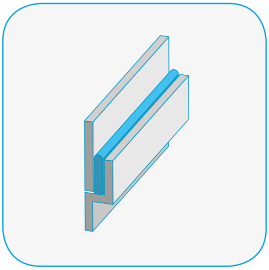
Pocket guide on hem flange bonding

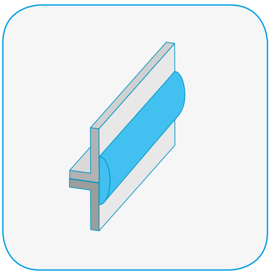
Contents

1. Introduction to adhesive bonding

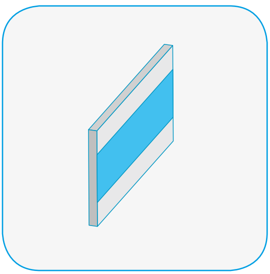
For almost every manufactured product on the market today, parts have to be assembled and attached to each other. Manufacturers increasingly require higher efficiency, speed, and accuracy from the joining technologies they use. In addition, demand is continually growing for new methods and materials to both reduce weight and fuel consumption and increase product performance. Adhesive bonding is one of the few joining technologies that can fulfill these requirements.



Bonding is a process designed to join two materials of similar or different characteristics using an adhesive material.



Sealing is a method for closing peripheral areas to prevent gases or liquids penetrating or escaping, i.e. to avoid leakages.



Insulating is a method of preventing or reducing the passage or transfer of heat, electricity, or sound.

1.1 Body in white production

In the body shop (body in white; BIW) sheet metal is joined to form the chassis of a car. The applied adhesive fulfills several functions, such as increasing crash performance, vehicle stiffness, and resistance against corrosion in hem flange areas. Depending on the joining task, there are several methods available to fulfill the corresponding requirements.

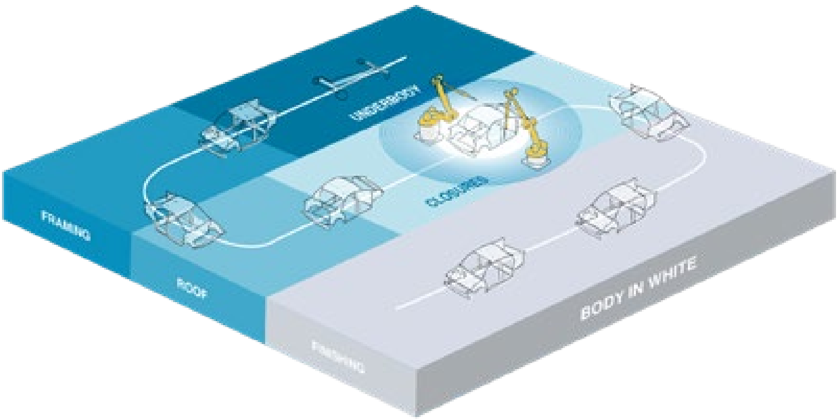
We typically find three application areas linked to BIW production:

1. Structural bonding
2. Stiffening and anti-flutter
3. Hem flange bonding

Sometimes there is also a need to seal joints in the area of the filler cap or the headlights.

Where do we find the hem flange process?

The production of the closure parts (doors, engine hood, trunk, fenders) is a separate process step within the BIW production line. Here we find the hem flange process as one of the most demanding joining processes within the BIW manufacturing.



1.2 Adhesive bonding in BIW production

These days implementing lightweight materials is an overriding consideration in vehicle construction, but car manufacturers still are on the lookout for methods to improve stiffness, increase crash durability and reduce metal/material fatigue, all the while contributing to weight reduction.

Structural bonding

Typically, the high-strength, high-viscosity adhesives which are used to join metal sheets are dispensed as a continuous bead or as a stitched bead.

"Stitching" or "constricting" beads is a popular method to reduce the environmental impact (such as welding fumes) of spot welding in combination with adhesives.

Stiffening and Anti-Flutter

Doors, hoods and bonnets often consist of several parts which require flexible connections. They reduce vulnerability to vibrations and noise during driving.

The dispensed beads or dots act both as dampeners and spacers between the inner and outer parts.

Hem flange bonding

The hemmed seams of hang-on parts like doors have to be precisely filled with high-strength adhesive for crash-safety reasons. Additionally, the filling avoids corrosion.

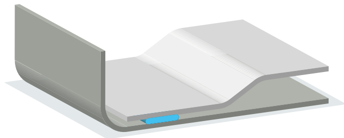
Applying a continuous bead is the favored way for many manufacturers today. A method to improve production quality in hem flange bonding is the Swirl technology.

1.3 What is a hem flange?

The hem flange describes a mechanical joint design which is used for joining inner and outer closure panels, as in metal doors, hoods, bonnets, or liftgates. To increase crash resistance the gap between the hemmed panels is filled with high-strength adhesive which also prevents corrosion.

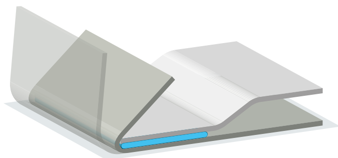
1

Nesting: The inner panel will be nested with the outer panel where adhesive has already been applied. Plane-parallel nesting brings the optimal result.



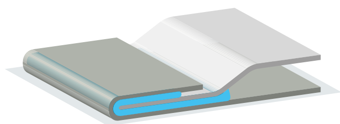
2

Hemming: Mechanical forming via different methods which gives the hem its final shape.



3

Final hem: An optimal filled hem excluding air prevents corrosion needs period for consistency.



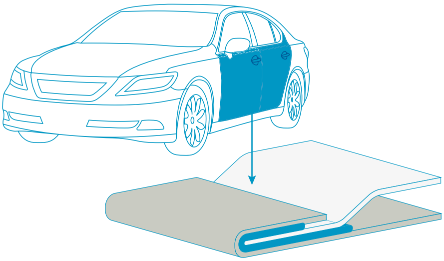
1.4 Why do you need to hem and bond a flange?

Hemming parts hides the cutting edges of the metal sheets. This helps both to prevent injuries and to improve the external appearance.

While the adhesive between the inner and outer sheet fulfills a structural function, it also helps to prevent corrosion. Mechanical joining techniques as well as spot-welding are not suitable for the hem flange production, since they would leave unwanted visible spots on the joints. This is why adhesive bonding plays an extremely important role in the BIW production of all closure parts.

1.5 Challenges in the industry

Hang-on parts need a high degree of quality and therefore require an optimal adhesive application. Hem flange bonding is one of the most challenging process steps in the BIW production process.



Did you know?

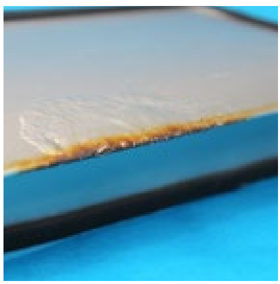
Hem flange joints are one of the most demanding joining processes in automotive BIW production.

Automotive manufacturers are facing challenges such as:

- Optimal filling inside the hemmed area
- Avoiding air ducts which lead to corrosion
- Complex geometries of the components
- Clean application patterns with sharp outer edges

Insufficient filling

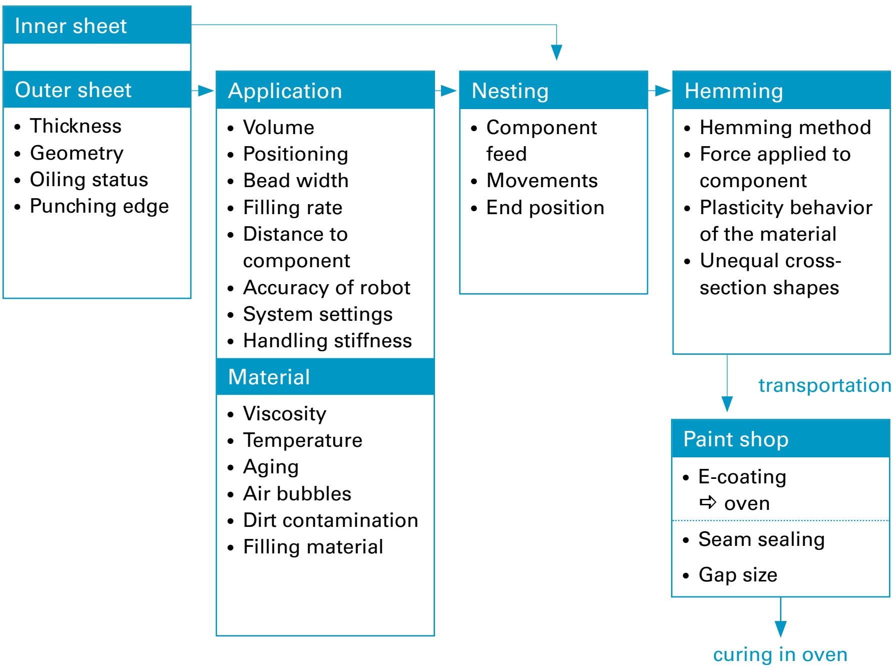
Material squeeze out



Corroded door flange

2. Influence factors

The quality of the final hem flange is influenced by many different factors. The graph shows a range of factors involving the inner and outer sheet, the application pattern, the adhesive material, the nesting and hemming process and process steps in paint shop applications.



Inner and outer sheet:

Tolerances of thickness or geometry coming from the stamping and cutting process can significantly impact hem flange quality. The oiling status of the metal sheets directly influences the adhesion of the adhesive applied on the metal sheet.

A rule of thumb says that a steel sheet should have a maximum oiling of 5 g/m^2 to ensure optimal adhesion. Aluminum sheets should be cleaned to achieve a maximum oiling of 0.5 g/m^2.

Application:

The adhesive application can be partly influenced and controlled by the robot and by the metering/dispensing system, which should be set to provide the correct volume, bead positioning and bead width. Inside the hemmed area, **the filling rate** is usually defined by the quality department, and the correct **distance** to the component during the application is dependent on the chosen application type. The increased **accuracy of a robot** adds significantly to the quality of the application since an unstable movement can be seen in the final result. The overall system settings have to be adjusted exactly to the individual application.

Volume

Describes the amount of three-dimensional space enclosed by a certain boundary; for example, the space that a substance (solid, liquid, gas) or shape occupies or contains. It is possible to calculate volume using different formulae, depending on the shape of an object or room.

Material: The viscosity of the adhesive plays a major role in the processing. Ambient temperature directly influences the viscosity of a material and therefore the application quality. The limited shelf-life of adhesives should also be taken into account. Using expired material can have a significant impact because the chemical ingredients of the material and their reactions change over time. This may lead to an insufficient adhesion between the metal parts or to other changes which have an impact on the result. Applying air bubbles within the adhesive can lead to application interruptions. If this defect is detected, costly rework is required. If the defect isn't detected, the faulty part is mounted on the car body, which can cause corrosion issues after a few years in the car's lifetime. Another effect of applying adhesives with air inclusions might be the expansion of the trapped moisture in the curing process which then leads to so-called PVC bubbles (pictured below). Any contaminations inside the material also exert an influence on the application and the final result. Filling materials of various types can be used inside the adhesive to reinforce or influence the adhesive's behavior.

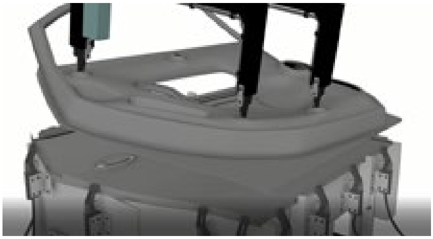
Viscosity

Is the resistance of a substrate to flow. Viscosity is related to the concept of shear force; it can be understood as the effect of different layers of the fluid exerting shearing force on each other, or on other surfaces, as they move against each other. From an adhesive bonding perspective, viscosity is important due to its influence on the quality of an application bead.

Viscosity range

Thin/liquid: 10-100 mPas
High viscosity to pasty: > 15 000 mPas

Nesting: The component feed describes the process when the inner part is married with the outer part. Experts recommend carrying out this nesting plane-parallel (further information in chapter 3). The movements during the nesting have a significant influence on the material distribution. The end position of the inner part plays an important role during the hemming and the associated distribution of material.



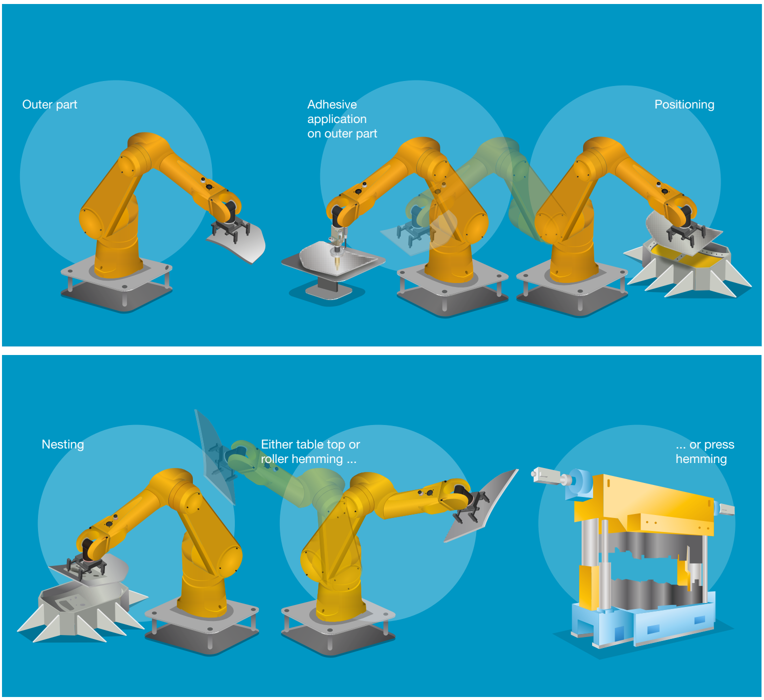
Hemming: Method which is used to mold the final shape of the hem. A force acts on the component which affects the distribution of the adhesive inside the hemmed area as well as shape of the hem itself. The plastic behavior and the elastic spring back of the metal sheets play a decisive role in achieving the required quality and must therefore be considered. Further details about the different hemming methods which involve their individual advantages and disadvantages are described in chapter 3.3.

Paint shop: After the hemming process the closures are moved to the paint shop. Here, they receive e-coating and seam sealing treatment which are important protection applications. For further information please find our leaflet on cosmetic sealing.

3. Process description

In order to meet different requirements (e.g. cycle time), each automobile manufacturer uses a different cell set-up for the hem flange process. A typical process includes the following steps:

- Positioning of outer part
- Application of adhesive (hem adhesive & anti-flutter)
- Nesting (marriage of inner to outer part)
- Hemming (table top, roller hemming or press)



Within the individual production steps customers face several challenges from different influence factors (described in chapter 2).

After the hemming process, the closures are moved to the paint shop where they receive important protective applications.

3.1 Layouts

Each automotive manufacturer uses a different layout for the hem flange process depending on their different requirements and space conditions. In principle, three different layout types can be distinguished:

1. Manual
2. Automated – Pedestal
3. Automated – Robot

Manual applications are typically used in prototyping phases or in low volume productions. Automated applications are used for high quality and high volume applications where repeatability is important. Both for pedestal or robot mounted systems, there are two different ways to connect the metering unit and applicator:

Applicator mounted onto the robot flange:

By using this type of set-up, the meter size does not restrict the flexibility and speed of the robot as it is mounted on robot axis 3 or 7. Also, by keeping the load to a minimum, smaller robots may be used. In addition, the compact design of the applicator increases accessibility during application.

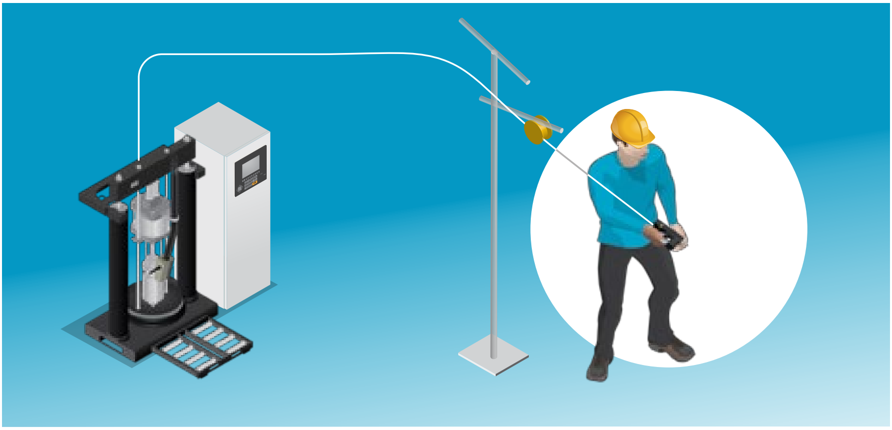
Applicator directly mounted to the meter:

This set-up option is a common choice when the carrying capacity and dynamics of the robot, as well as access to the parts, are not restricted. By reducing the distance between meter and applicator, the material is dispensed with even higher accuracy. This is especially important in high-performance stitch bead but also in constricted applications.

Usually, the hemming equipment is included inside the adhesive cell. After the material is applied on the outer sheet, the inner part will be nested and then hemmed. The hemming gives the final outer appearance of the hang-on part.

3.1.1 Manual

There will always be applications where automation is not an option. Reasons for opting for manual solutions may include higher accessibility, flexibility and faster returns on investment costs.



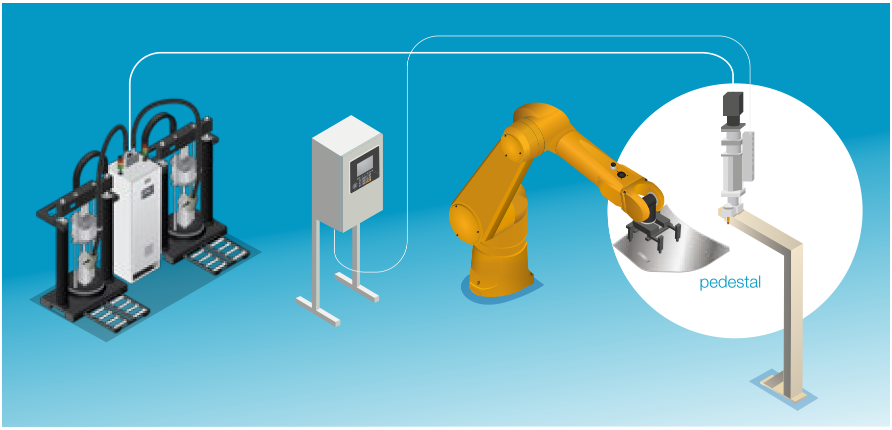
The system set-up of a manual cell consists mainly of a material supply system which is directly connected to the applicator. The operator needs to have significant expertise in order to achieve the required quality (e.g. applying the required volume).

- **Low initial investment**
- **Flexible system layout**

- **Quality result dependent on operator skills (repeatability)**
- **Higher cycle time**

3.1.2 Automated – Pedestal

Mounting the metering unit together with the applicator on a pedestal is the solution for saving space and initial cost.



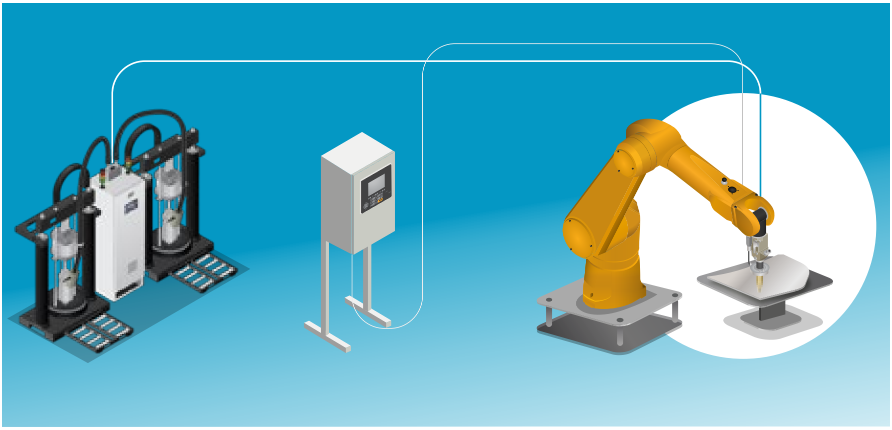
The system set-up of an automated cell consists of a material supply system (in BIW typically a double barrel pump with pump control) which is connected to the metering unit. In addition, this is connected to the system control. The robot is equipped with a gripper which moves the part under the applicator on the pedestal.

- **Lower initial cost (no application bed)**
- **Gripper can fulfill several tasks**
- **Higher durability of hoses and cables (no movements)**

- **Gripper inaccuracy**
- **Less precise application**
- **High process fluctuations**
- **Restrictions on panel size (repeatability & accuracy)**

3.1.3 Automated – Robot

A robot mounted system offers high flexibility within the application process.



- **High degree of flexibility regarding panel size**
- **Very precise application & high degree of repeat accuracy**

- **More floor space required**
- **Higher initial cost**
- **Durability (e.g. hoses due to movements)**

3.2 Typical materials and system parameters in use

Within the hem flange process we find a wide range of adhesives in use and the individual system parameters for the application.

Typically, epoxy material (with or without glass balls), rubber based materials or two component materials are used for the hem flange bonding.

Setting the right system parameters is dependent on several factors such as material in use, cycle time or filling requirements.

Did you know?

Many materials used for hem flange bonding contain glass balls. They keep the distance between the hemmed metal parts. Those filler materials can be highly abrasive. The material supply should meet high demands in terms of performance and durability.

Typical materials in use (w/wo GB)

- Epoxy w/wo GB
- Rubber based
- 2 components

Parameters

- Robot speed: 250-400 mm/s
- Material flow: 3-10 ccm/s
- Material temp.: 30-60°C
- Pressure: 25-80 bar
- Total volume: 10-30 ccm
- Application time: 10-35 sec.

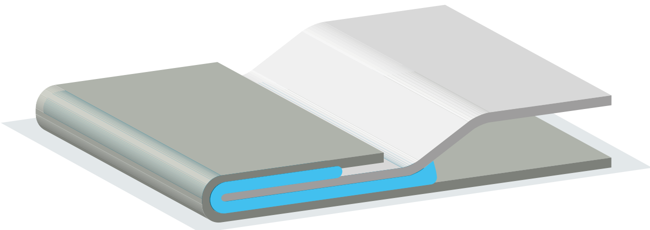
Source: Real time system parameters collected from different customers globally

3.3 Hemming methods

Automobile manufacturers demand a highly reliable process design for the forming process.

We already learned that the hem flange process is one of the most demanding steps in the BIW production.

Hemming describes the mechanical joining of an inner and outer closure panel. There is no right or wrong in the choice of the hemming method. Each method provides its individual advantages and disadvantages.



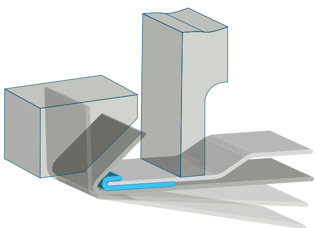
3.3.1 Table top hemming

Manufacturers choose table top hemming when producing medium to high production volumes with the ability to achieve cycle times as low as 15 seconds.

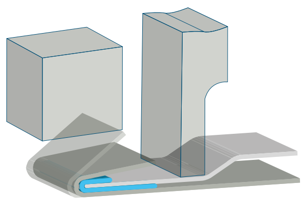
The two stages of the process

- Stroke or pressure
- Table moves to the individual position

Pre-hemming



Final hemming



- **Low cycle time**
- **Simple operation**

- **Difficult to change (individual die for each part)**

3.3.2 Roller hemming

This hemming method usually is chosen in a low volume or prototyping production phase and often used due to accessibility reasons. The cycle time very much depends on the robot speed, part dimensions or repetitions. By using roller hemming, the surface quality of complex sheet metal geometries is improved.

A standard roller hemming head follows the contours of the outer flanges of a sheet metal component (e.g. roof opening, wheel arc). Typically, a roller hemming tool provides three different die sizes.

- **Flexible movements and force distribution**
- **Very precise**

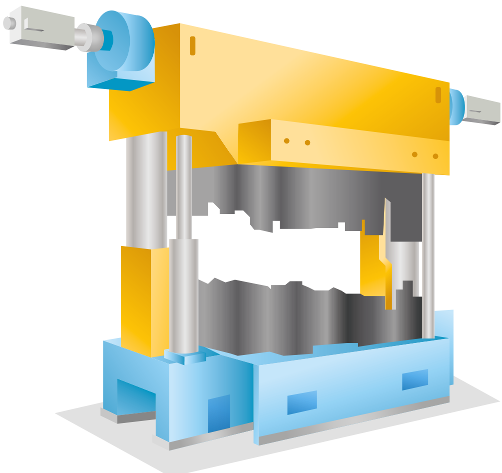
- **Programming effort (robot and process expertise required)**
- **Cycle time**

3.3.3 Press hemming

Because it can reduce cycle times down to a few seconds, press hemming is well established for high volume use in the automotive industry. Additionally, some presses are able to produce different parts in the same operation.

The process is quite simple: the inner and outer parts are placed into the press die. The press moves down and the hemming is done.

Some system set-ups offer the opportunity of a multi-model production by using several press stations for different car models. The advantage here is that the application systems for the hem flange adhesive and the anti-flutter can be used for several models.

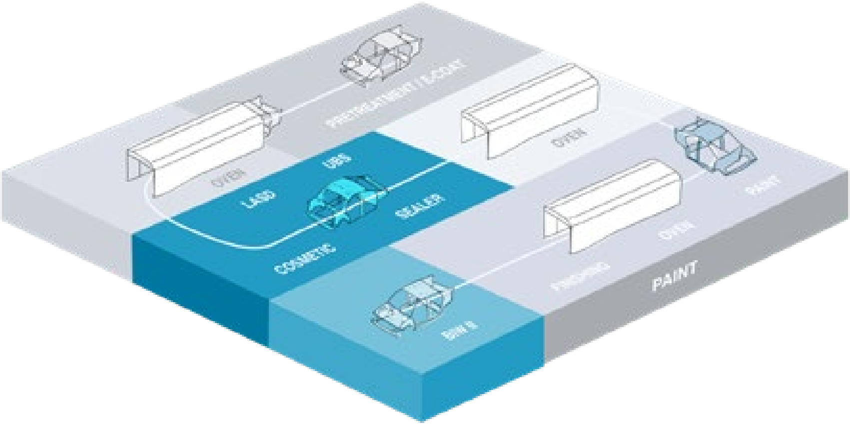


- **Fast process**
- **Multi-model production**
- **Less equipment needed**

- **Change of dies for different parts (if only one press is used)**
- **Difficult to control forces**

3.4 Additional production steps

After the car body receives its body structure and the hang-on parts are mounted in the BIW assembly station, it moves to the paint shop. As described in chapter 2, the e-coating may have an influence on the hem flange quality. If the adhesive wasn't applied properly, the e-coating bath might wash out the adhesive from the hem.



After the car body passes the oven it will receive some protecting applications. At the closures, cosmetic sealing applications are essential to protect additionally against moisture penetration. Furthermore, this application provides an attractive finish.

4. Quality

"In manufacturing, a measure of excellence or a state of being free from defects, deficiencies and significant variations. It is brought about by strict and consistent commitment to certain standards that achieve uniformity of a product in order to satisfy specific customer or user requirements. ISO 8402-1986 standard defines quality as "the totality of features and characteristics of a product or service that bears its ability to satisfy stated or implied needs." If an automobile company finds a defect in one of their cars and makes a product recall, customer reliability and therefore production will decrease because trust will be lost in the car's quality ." [1]

4.1 Quality requirements

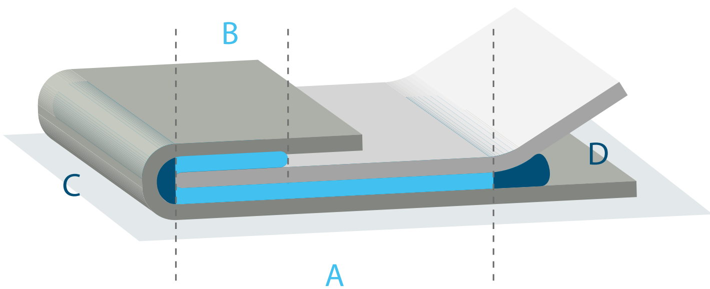
Within the Atlas Copco environment, we have the highest quality standards found in the manufacturing industry.

A. 100% bonding

B. X% bonding between contact surface "outer and inner part"

C. Fully filled with adhesive

D. Visible adhesive escapes to the inner



[1] Source: http://www.businessdictionary.com/definition/quality.html

4.2 Quality Issues

As the overall process of hemming parts is one of the most challenging production steps in BIW, car manufacturers are facing several quality issues.

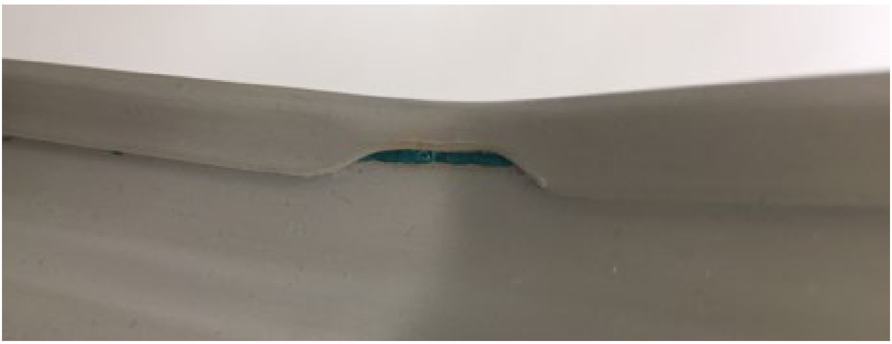
Few of these issues can be attributed directly to the adhesive application. They are a result of different influence factors (described in chapter 2) before, during and after the application which lead to various impacts.

Competence

To determine the exact cause of possible quality issues, the overall hemming process needs to be analyzed. As described in chapter 2, the quality of the final hem can be influenced by many different factors, beginning at the stamping and ending after the paint shop treatments. Therefore, it requires a high competence and understanding in this overall process to determine and eliminate the root cause.

4.2.1 Squeeze outs

The direct consequence of squeeze outs is in the first step the rework effort. If the leaked material is not removed this can lead to contamination not only of the hemming tools but also of the e-coating bath which leads to further issues. When the hemmed part reaches the paint shop, the squeeze outs can lead to cosmetic sealing issues if applied.



The root causes are mainly attributable to:

1. Too much material applied: during the hemming, the excess material will be squeezed out.

2. Inaccurate robot programming (bead position): if the bead position is not in the required position, this can have significant effects on the material distribution inside the hem. This could also lead to squeeze outs even if the gap inside the hemmed area is not filled according to the requirements.

3. The hemming process: each hemming method provides its individual advantages and disadvantages as described in chapter 3.3.

4.2.2 Meander

This phenomenon describes a pattern which can be found in nature. Meander is the description of a river which has additional river loops and forms a curved pattern. This pattern can also be found in hem flange bonding, but only when the part is opened after curing (see chapter 4.3.2: Destructive testing).

Possible reasons for meander inside a cured hem flange application:

Spring back behavior of metal sheets:
After hemming, the two metal sheets do not stay in their hemmed position. Due to their elastic behavior they tend to move slightly apart, which might lead to an unequal material distribution inside the hem.

Not enough material applied: Meander can be caused by insufficient filling inside the hem.

Parts are overpressed: As described in chapter 3.3 each hemming method brings advantages and disadvantages. The force which is exerted during the hemming process can lead to a displacement of the material in some areas.

Oily part: Metal sheets always have an oily surface when they arrive from the press shop or in racks from the buffer stock. The oil might impede an optimal material distribution and can lead to a displacement of the material in some areas.

4.2.3 PVC bubbles

If the hem flange seal encloses air, this might lead to an issue which becomes visible after later process steps. The so called PVC bubbles are the result of an evaporation of the moisture inside the hemmed and sealed flange when the car body passes through the oven. PVC bubbles have an unappealing outer appearance which is why automobile manufacturers try to avoid them. Therefore it is essential to understand how and why the bubbles occur. The first possibility is that air bubbles are already included inside the material and are then applied during the application. Another option is that the bubble is formed during or after the application process.

Also during the hemming or the e-coating, air bubbles might be inserted inside the hemmed area.

4.3 Quality monitoring and test methods

Different quality monitoring and test methods are used to verify if the required quality has been achieved. Quality monitoring means that the application or the application result is checked directly within or after the application process. This can be carried out manually or automated.

In principle, two main categories of test methods can be distinguished: destructive and non-destructive testing, each of which can involve different methods.

Depending on the quality standards, quality tests are carried out within different time frames. This can mean having one testing per shift, one per day, per week or even one per month or less.

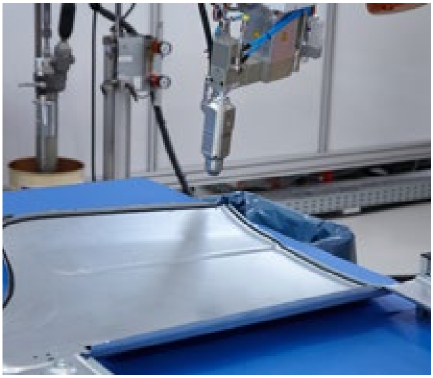
Each test method provides advantages but is also limited in some areas.

4.3.1 Visual inspections

The simplest method of evaluating a hem flange application is visual inspection. It is done manually and is the subjective assessment of the inspector. Visible imperfections from a certain size can be detected.

Without camera

The test method without camera means that an operator is checking the application visually. Usually there is a part which has already been applied next to the fence which is used as reference. The operator checks if the application is in the right position and/or if there are any bead interruptions. The frequency of this method is different from OEM to OEM. Most of them are checking visually once per shift or once per day.



The disadvantages of this test methods are:

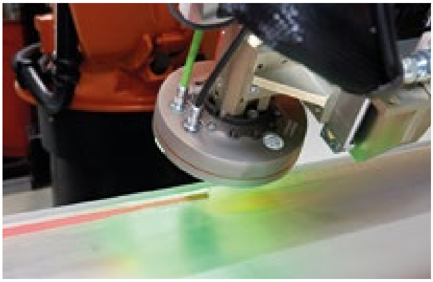
1. Operator dependent & inconsistent: Depending on the competence level, personal condition or other factors, the visual inspection of an inspector can vary from time to time.

2. Imperfections inside the application: Not every defect can be detected from outside. Imperfections inside the application can lead to deformations of the sealing which will only be detected after other process steps.

3. No automation: When a bead interruption or any other defects are detected, there is no automation in the system which channels out faulty parts. This has to be done manually by the operator. He usually initiates a line stop manually when there have been four or five faulty parts applied in a row. In order to investigate and eliminate the cause of the defect the process has to be interrupted. Moreover, the line stop is necessary in order to avoid additional parts being applied incorrectly. In addition, there is no automated documentation in the system which might be useful for further analysis.

With camera

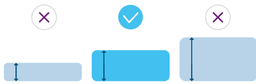
A visual inspection system can be used to monitor safety critical applications and meet strictest quality standards without loss of productivity. Some camera systems already provide a bead repair functionality which allows an automated repair in case of bead interruptions in the adhesive application.



Example: Hem flange application with camera monitoring

A typical visual inspection ensures that beads...

Bead width

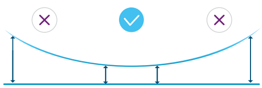


have the right geometry and width

Bead continuity

are continuously applied

Bead position



are in the right position

But this test method also comes with limitations. The system can only compare live data with a reference which has been specified. If the installation or programming was already incorrect the system can't detect the defect.

4.3.2 Destructive testing

Visual inspections of the applied adhesive are the first step of a consequent quality control of the hem flange bonding. However after the adhesive application it takes some additional process steps to achieve the final hemming result. As these process steps can have an influence on the application, it is usual to inspect the parts after hemming within defined intervals (e.g. once per day or week). This makes it possible to check if the adhesive is spread properly inside the hemmed area.

Source: Volkswagen Sachsen GmbH

But destructive testing has the disadvantage that the method is quite costly as each part has to be scrapped.

As the testing is conducted after the e-coating, timely corrections are not possible. This means that many defective parts can be produced before a possible defect is detected during the testing. Also the loop back to the production takes some time until the cause for the defect is identified and eliminated.

Strictly speaking, destructive testing is also a kind of visible inspection as the inspector is verifying the part after opening visually. Also the documentation and reporting of defects which were detected must be done manually. Therefore, destructive testing involves similar disadvantages as described in 4.3.1

Additionally, the method constitutes a risk of injury as the metal parts have sharp edges and the opening has to be done manually.

4.3.3 Dye penetration test

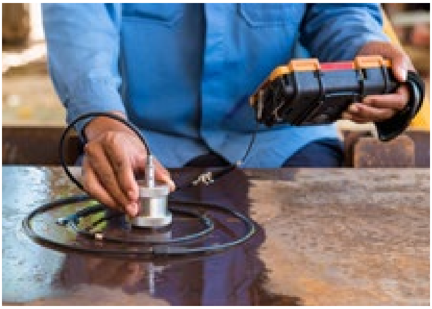
Typically, the dye penetration test is conducted as an accompaniment to destructive testing. With this method very small imperfections can be detected.

Procedure: The hang-on part which has to be tested has already passed the e-coating bath. Liquid color is pipetted between the hemmed area of the inner and outer part. By moving the part, the color is spread. Then the part will be opened and analyzed to see if there is any color visible inside the adhesive area.

The disadvantages of the dye penetration test are the same as for destructive testing. Furthermore, there is an additional time effort for the color pipetting and distribution.

4.3.4 Ultrasound

The ultrasonic test is an acoustic method for finding material defects by means of ultrasound. It belongs to the non-destructive testing methods. Ultrasonic testing is a suitable test method for sound conductive materials (this includes most metals) for the detection of internal and external defects, e.g. as in welds, forgings, castings, semi-finished products or pipes.



Ultrasonic test to detect imperfection or defect of steel plate

For the hem flange bonding ultrasound offers the possibility of testing the adhesive distribution inside the hemmed area to detect areas without adhesive without any destruction of the part. The test head will be moved around the hemmed area manually and the system gives a visual feedback of the filling. This gives an insight into where to find bead interruptions or imperfections and thus the possibility of specific tracking of issues within the application process.

The disadvantage of this test method is on one hand the dependency on the operator. The dispense of the couplants is essential in order to achieve a proper test result. Additionally, the test head has to be moved precisely, and the process is time-consuming.

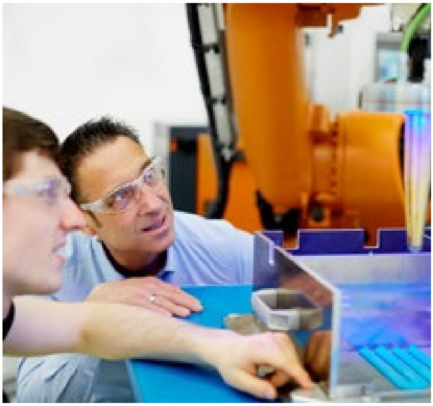
The technology is not yet established in the industry but offers great potential for non-destructive quality testing.

5. Atlas Copco is your global solution provider

Deep know-how and a broad experience in customer processes is essential in order to analyze and evaluate influence factors and find solutions for different joining challenges.

Our customer support

We at Atlas Copco are happy to support you with our knowledge and experience. We can carry out on-site workshops with all necessary personnel – either participating or simply moderating, according to your needs. Together we can handle your production process and quality testing by analysing and discussing the problem before proposing solutions. After the analyzation and discussion of your individual issues we strive for solutions.



Innovation Center

Our employees are trained and experienced in different joining techniques such as adhesive dispensing, self-pierce riveting or flow drill fastening. With our competent and reliable support, we offer a close cooperation between customers and suppliers (e.g. material or component suppliers).

Our joining technologies

adhesive dispensing

self-pierce riveting

flow drill fastening

Global customer care

We transfer the acquired know-how into all globally operating Innovation Centers to support our customers with knowledge and experience locally. Moreover, we have a global interaction between all Innovation Centers in order to provide the best possible support.

Additional customer value: our test labs

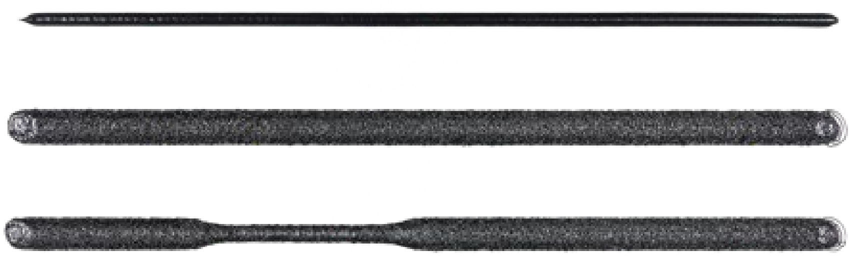
Our target: to develop the most optimal joint based on your input. Therefore, we offer the opportunity to use our integrated labs equipped with different analysis instruments, where individual test trials can be analyzed and evaluated. We cover different analysis methods such as tensile testing or microsection analysis.

Innovative product solutions

Our products and systems are developed in close cooperation with the industries we serve. Each of our product developments offers individual customer value.

In hem flange bonding, the bead application is one of the most established application types. But also the swirl application gets more and more attention in the industry due to its ability to offer an excellent material distribution and a more reliable process window.
The two application types have different advantages depending on their utilization. Experts know that the handling of a bead application can become quite difficult when it comes to complex part geometries. Keeping the exact distance from the component (usually the distance is equal to the bead diameter) is very challenging but essential in order to achieve the perfect application result.
The swirl technology enables application from a distance of up to 50 mm and therefore offers a high flexibility within the application process.

e.g E-Swirl 2 AdX BIW from Atlas Copco; SCA product line

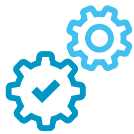


One applicator, three different settings: The E-Swirl 2 AdX BIW can handle beads as well as fixed and constricted swirl applications to match complex car geometries.

What we stand for

Global network
We are wherever
you are.

Competence
Benefit from our process
and application experience



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We make performance stand the test of time.
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