Adhesive bondings
Design for HP MJF: Union joints design

Introduction

When using HP Multi Jet Fusion technology, it is sometimes necessary to split a part into different pieces and then re-join them. There are two main reasons why bonding parts together may be necessary:

Splitting big parts

Some big parts do not fit inside the build chamber of HP Jet Fusion 3D printers. Therefore, the parts can be split into several pieces and then re-assembled after printing. This can occur in the automotive industry or in applications such as jigs and fixtures, where big parts could require bonding to ensure a strong joint and achieve a proper solution.

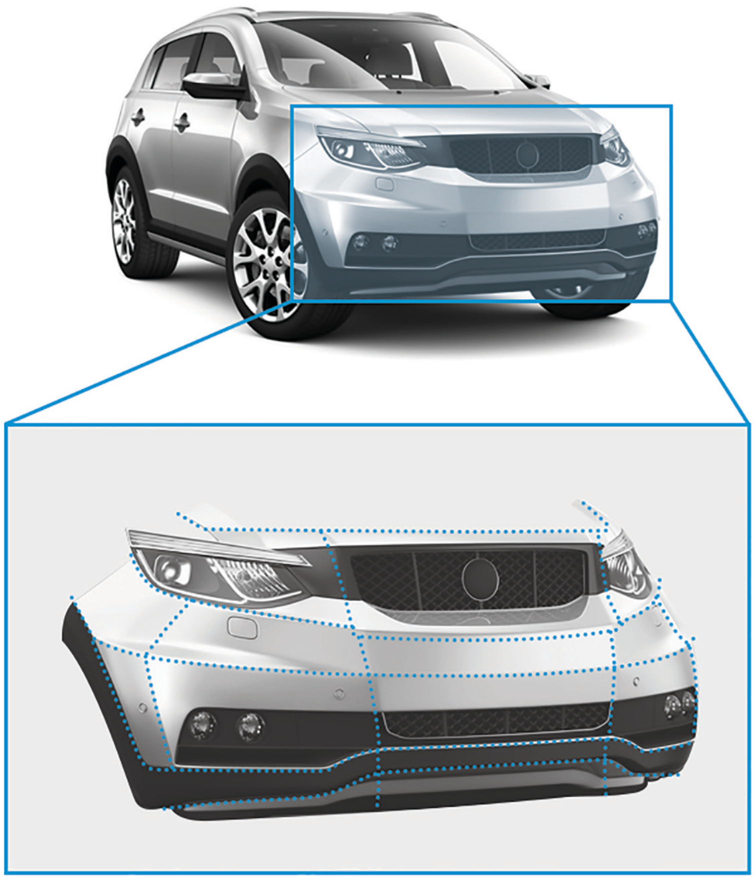


Figure 1: Bumper split proposal

Increasing packing density

The maximum printing efficiency in terms of cost and productivity is achieved by increasing the packing density. Depending on the geometry, there may be packing limitations for the achievable maximum value. In these cases, splitting the parts is a possible option.

For example, a part's packing density could be optimized by adding hinges that allow it to fold. These could be blocked after printing by using an adhesive or other mechanical locker.

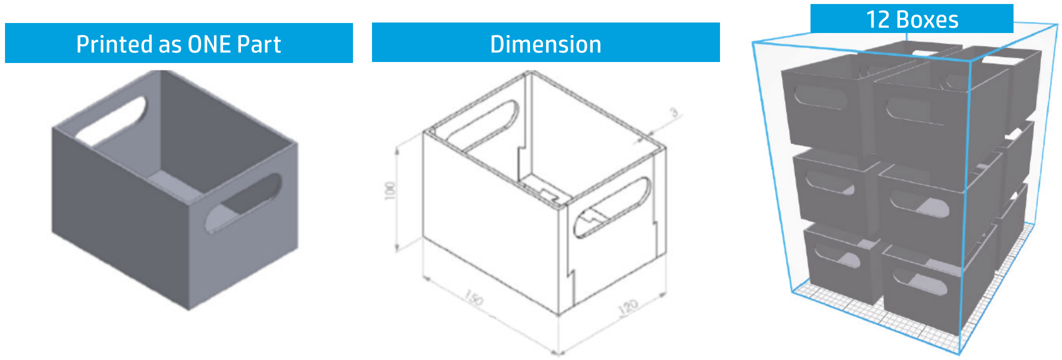


Figure 2: Example of packing density optimization: Box original design and number of parts that fit in the print bed. Data courtesy of Henkel AG & Co. KgaA

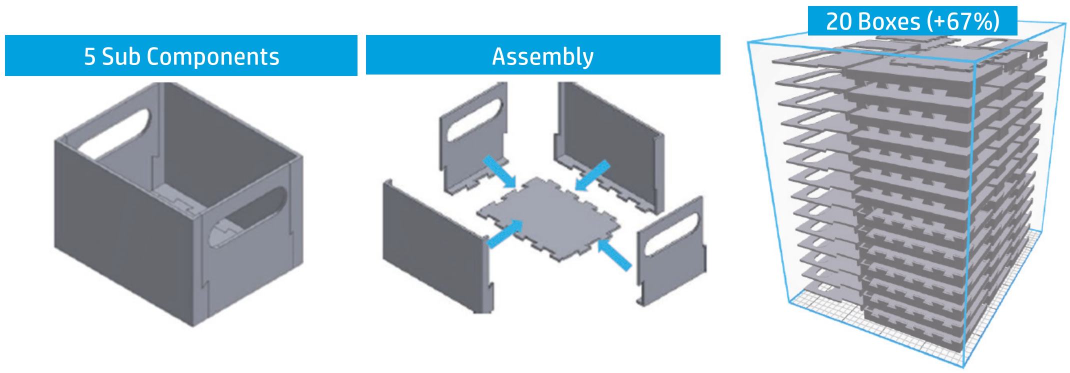


Figure 3: Example of split part to optimize packing density: With the split, the packing density increased by 67%. Data courtesy of Henkel AG & Co. KgaA

Design guidelines

Bonding robustness depends highly on the design of the union and the way the part has been split or cut into different pieces. A proper bonding design is critical for success.

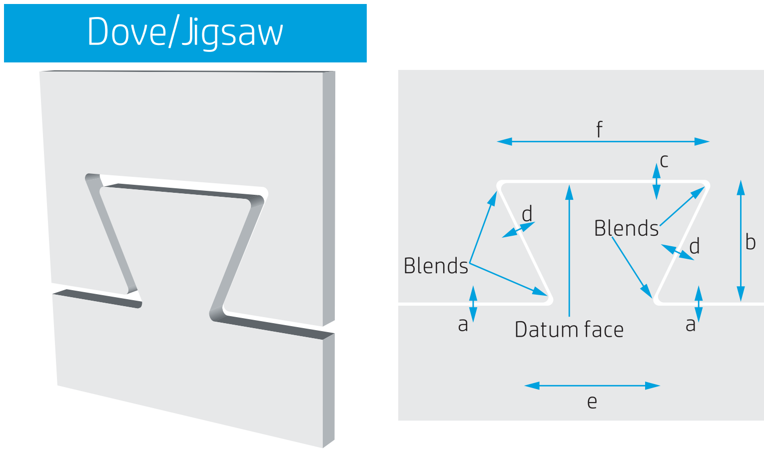
Union design

The union design of the bonding is key to ensure proper performance of the bonding in the final part. The time invested in designing a proper union may depend on the final use of the pieces that will be bonded. For example, a visual prototype that will not withstand any loads would require a simple design union, while an automotive part that will be included in the final product should be designed to optimize its performance.

Design options depend on the thickness of the bonded parts and on the possibility of modifying the final geometry.

<u>Thickness < 1.7 mm with no geometry modification allowed</u>

One of the objectives in the design of the union is to increase the bond area as much as possible. Including features that will help reference one piece to the other during bonding will help achieve the proper position between the parts and will optimize the final result. The most recommended design option for this case is a dove or jigsaw feature, as shown below:



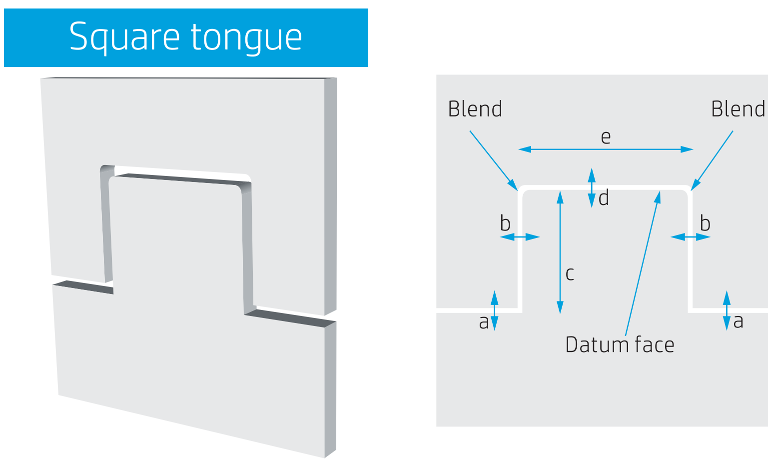
Recommended dimensions:

a:	0.2 mm
b:	10 mm
c:	0-0.1 mm
d:	0.2 mm
e:	10 mm
f:	20 mm

Figure 4: Dove/jigsaw design recommendations

This type of union will help increase the bonding area and, at the same time, it positions and holds both pieces that will be assembled.

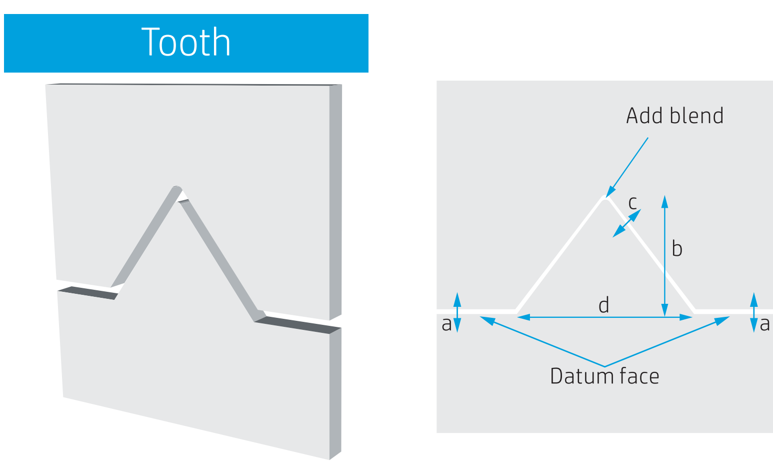
There are also other design options that are simpler and will also provide satisfactory results, which could be an option for faster designs:



Recommended dimensions:

a:	0.4 mm
b:	0.2 mm
c:	10 mm
d:	0-0.1 mm
e:	10 mm

Figure 5: Square tongue design recommendations



Recommended dimensions:

a:	0-0.1 mm
b:	10 mm
c:	0.2 mm
d:	20 mm

Figure 6: Tooth design recommendations

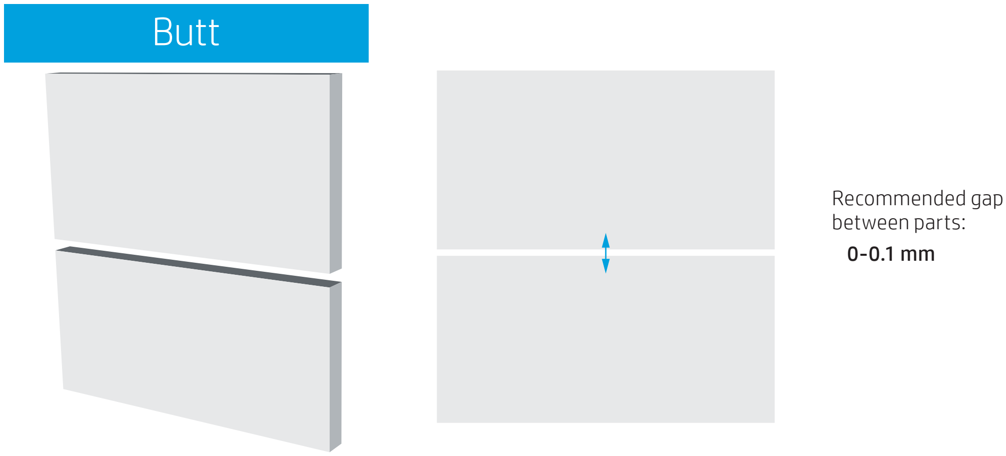


Figure 7: Butt design recommendations

When adding a union design that is not viable due to geometrical constraints (such as a dove, square tongues, or a tooth), a butt union design could be an alternative, bearing in mind that having a straight line in the bonding area is the weakest union design option due to its less-available bonding area.

All design options can be easily applied to a part using 3D software, such as Materialise Magics, or they can be directly designed using CAD software.

<u>**Thickness < 1.7 mm with geometry modification allowed**</u>

If a modification in the geometry is allowed, the bonding area can be increased and mechanically reinforced by adding an overlap between the bonded areas.

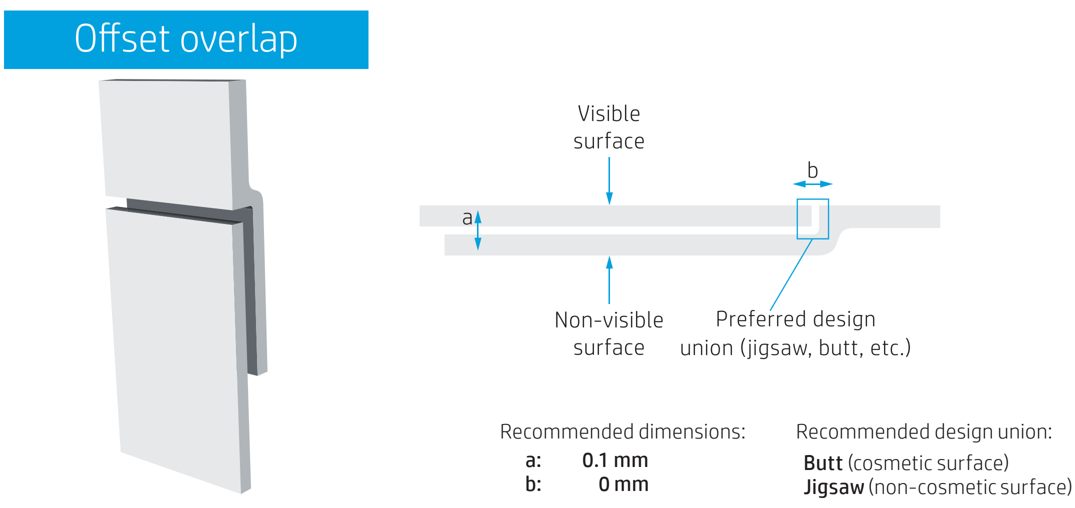
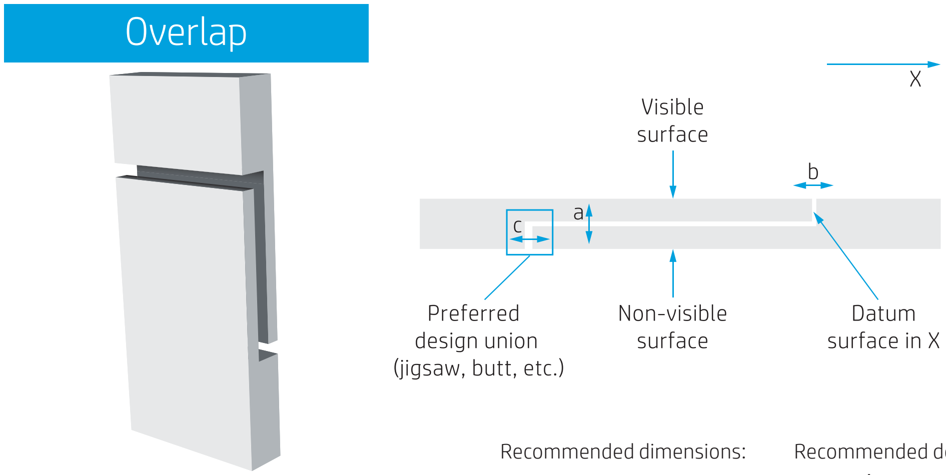


Figure 8: Offset overlap design recommendations

Thickness > 1.7 mm

When there is adequate thickness to add an overlap between the parts, it is no longer necessary to modify the final geometry to reinforce it. The improvement and optimization of the bonding union can be executed directly in the original design, thus increasing and reinforcing the bonding area.



Recommended dimensions:

a:	**0.1 mm**
b:	**0 mm**
c≥	**0.4 mm**

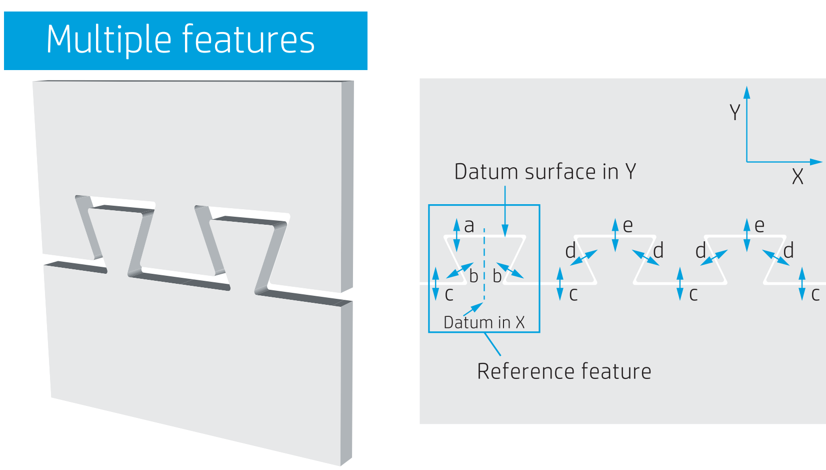
Recommended design union:

Jigsaw/Dove

Figure 9: Overlap design recommendations

Adding more than one union feature

When the bonding line is long, it may be helpful to add multiple features that will hold both pieces together when the adhesive is applied. Regardless of whether the position between both parts is critical to the design, the features design must be executed by first adding a reference feature that will position both parts in the XY plane, and then by adding the remaining features with a higher clearance in order to absorb any dimensional variation.



Recommended dimensions:

a:	**0.1 mm**
b:	**0.2 mm**
c:	**≥0.4 mm**
d:	**≥0.3 mm**
e:	**0.2 mm**

Figure 10: Multiple union features: Design recommendations

<u>**Combination of overlap joint with multiple jigsaw features**</u>

When taking into account all of the design recommendations mentioned above, the preferred union design is the combination of the overlap joint with reference features such as the jigsaw. Those reference features can be added to the non-visible surface and will help reference the two pieces between them to optimize the bonding performance.

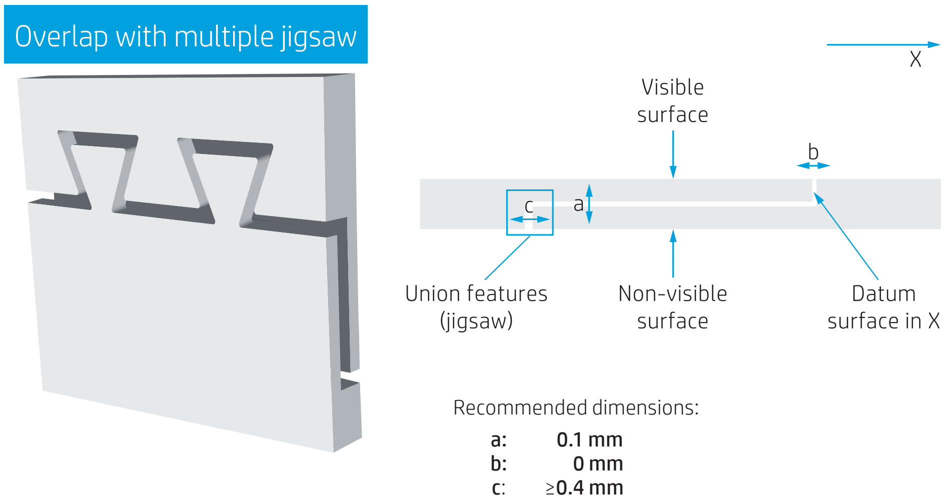


Figure 11: Overlap with multiple jigsaw features: Design recommendations

Additional options to increase bonding adhesion

When the adhesive material has the ability to fill gaps, the mechanical adhesion between the adhesive and the bonding parts can be improved by adding textures to their surfaces. This roughness improvement allows for mechanical interlocking by adding "teeth" to the surface and increases the total effective bonding area.

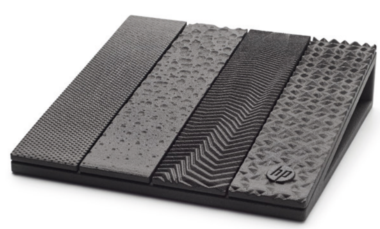


Figure 12: Example of texture to increase adhesion

An additional option to increase the bonding area is to include grooves to the bonding parts' surfaces.

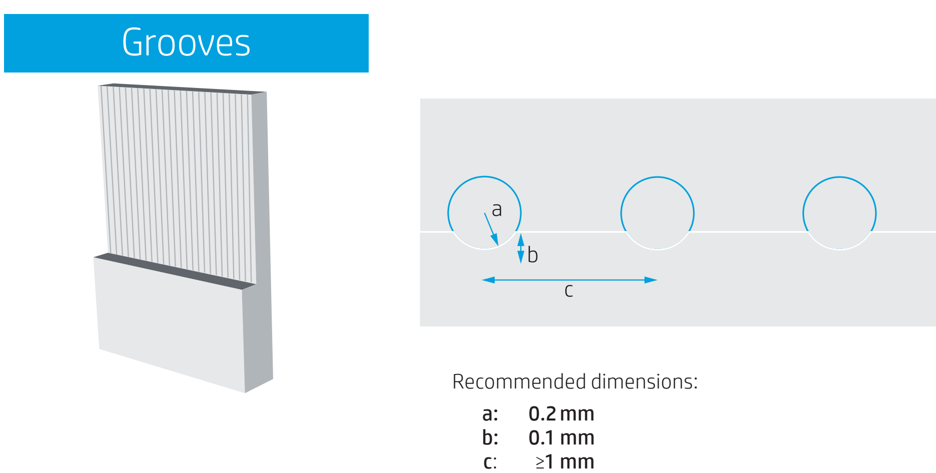


Figure 13: Grooves to increase bonding area: Design recommendations

Cutting recommendations

When a part needs to be cut, bear in mind which parts are the loads that will be applied to the final bonded assembly, as the bond robustness can be highly optimized depending on the design decisions.

The stress that appears in the bonding area depends on the applied loads. The most common are as follows:

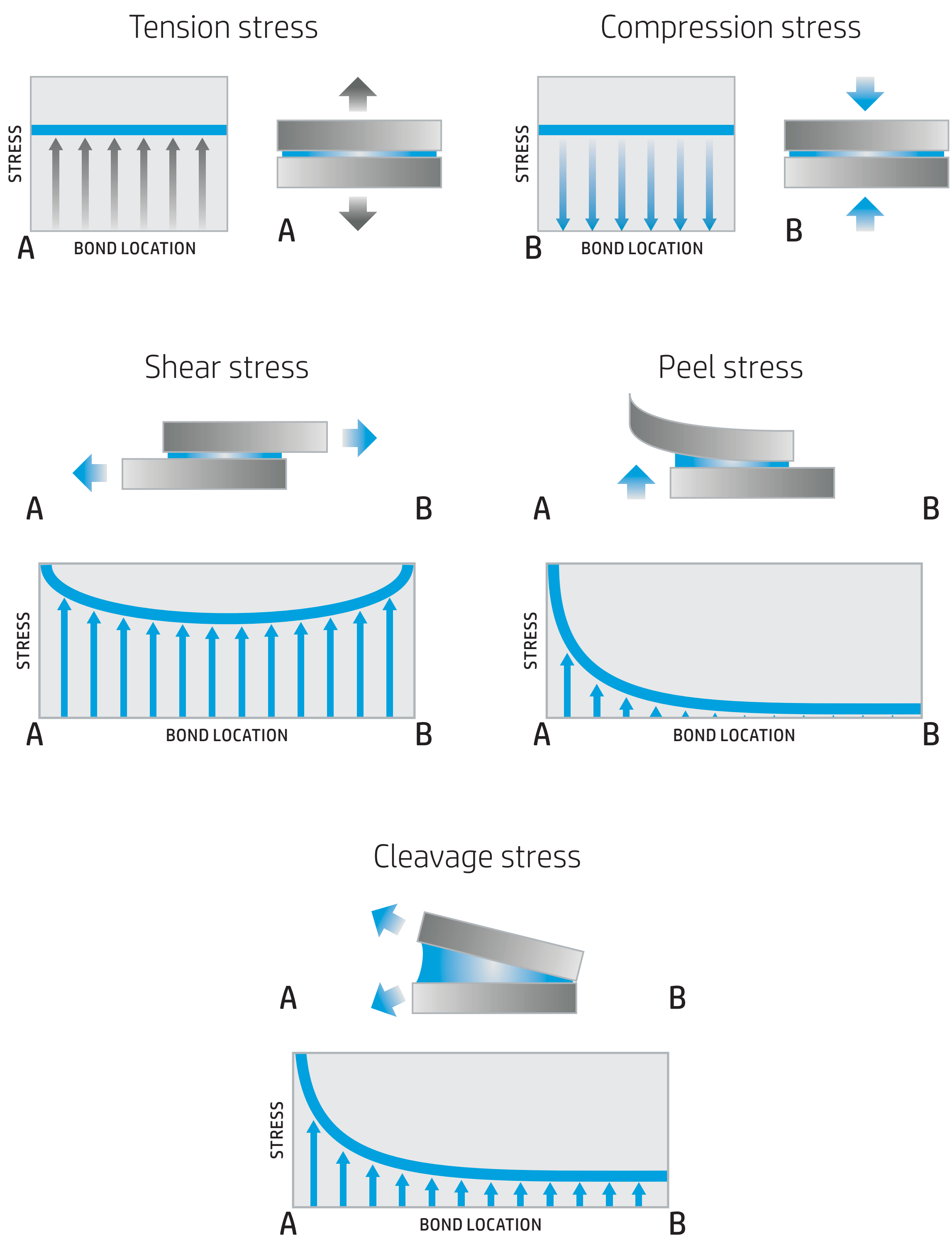


Figure 14: Stress distribution generated by different loads. Data courtesy of Henkel AG & Co. KgaA

When the cut is created, the design should be finished in order to prevent the development of peel, cleavage, or tension stress. The adhesive bondings work better under shear or compression stress, and the design should maximize the generation of those types of stresses to achieve a robust joint. The introduction of the overlap in the joint helps develop a bonding that works better under shear stress, which maximizes the performance of the union.

It is recommended to have a wider overlap area rather than a longer one. Having a wider overlap helps distribute more stress along the width and reduces the maximum values that appear on the sides.

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