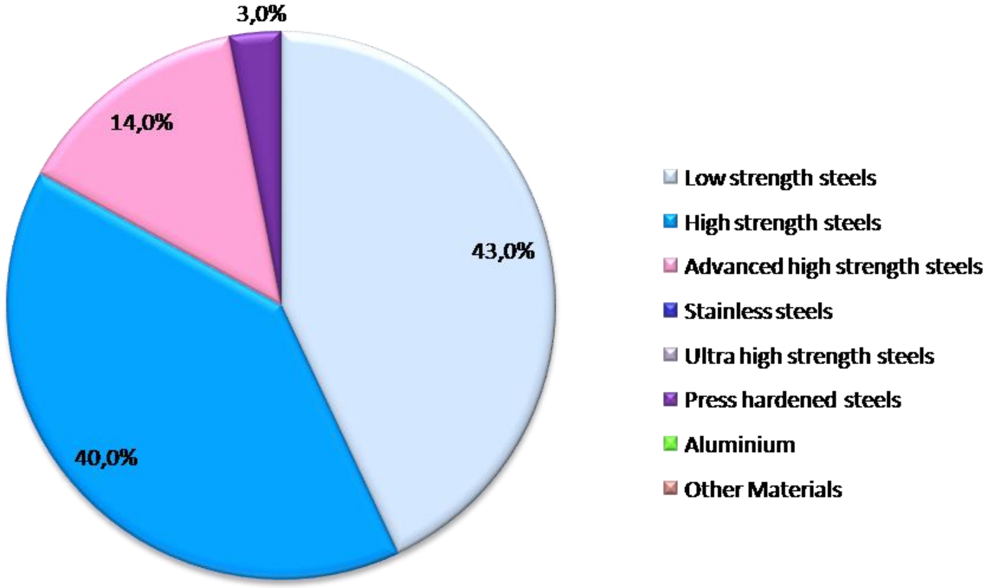
Mercedes B-Klasse



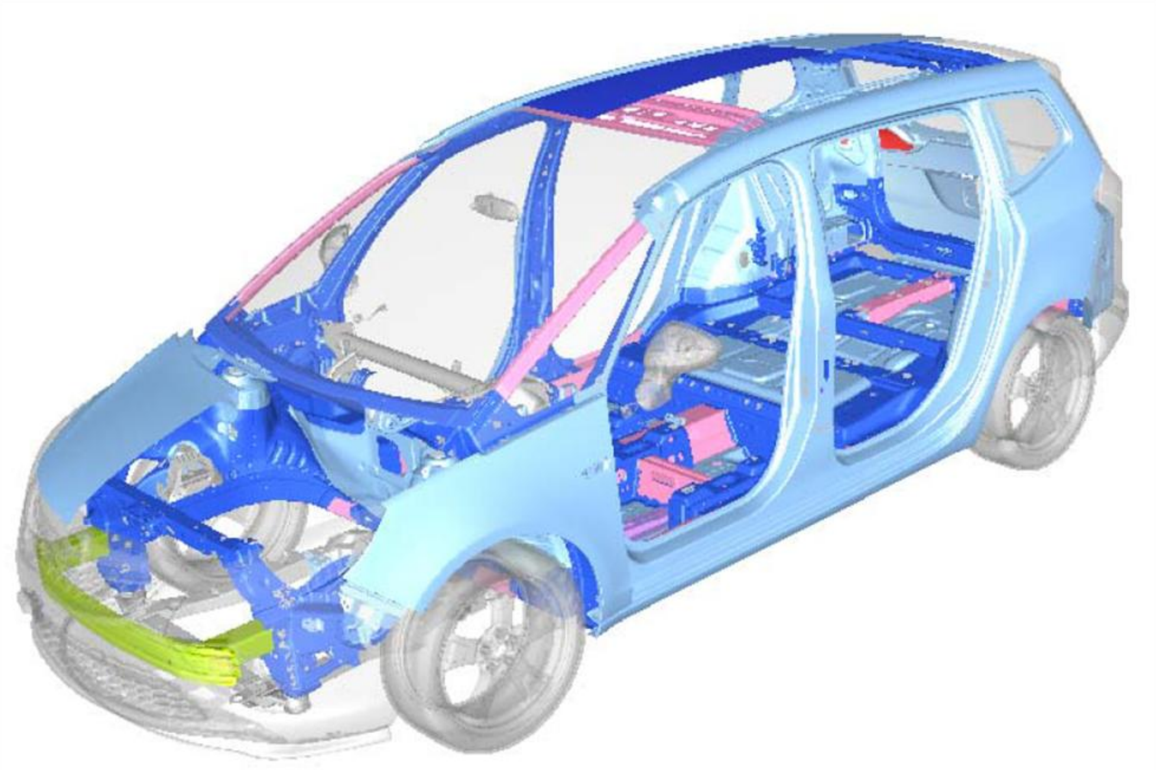


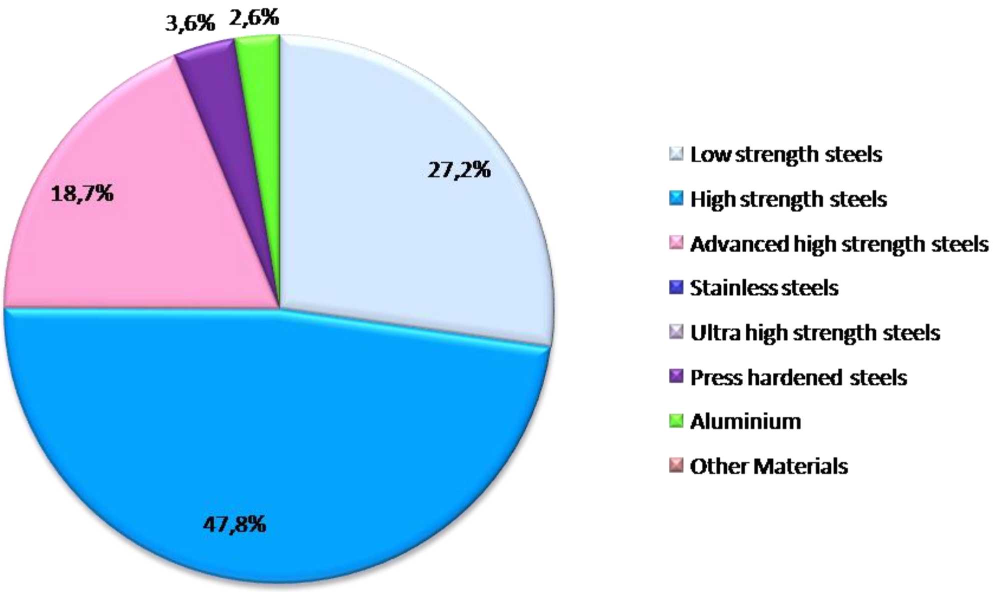
Mazda CX5



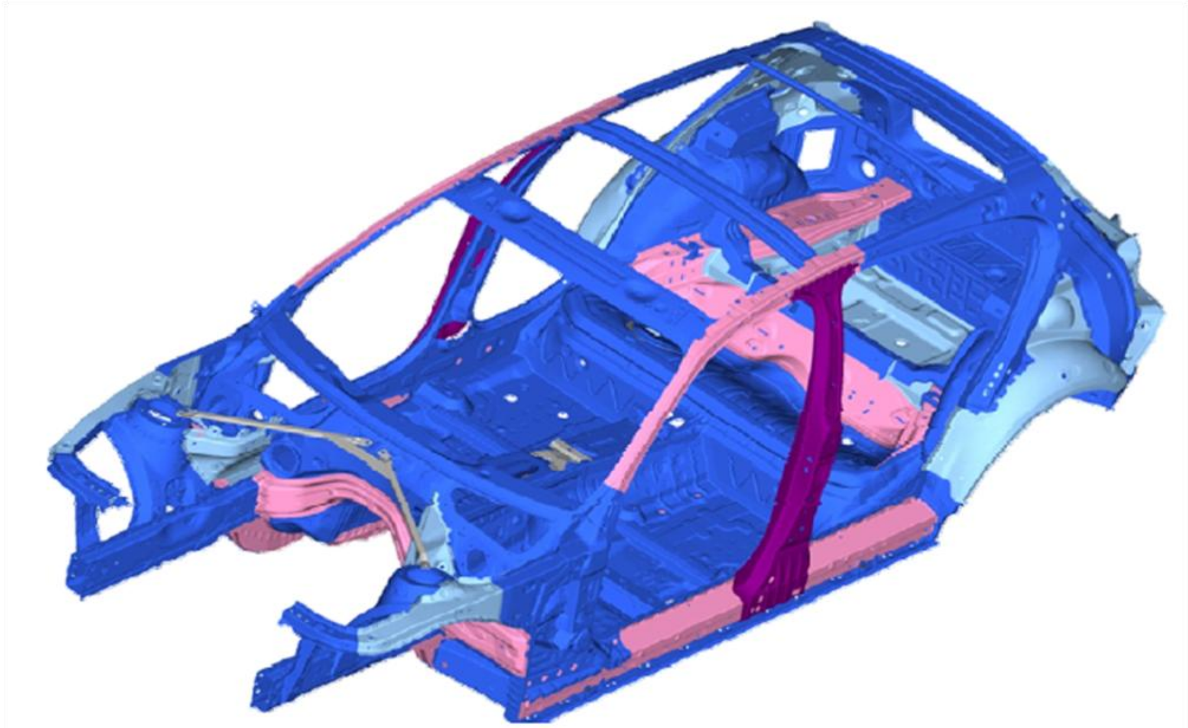

3,0%
14,0%
43,0%
40,0%
Low strength steels
High strength steels
Advanced high strength steels
Stainless steels
Ultra high strength steels
Press hardened steels
Aluminium
Other Materials

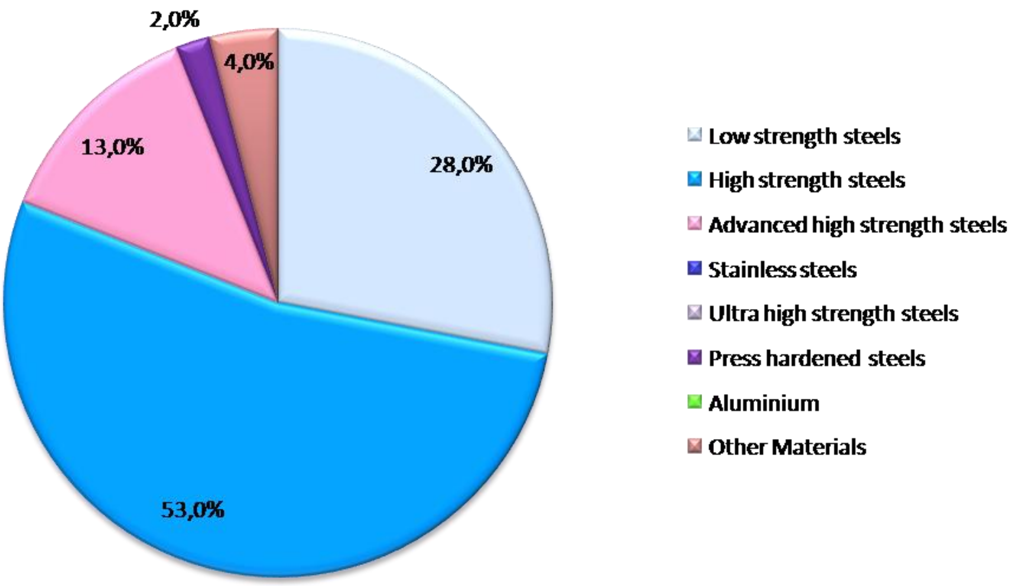
Opel Zafira



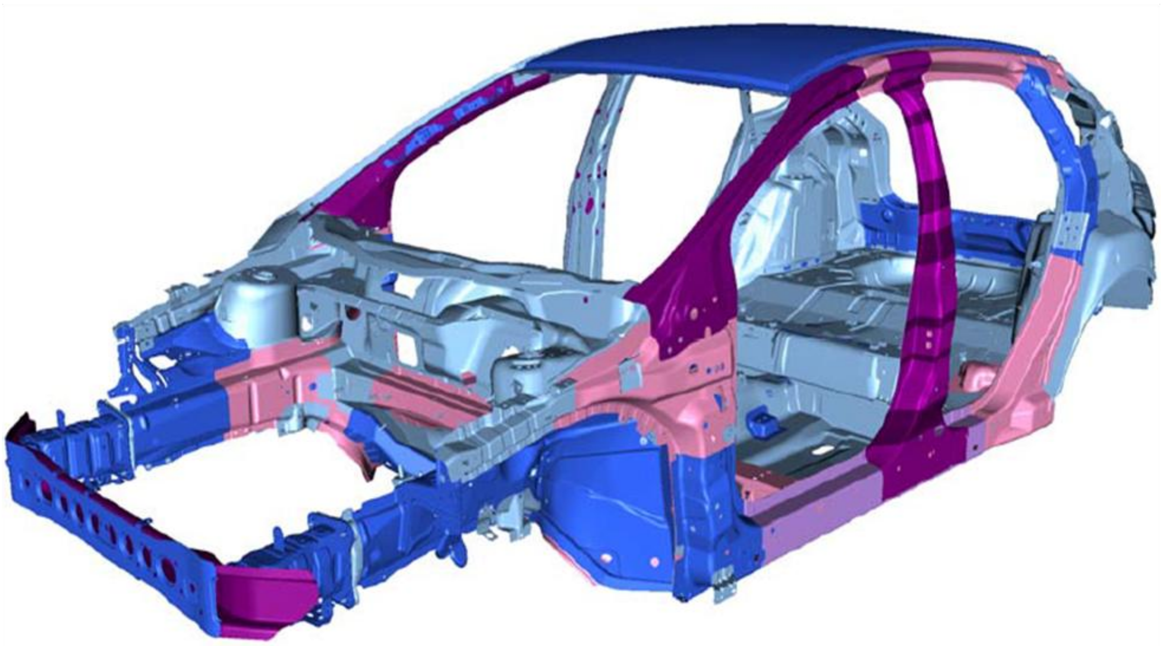

3,6%
2,6%
27,2%
18,7%
47,8%
Low strength steels
High strength steels
Advanced high strength steels
Stainless steels
Ultra high strength steels
Press hardened steels
Aluminium
Other Materials

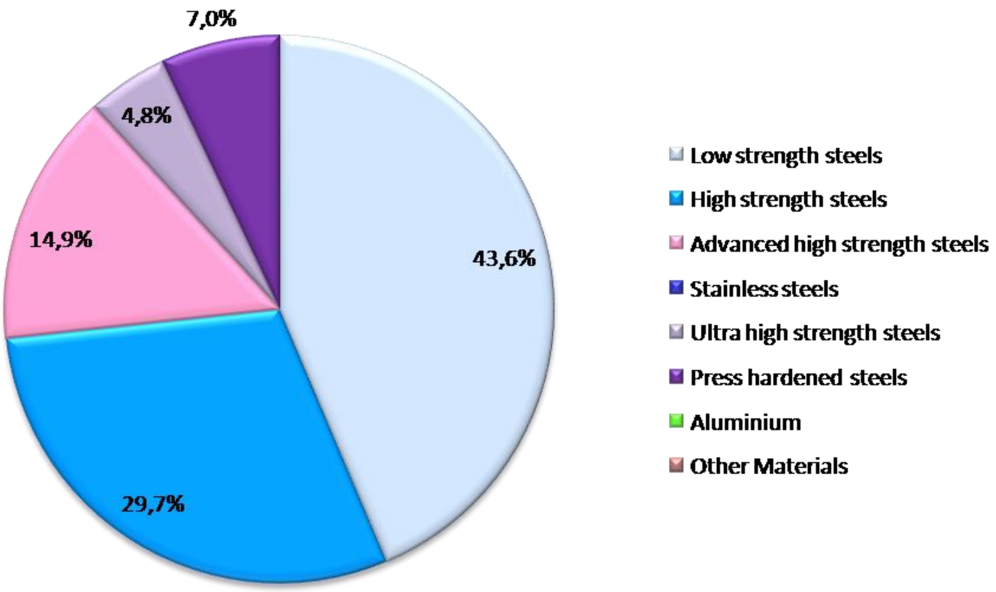
BMW 1




2,0%
4,0%
13,0%
28,0%
53,0%
Low strength steels
High strength steels
Advanced high strength steels
Stainless steels
Ultra high strength steels
Press hardened steels
Aluminium
Other Materials

Ford Focus

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4,8%
14,9%
43,6%
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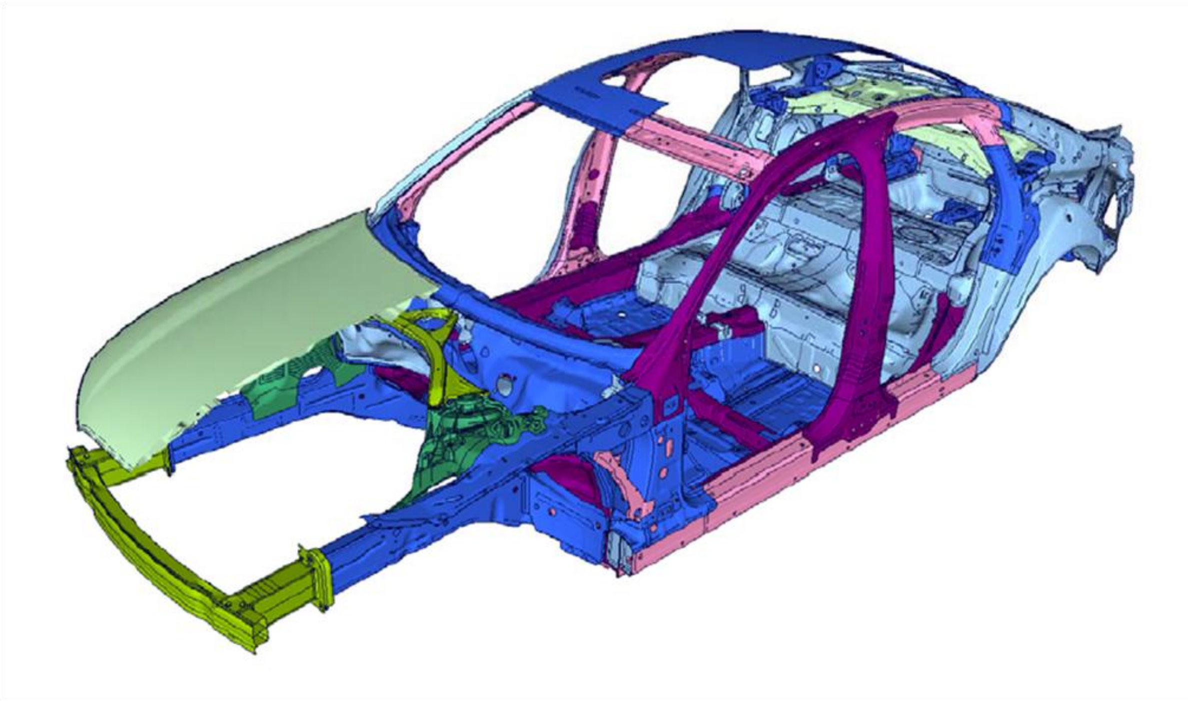
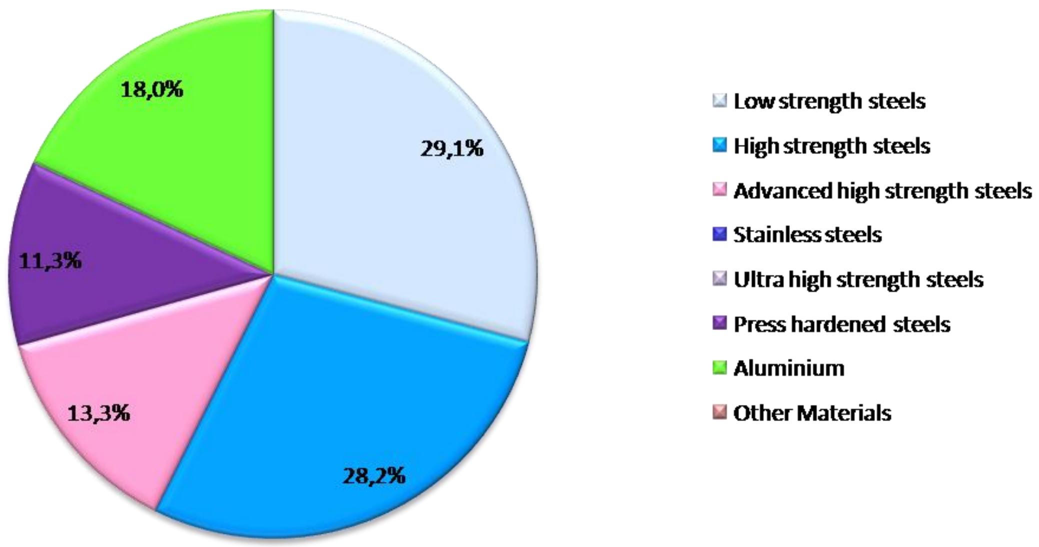
High strength steels
Advanced high strength steels
Stainless steels
Ultra high strength steels
Press hardened steels
Aluminium
Other Materials

Audi A6

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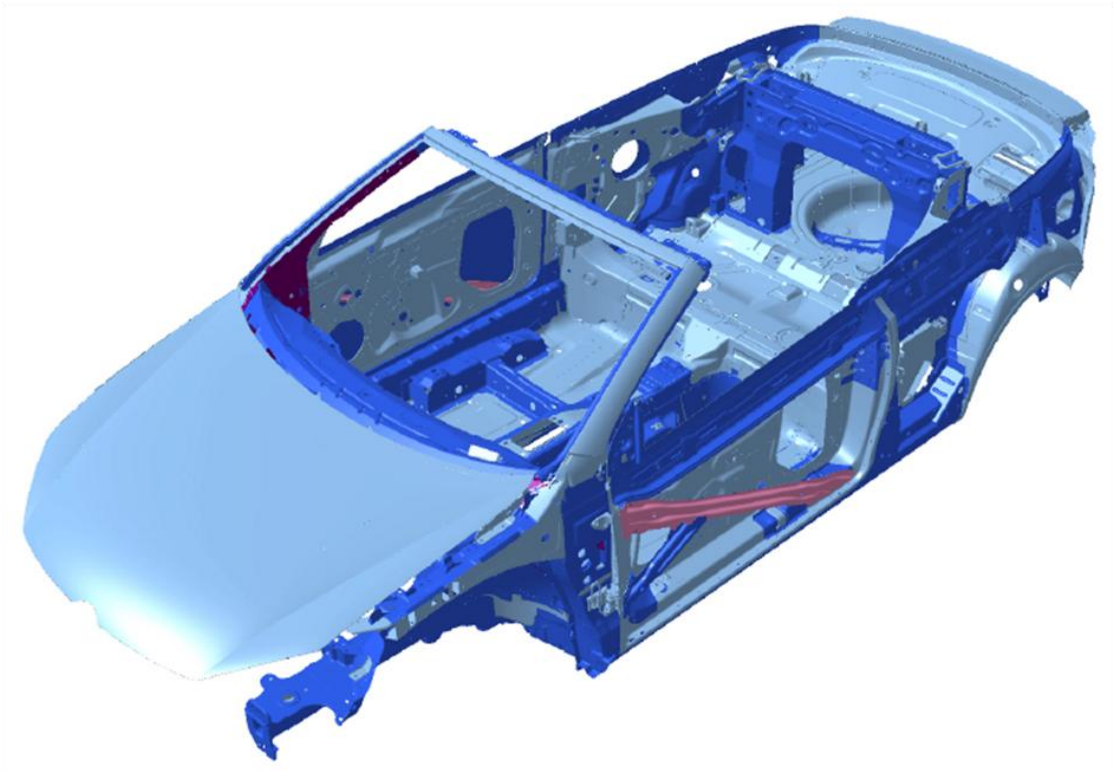
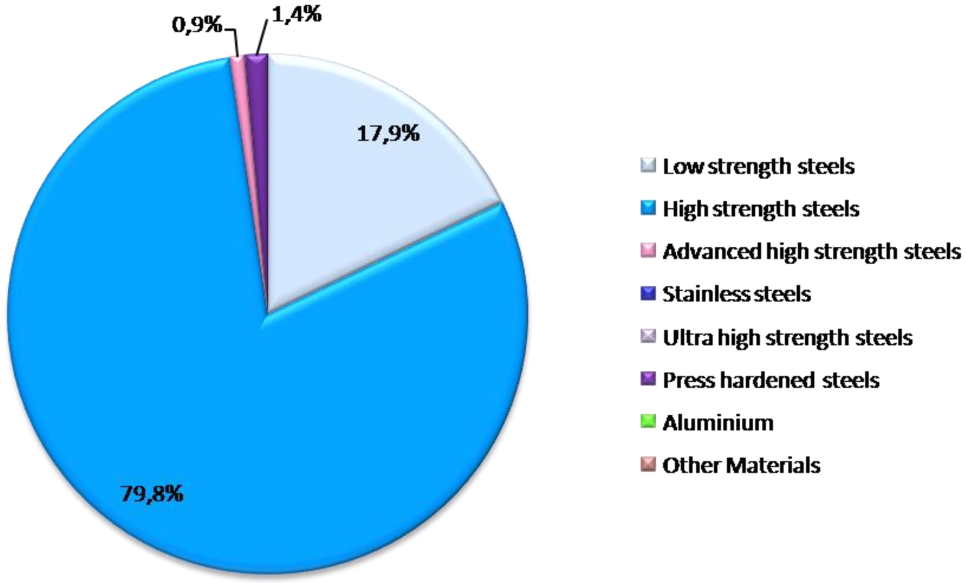
Aluminium
Other Materials

VW Cabrio

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Other Materials

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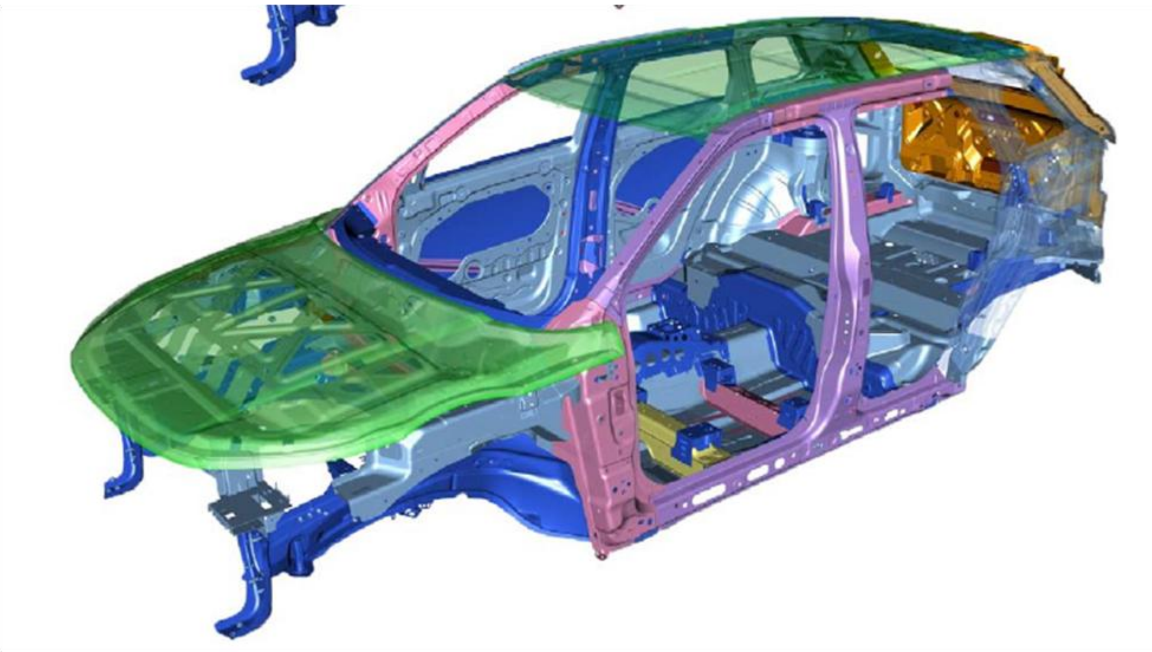

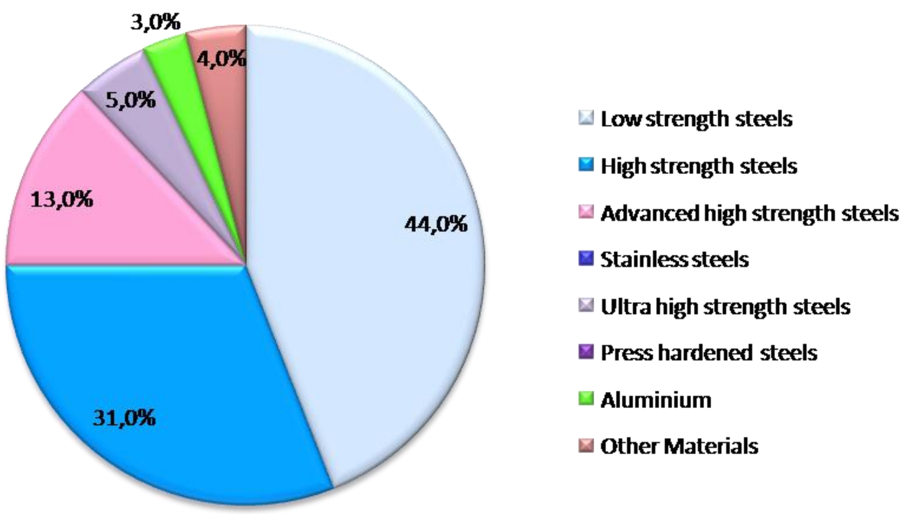

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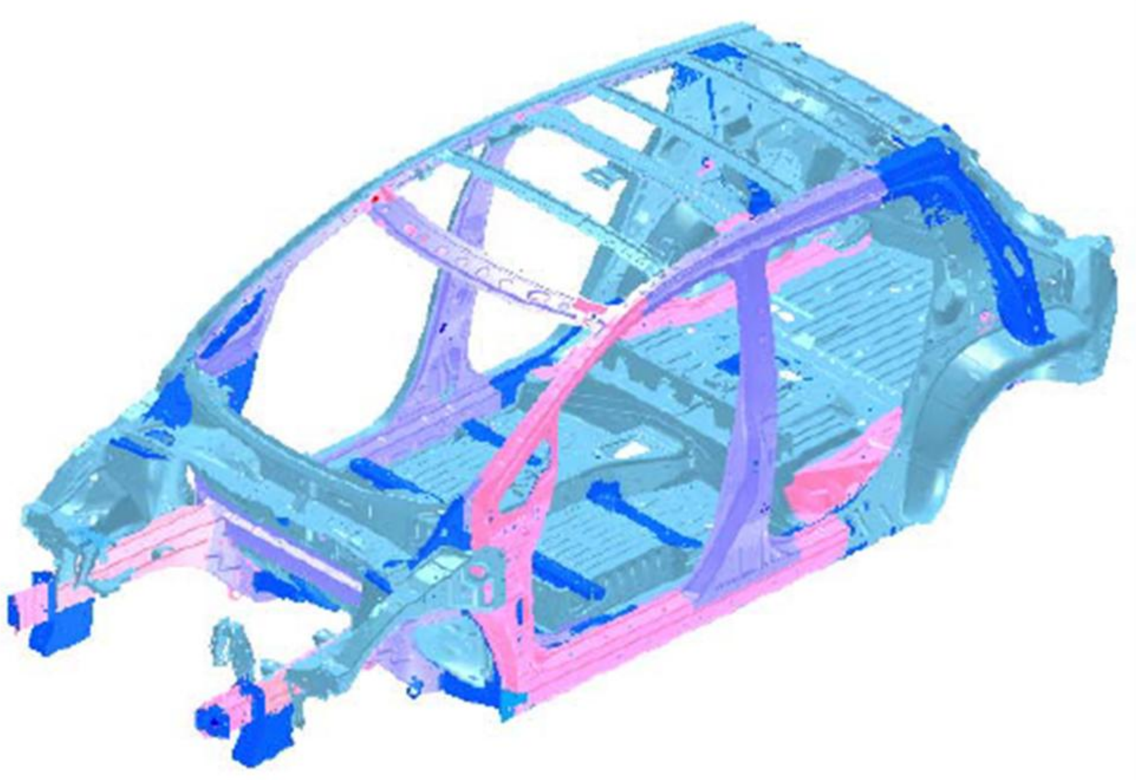

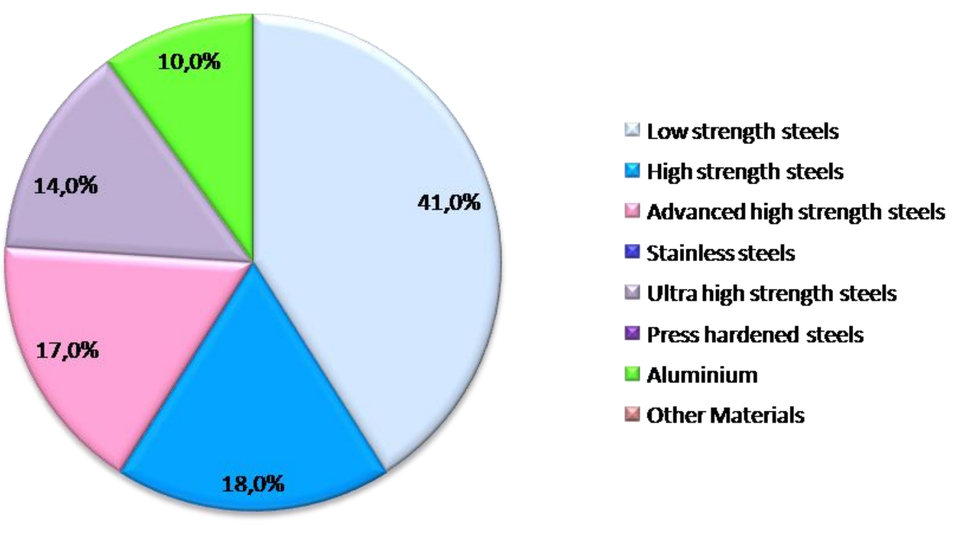
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Aluminium
Other Materials

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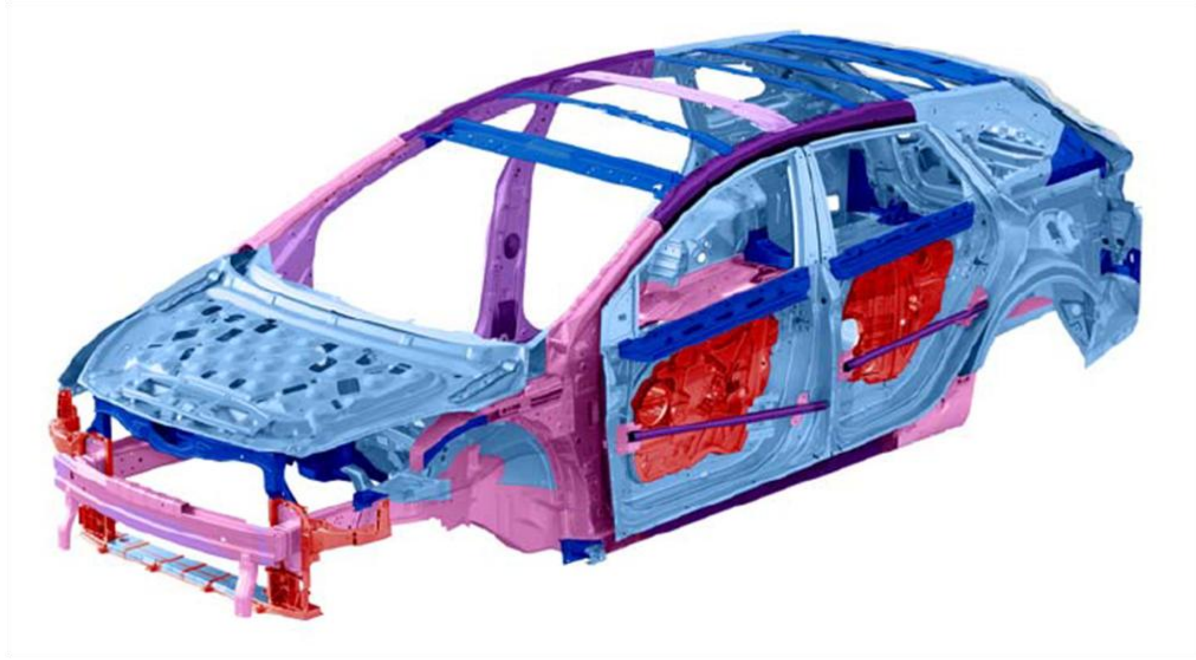

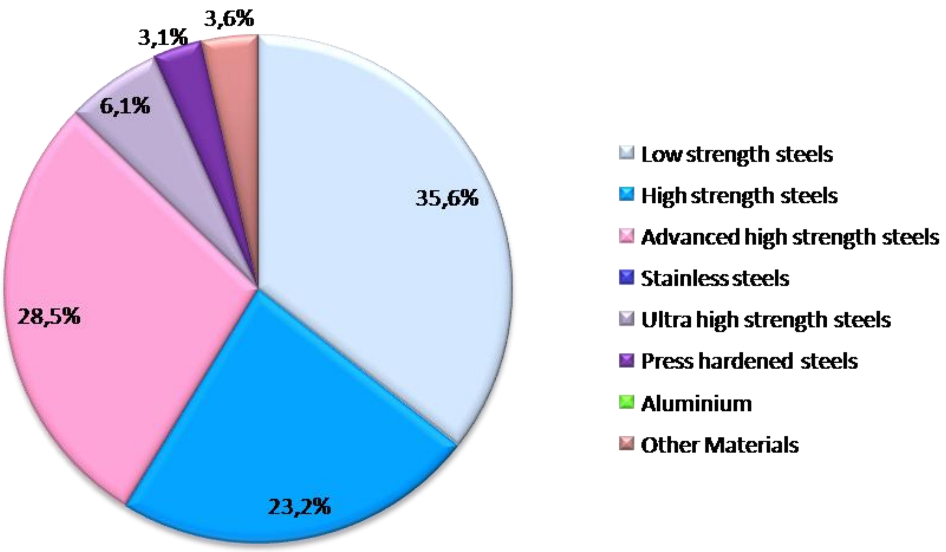
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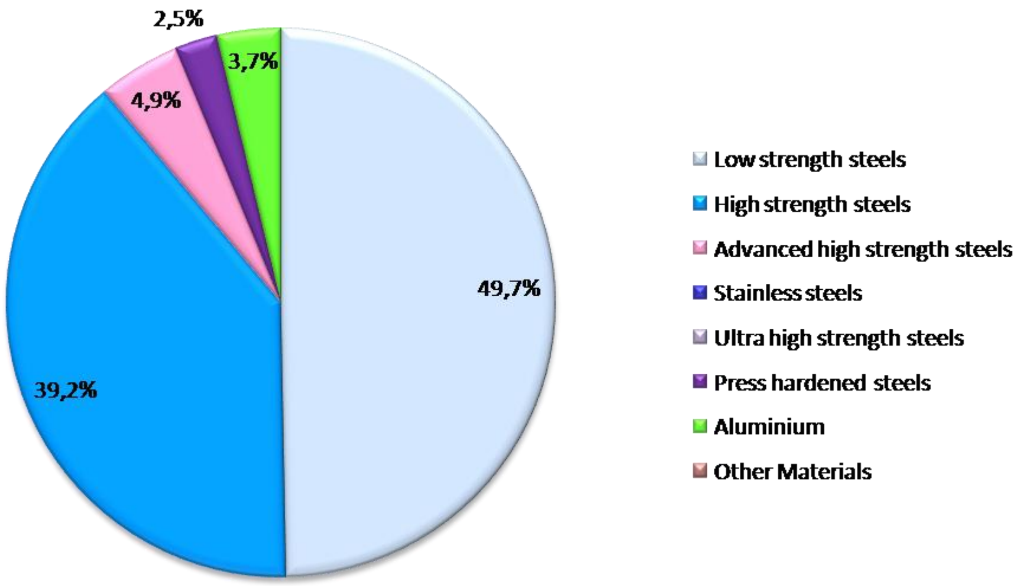
Stainless steels
Ultra high strength steels
Press hardened steels
Aluminium
Other Materials

<u>Euro Car Body 2010:</u>

Citroen C4



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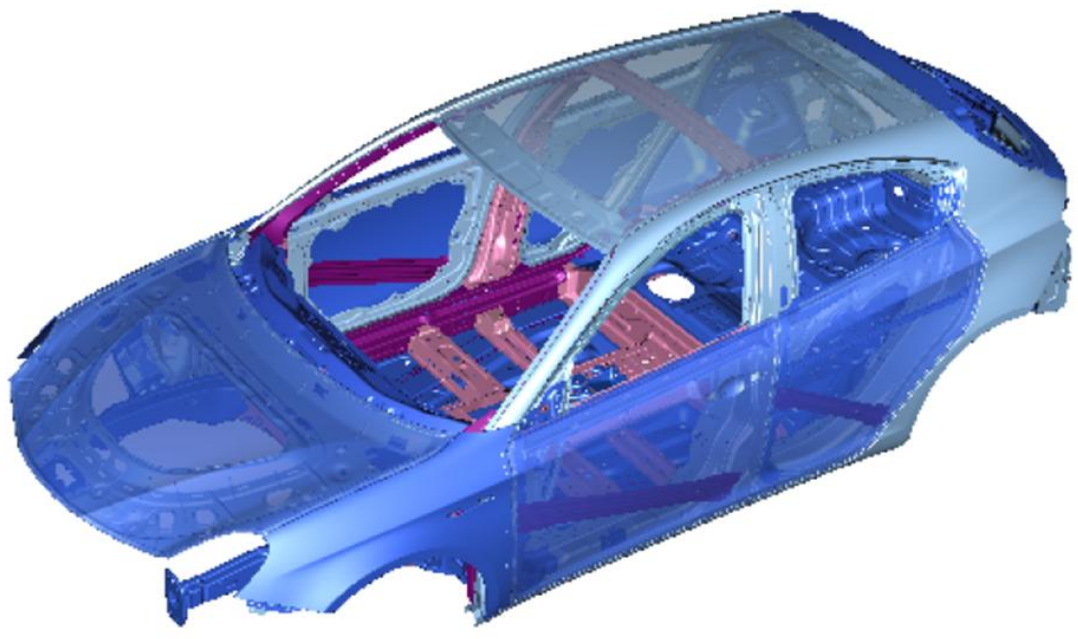

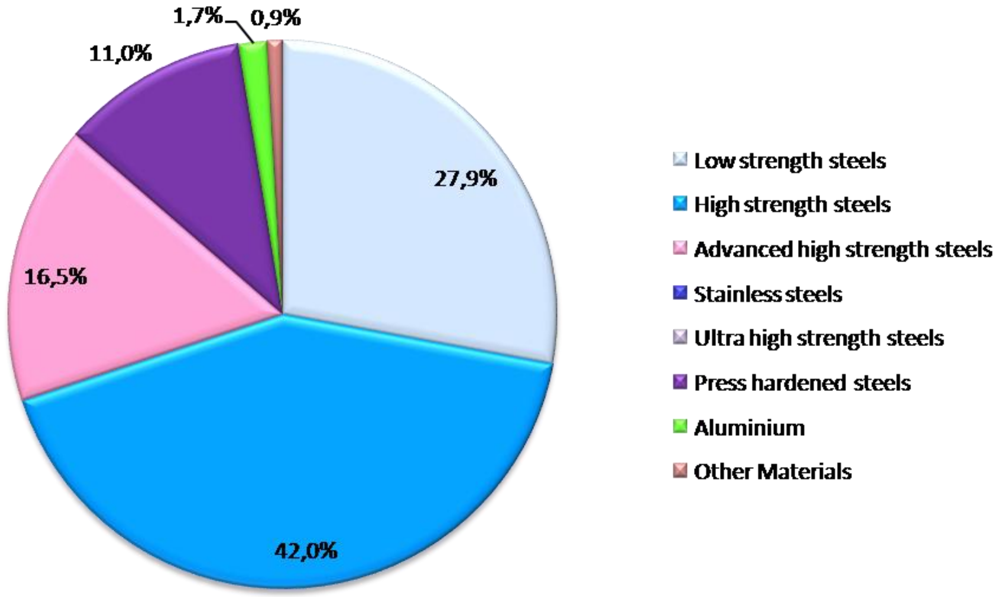

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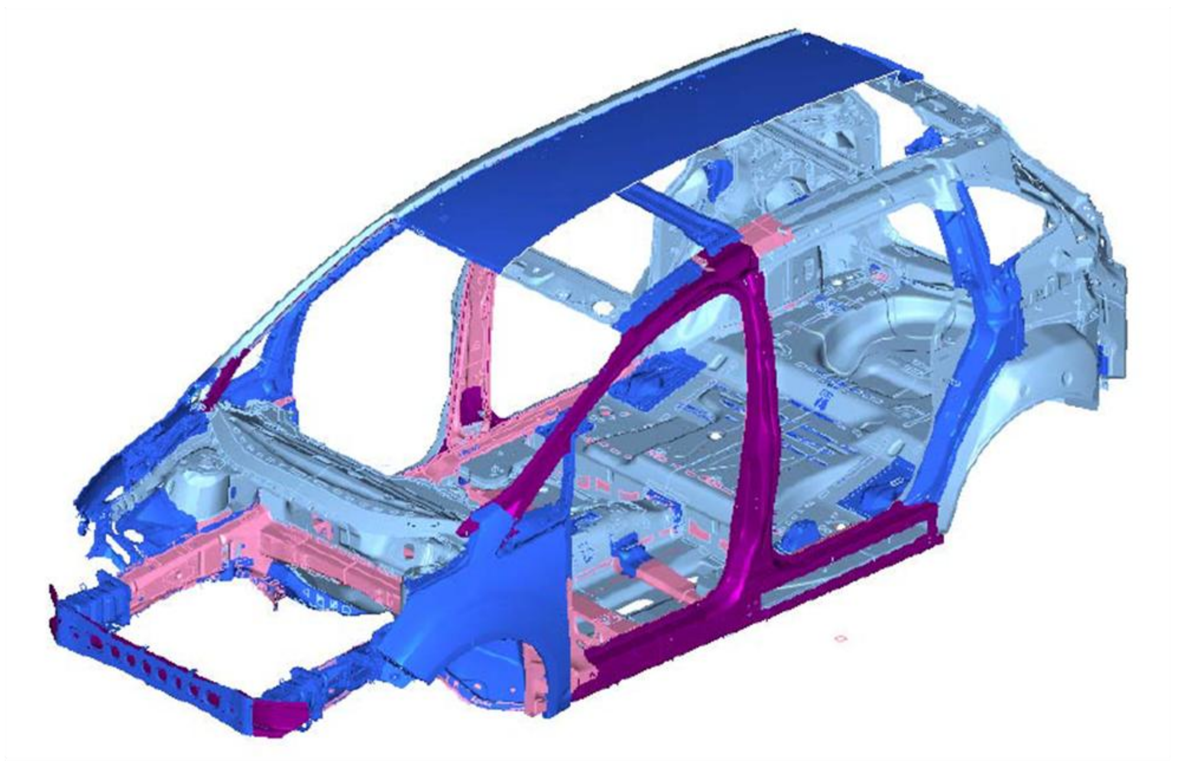

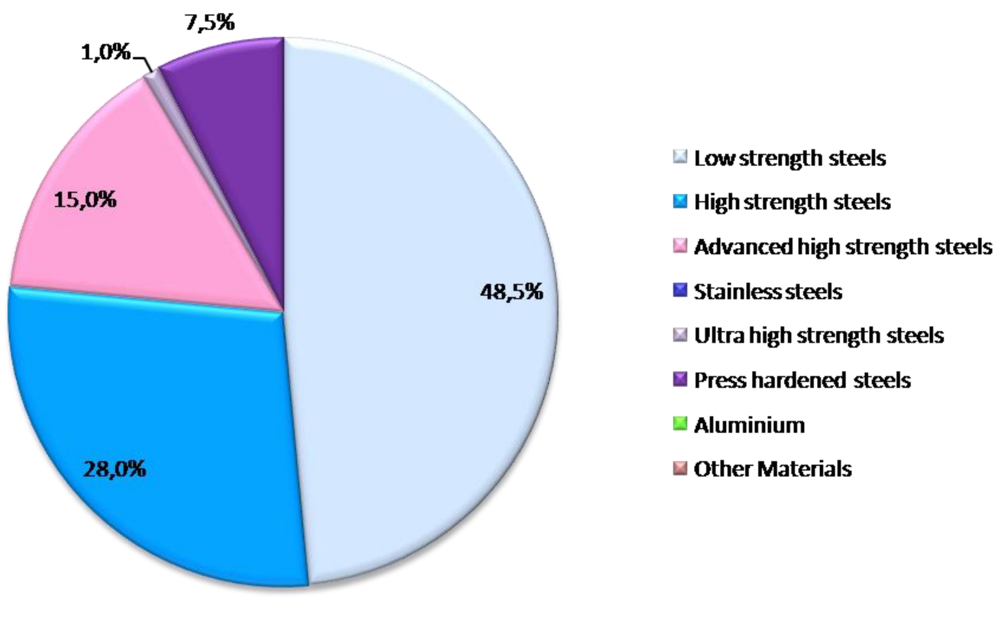
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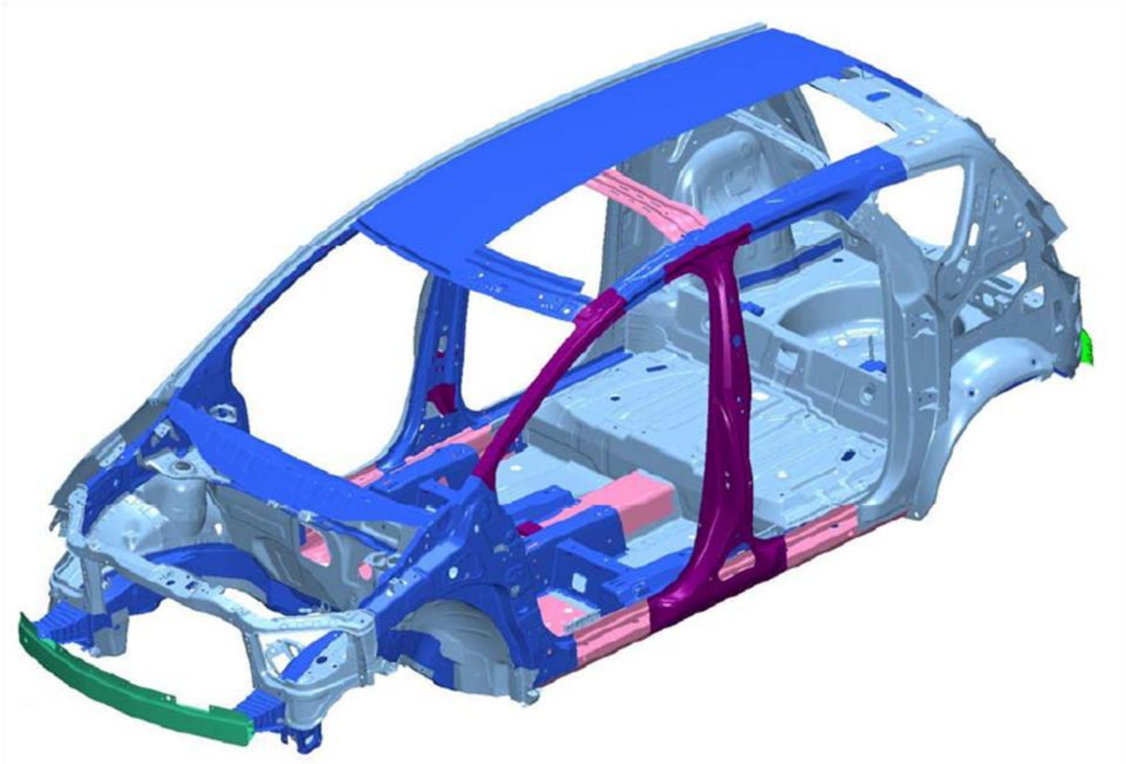
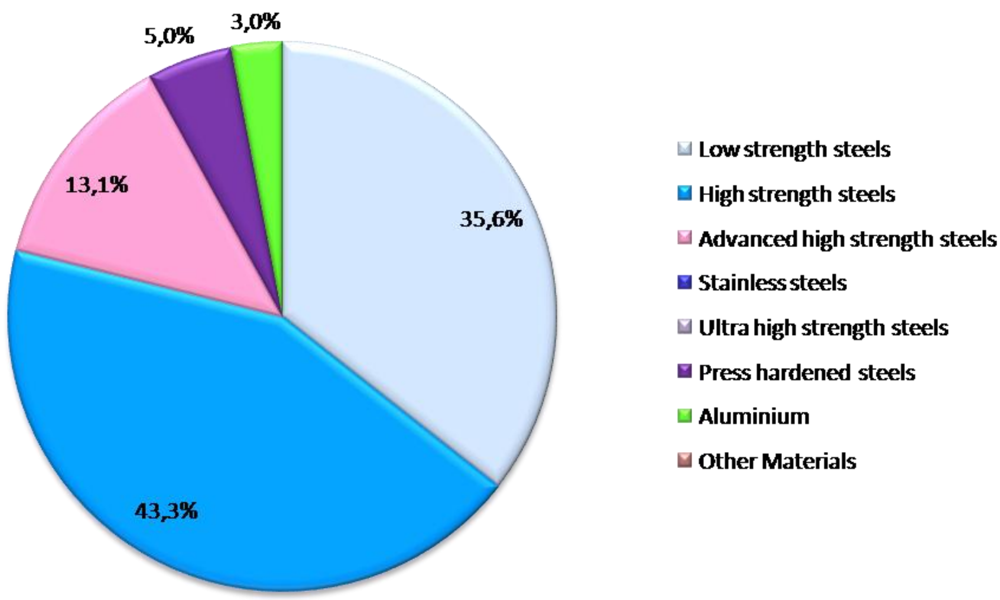
Press hardened steels
Aluminium
Other Materials

Opel Meriva

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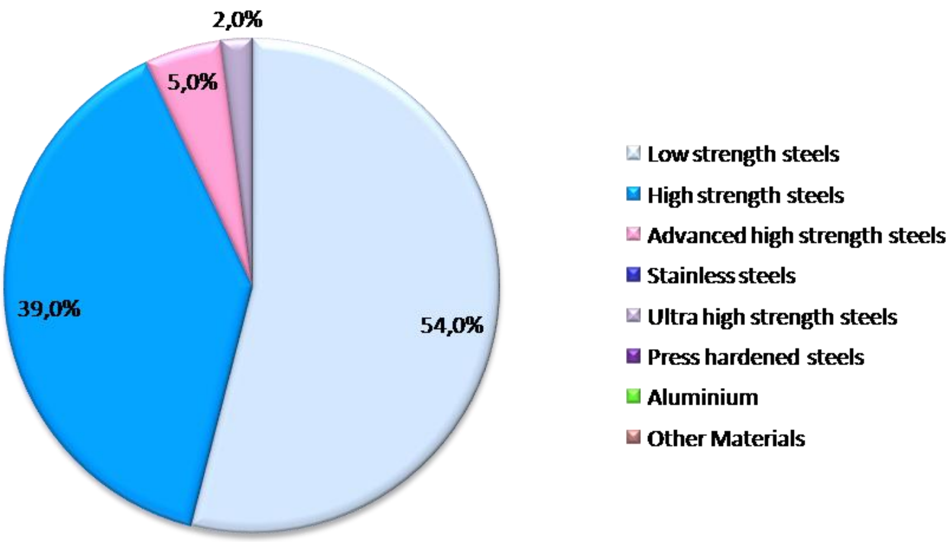
Advanced high strength steels
Stainless steels
Ultra high strength steels
Press hardened steels
Aluminium
Other Materials

Honda CR-X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Stainless steels
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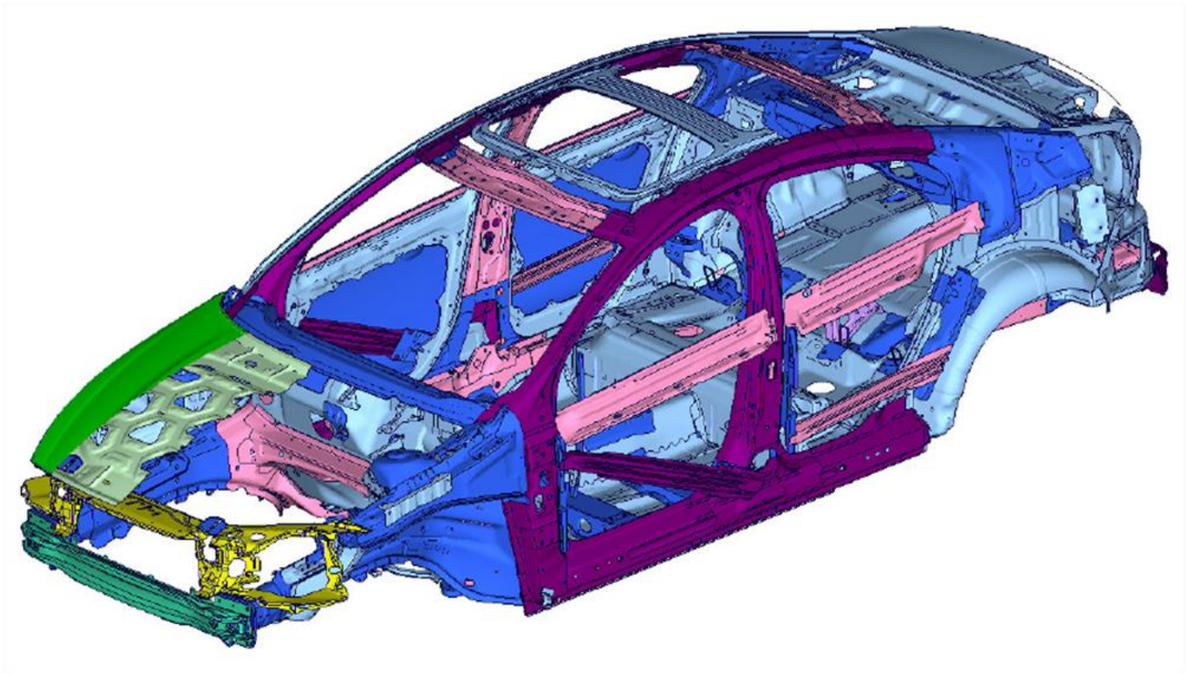
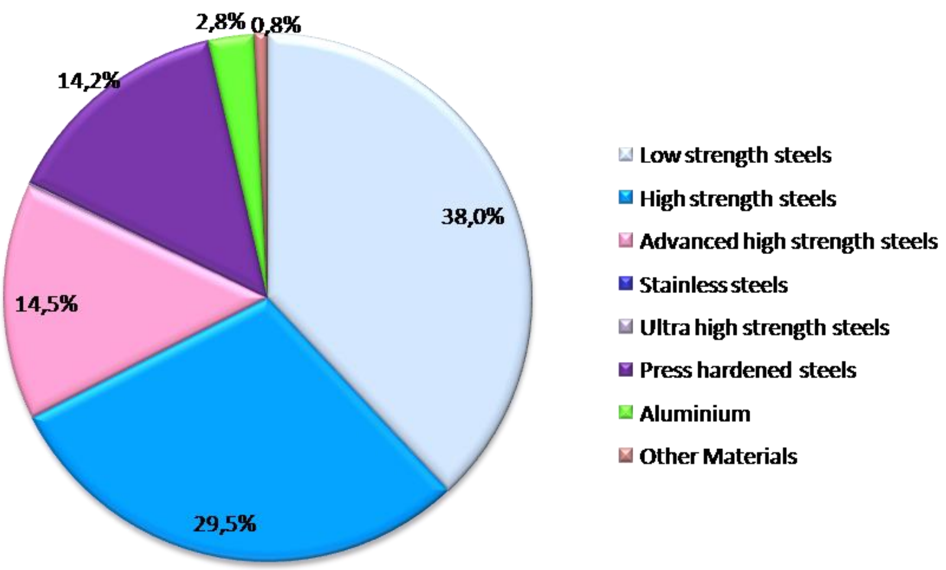
Aluminium
Other Materials

Volvo S60

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High strength steels
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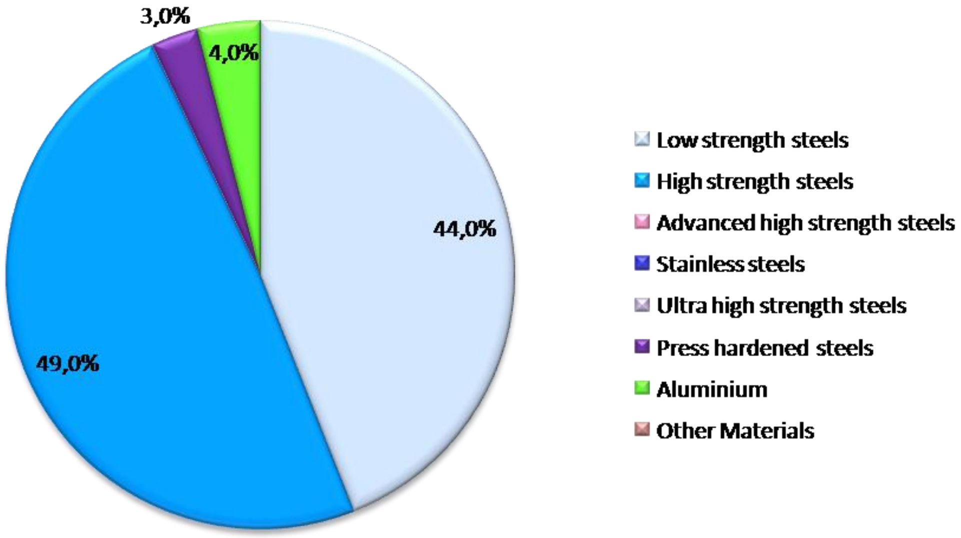
Aluminium
Other Materials

Renault Latitude



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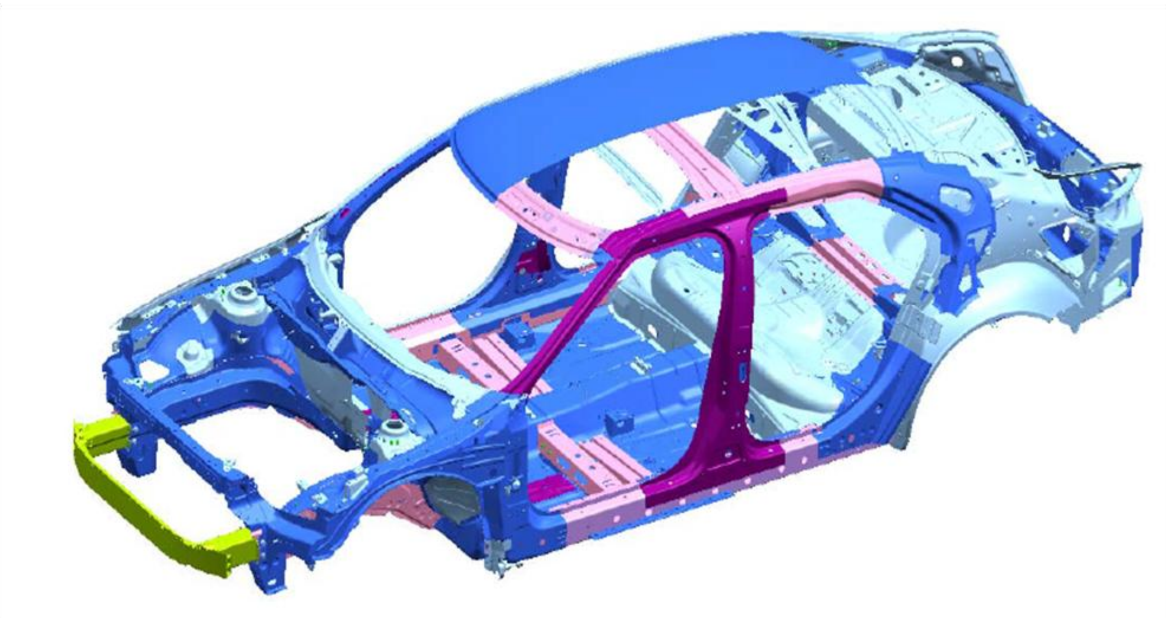

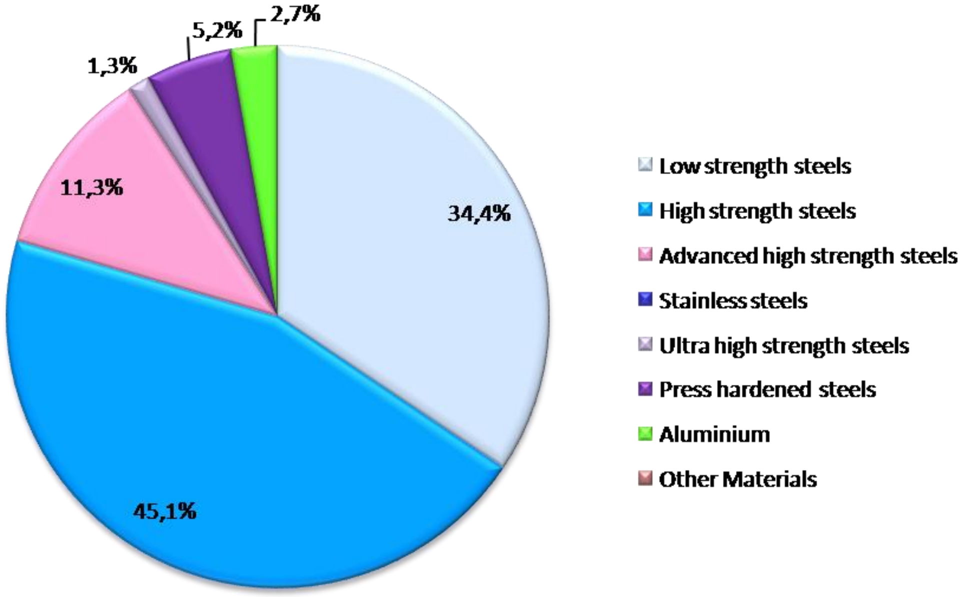
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High strength steels
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Stainless steels
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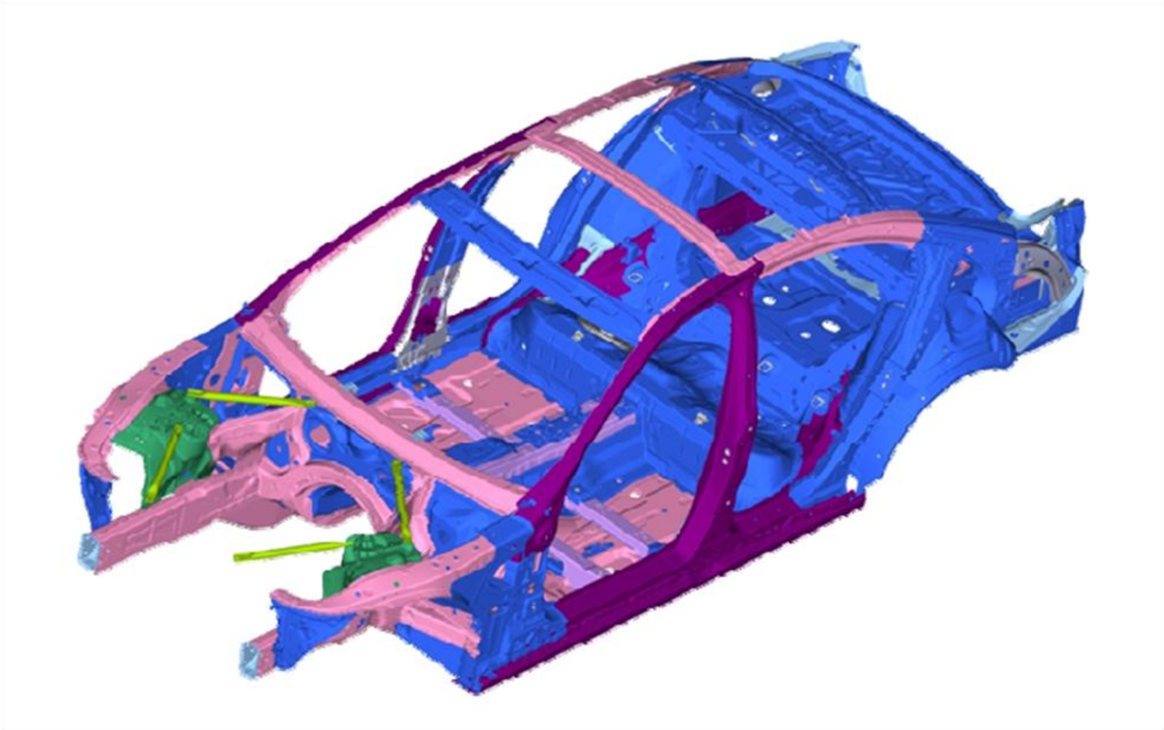
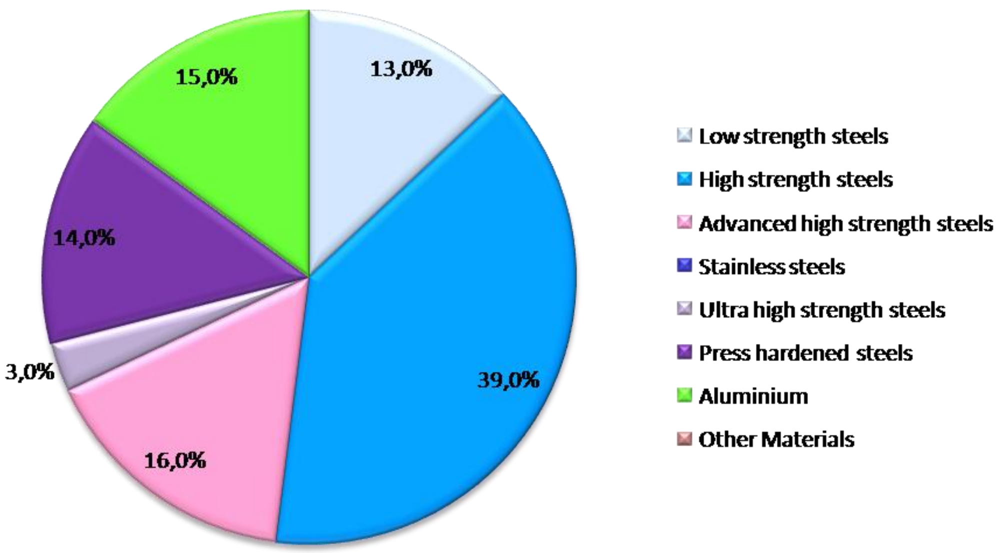
Press hardened steels
Aluminium
Other Materials

BMW 5

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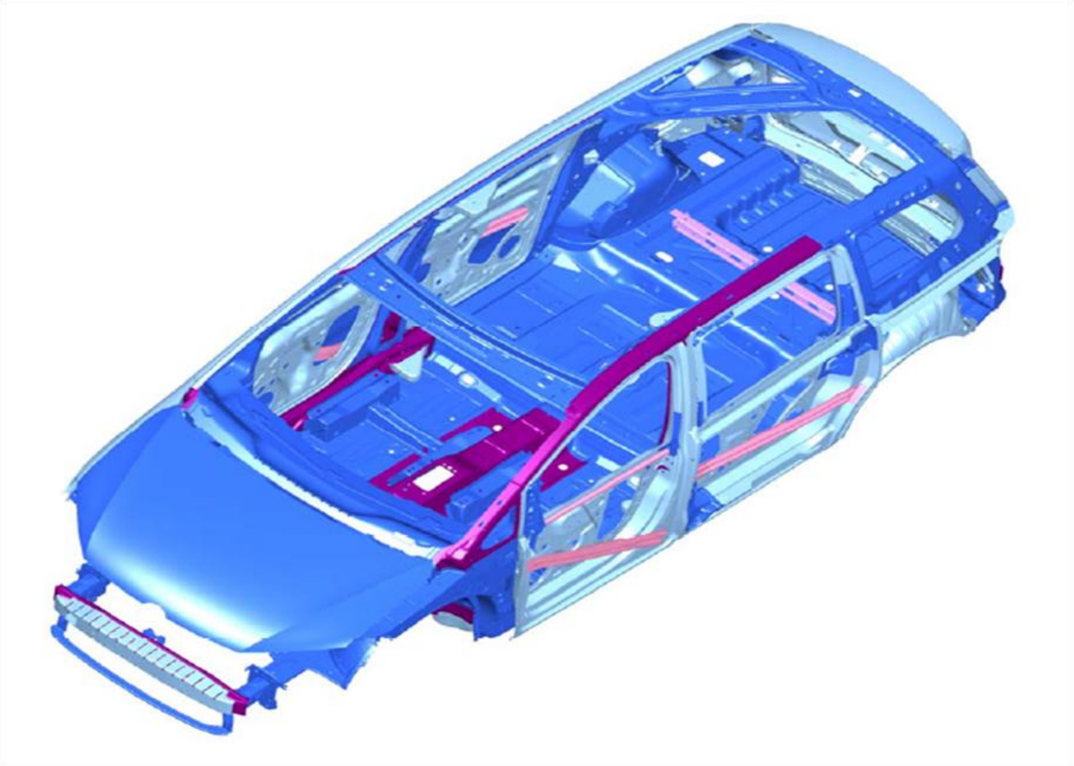
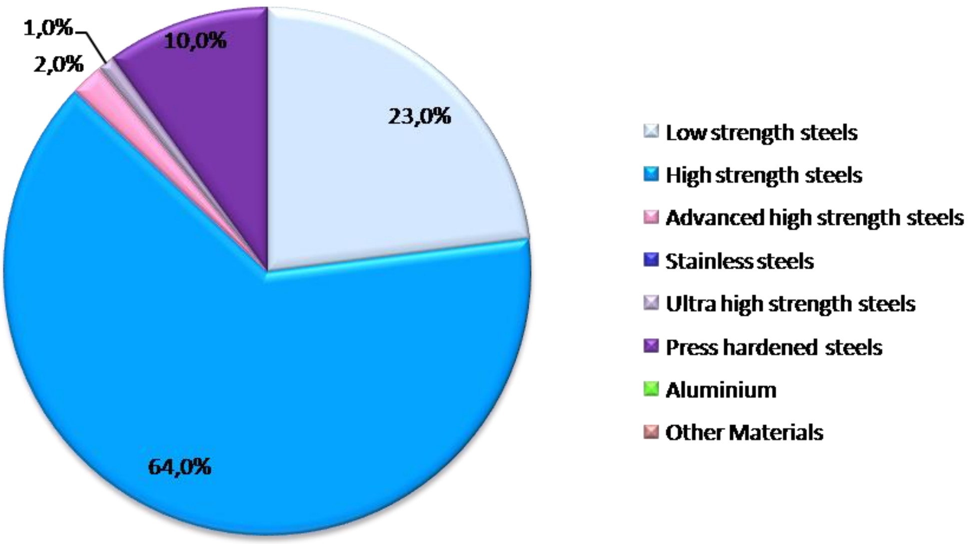
Aluminium
Other Materials

VW Sharan

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10,0%
23,0%
64,0%
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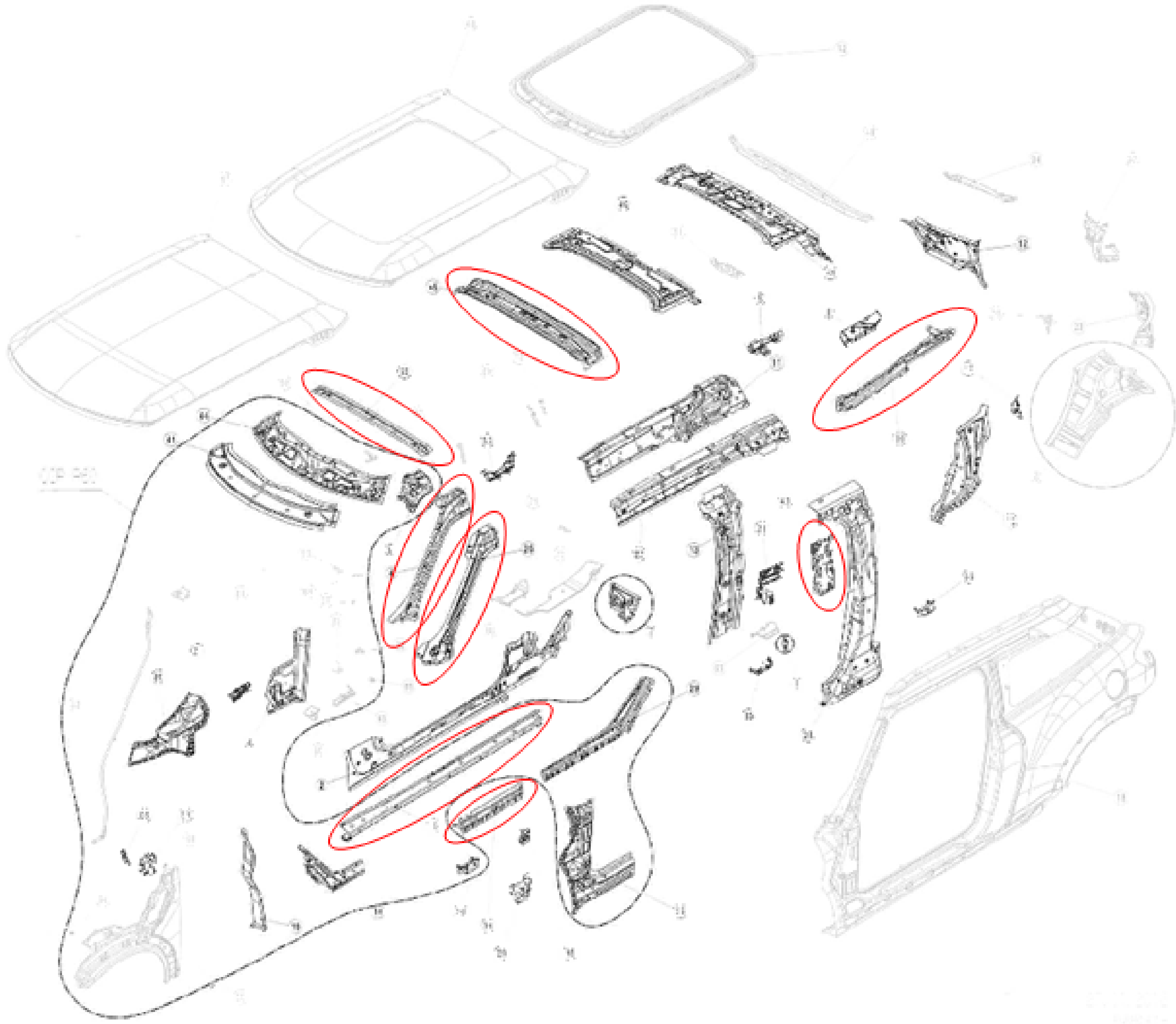
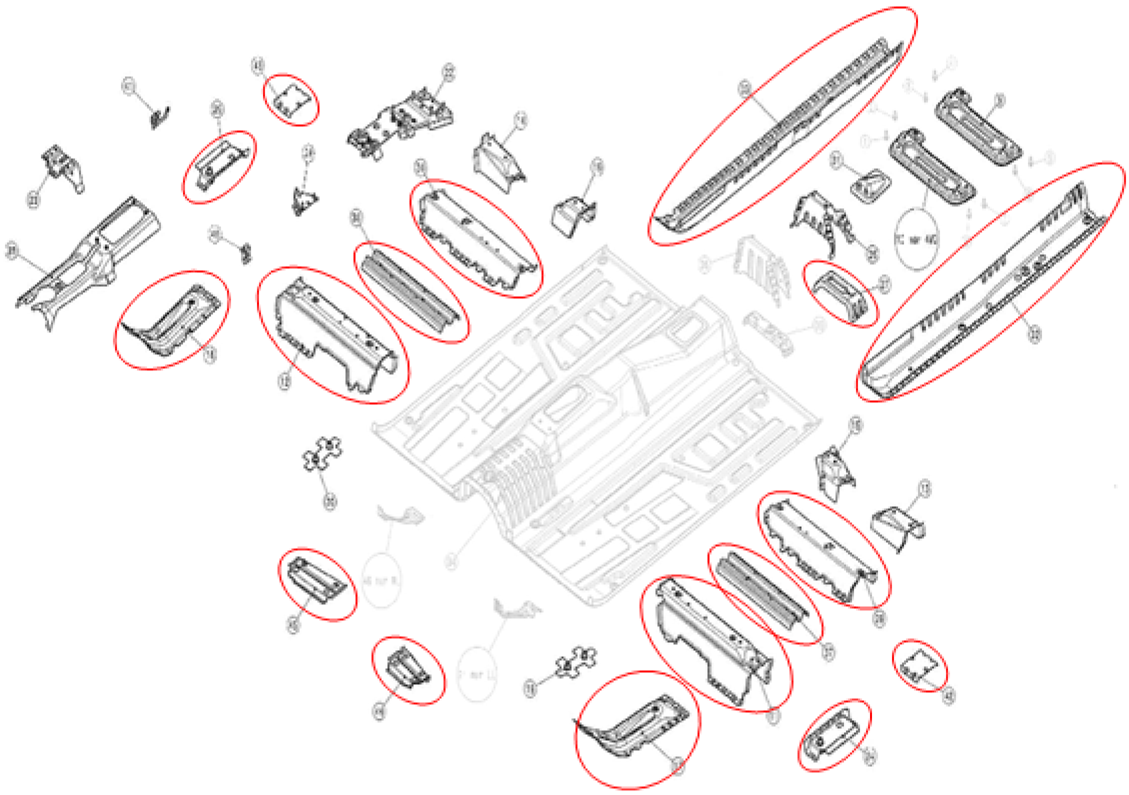
High strength steels
Advanced high strength steels
Stainless steels
Ultra high strength steels
Press hardened steels
Aluminium
Other Materials

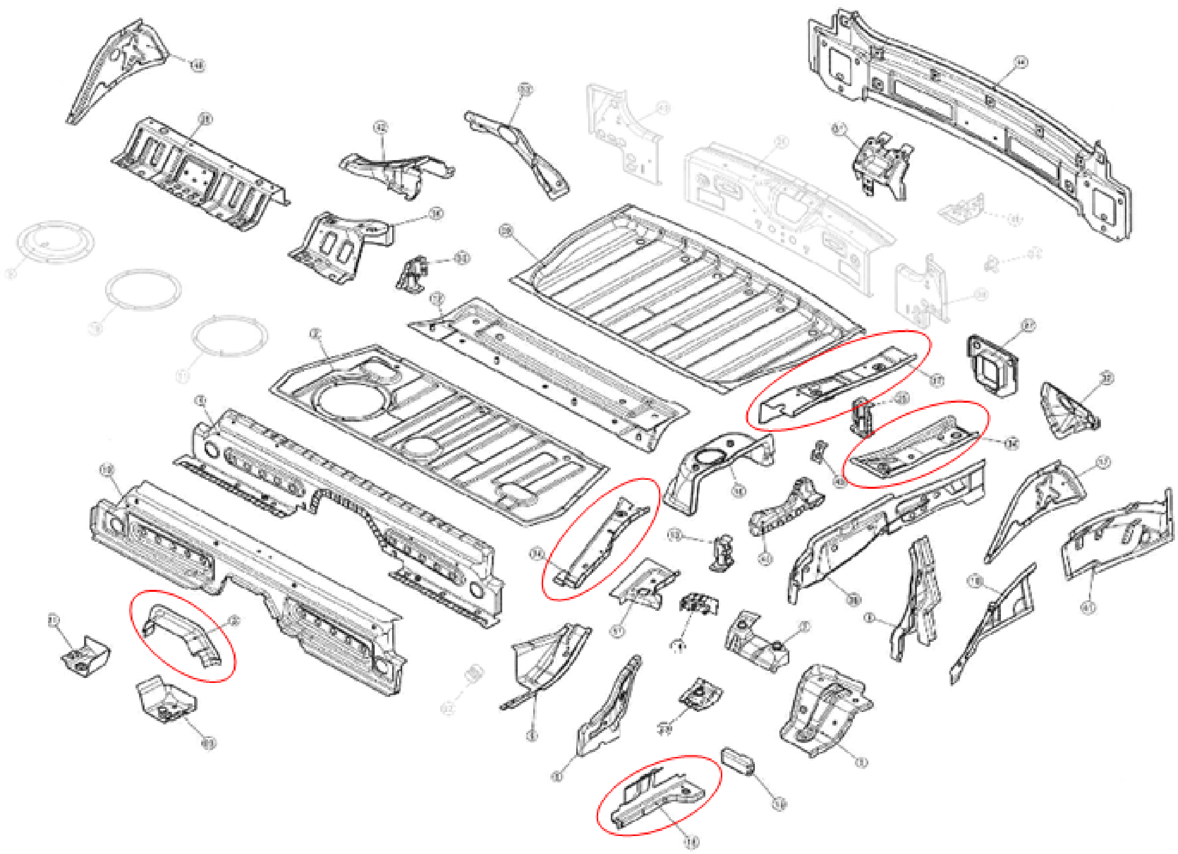
D. Roll Forming Potentials in a Car Body Frame



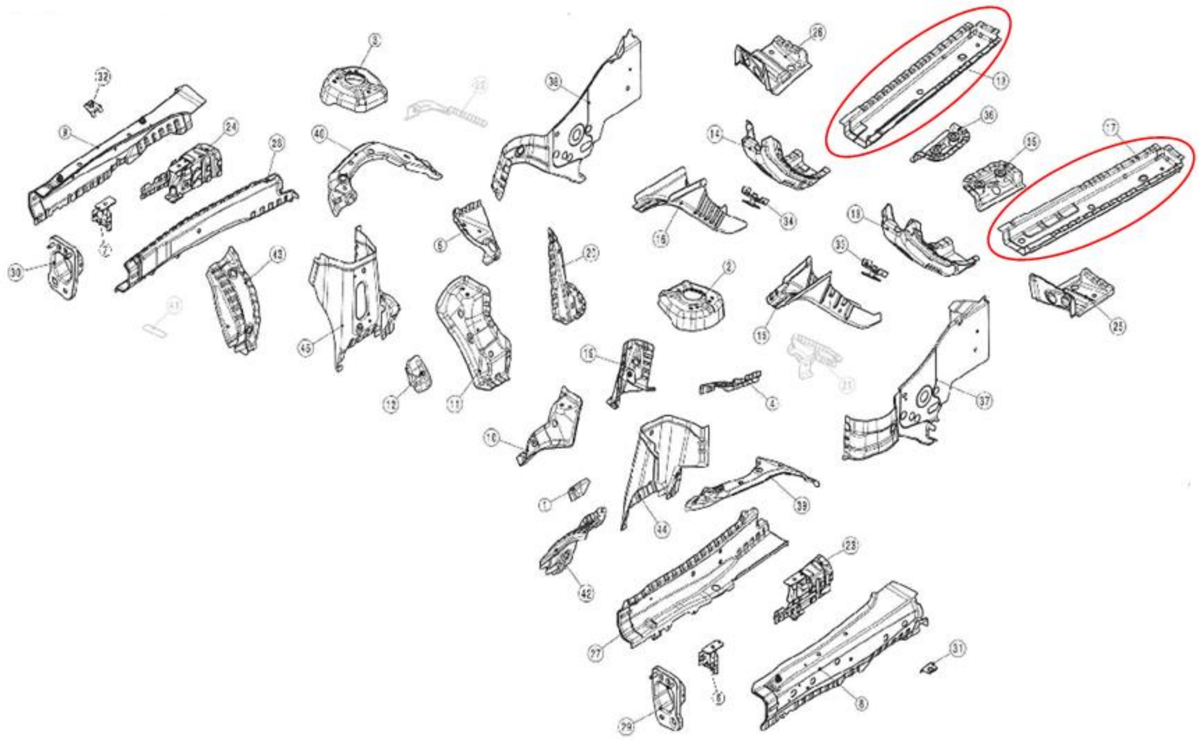
Part Number	Part Name	Weight [kg]
4	Side frame inlying front le	1,39
10	Parapet inlying le	1,25
15/1	Reinforcement LTR lateral le	3,62
15/2	Reinforcement LTR lateral ri	3,6
26	Reinforcement superior le	1,66
34	Reinforcement rocker panel le	0,48
40	Inlay B-Pillar le	0,56
45	Roof bow	1,55
52	Roof bow front	0,49



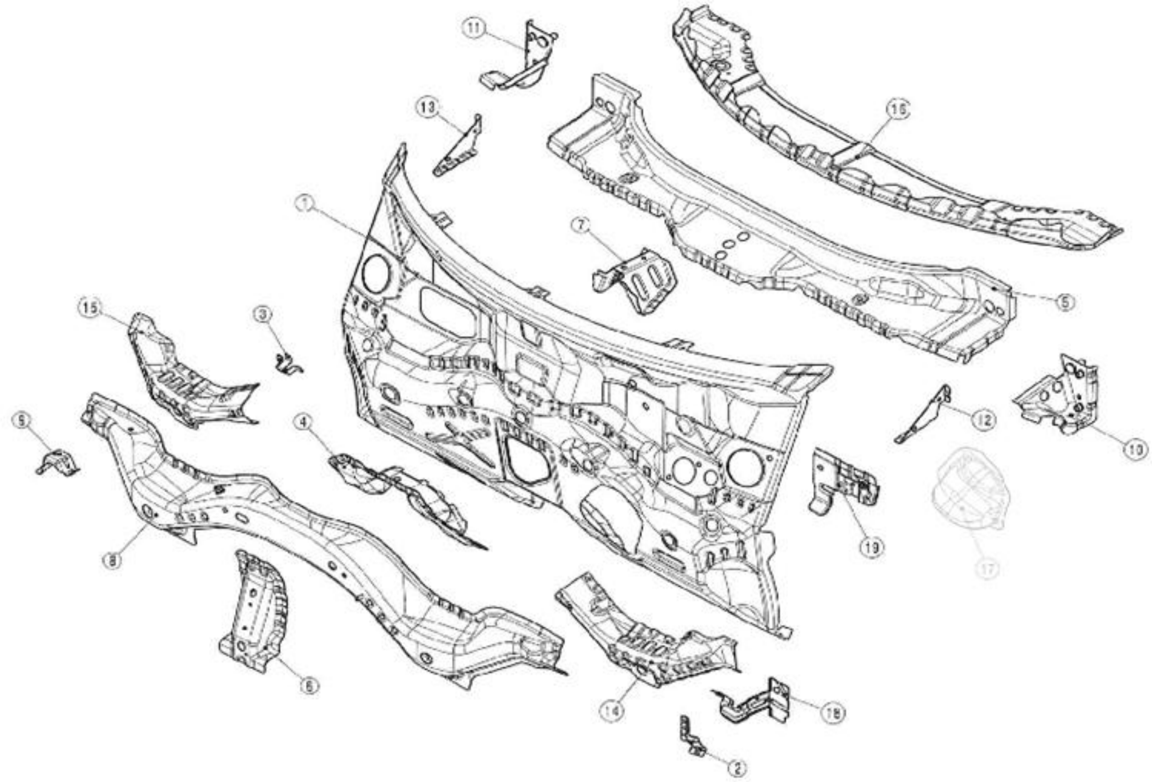
Part Number	Part Name	Weight [kg]
11	Seat crossmember front le	2,037
12	Seat crossmember front ri	2,164
17	Engine mount superior inlying le	1,37
18	Engine mount superior inlying ri	1,37
24	Carrier Pillar le	0,353
25	Carrier Pillar ri	0,344
27	Striker plate tunnel	0,252
29	Seat crossmember rear le	1,404
30	Seat crossmember rear ri	1,518
32	Side member tunnel le	2,61
33	Side member tunnel ri	2,535
37	Bulkhead seat crossmember rear le	0,668
38	Bulkhead seat crossmember rear ri	0,724
42	Tieback seat crossmember front le	0,108
43	Tieback seat crossmember front ri	0,108
44	Support engine mount superior inlying le	0,258
45	Support engine mount superior inlying ri	0,323



Part Number	Part Name	Weight [kg]
3	Inset floor panel rear	0,313
16	Inset rocker panel rear le/ri	0,555
24	Side member upper part mid le/ri	1,009
34	Side member lower part rear le/ri	0,797
37	Side member upper part rear le/ri	1,553



Part Number	Part Name	Weight [kg]
17	Engine mount rear le	1,326
18	Engine mount rear ri	1,326



Part Number	**Part Name**	**Weight**
		[kg]

List of Figures

List of Literature

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