

# HYBRID JOINING WITH PRESSURE SENSITIVE ADHESIVES

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## Abstract

Tack, ease of use and viscoelastic damping properties are the key features of pressure sensitive adhesives, opening a wide range of potential applications [1]. However creep under static mechanical load conditions and low strength at elevated temperatures limit the possibilities of using pressure sensitive adhesive joints in semi-structural and structural applications [2]. The principle of combining different joining technologies is often referred to as hybrid joining [3].

In hybrid joining two or more joining operations are carried out either simultaneously or sequentially, leading to enhanced properties of the joint due to a synergistic load bearing interaction under service conditions. Combining pressure sensitive adhesive bonding with mechanical joining or with structural adhesives can offer advantages in terms of processability and load bearing capacity when high levels of both static and dynamic mechanical resistance are required.

## Introduction

Hybrid joining has become a preferred practice in the assembly of modern lightweight automotive and commercial vehicle structures. One of the reasons for this development has been the increased demand in mixed material design (e.g. as in combinations of steel and aluminum parts) that cannot be realized with traditional joining technologies such as welding. Furthermore combining different joining technologies in hybrid joining can build on their individual strengths and advantages and counterbalance specific weaknesses. Such hybrid joining technologies are, for example, being used today in the automotive industry for the manufacturing of the body in white (BIW) structure, where BIW refers to the stage in which the car body sheet metal parts (including doors, hoods etc.) have been assembled but components like chassis, engine and trim have not yet been added.

Today's standard practices in hybrid joining with adhesives include spot weld bonding, hem flange folding and bonding, clinch bonding and adhesive bonding in combination with self-piercing rivets. The adhesives used in these hybrid bonds are predominantly liquid adhesives like single component hot curing or two-component room temperature curing toughened epoxy adhesives.

The focus of this paper is the question, whether pressure sensitive adhesives can provide advantages in hybrid joining, in terms of the joining process and / or the application specific mechanical properties of hybrid joined assemblies.

The apparent advantages of pressure sensitive adhesives include quick-fix properties due to tack, easy roll-on dispensing and viscoelastic properties creating a high level of impact resistance and vibration dampening properties for pressure sensitive adhesive joints. A second joining technology being evaluated is the combination of pressure sensitive adhesives with mechanical methods, such as self-piercing riveting and clinching. Additionally, pressure sensitive adhesives can be combined with structural thermosetting adhesives in a side-by-side manner, or as a formulated blend, creating a thermo curable, pressure sensitive bonding technology. This is the basis of the so-called structural bonding tapes. These exhibit pressure sensitive properties at ambient temperature, and at temperatures above 140 °C, can be cured to develop structural adhesive-like properties [4]. Therefore this material represents adhesive hybrid-systems combining pressure sensitive and structural adhesives.

As a third option, this structural bonding tape was evaluated in conjunction with self piercing riveting and clinching to take advantage of the mechanical fixture of the hybrid joint in the transition between the pressure sensitive state and the fully cured properties after the thermal activation.

### Experimental

The test specimen consisted of 1 mm thick aluminum (AlMg3) and 0.5 mm thick stainless steel (1.4571) blanks with a size of 200 mm x 30 mm. Hardened self piercing rivets (C-SKR 3 x 4) were used to mechanically join the mixed steel / aluminum joints. Clinching with a 4.5 mm punch was used to mechanically join aluminium-aluminum specimen (Figure 1).

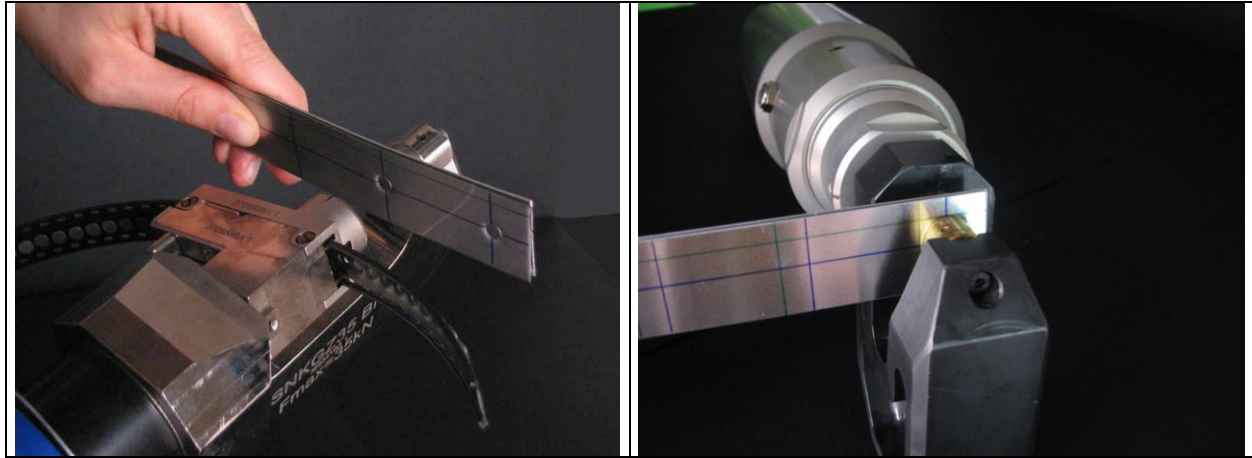


Figure 1: Mechanical joining, self-piercing riveting (left), clinching (right)

Double-faced high performance acrylic tapes with a thickness of 1 mm were used as pressure sensitive adhesives. The thermo-curable pressure sensitive structural bonding tape had a thickness of 0.5 mm. Prior to bonding, the test specimens were ultrasonically cleaned in acetone. The samples were adhesively joined by placing a 25 mm wide strip of adhesive tape along the centerline of the 30 mm wide metal blanks. In the case of the hybrid joints, four mechanical joint elements were placed at a distance of 40 mm from each other. Testing was done in a T-peel geometry at peel rates of 5 mm/min and 500 mm/min. Figure 2 illustrates the final sample geometry before testing.

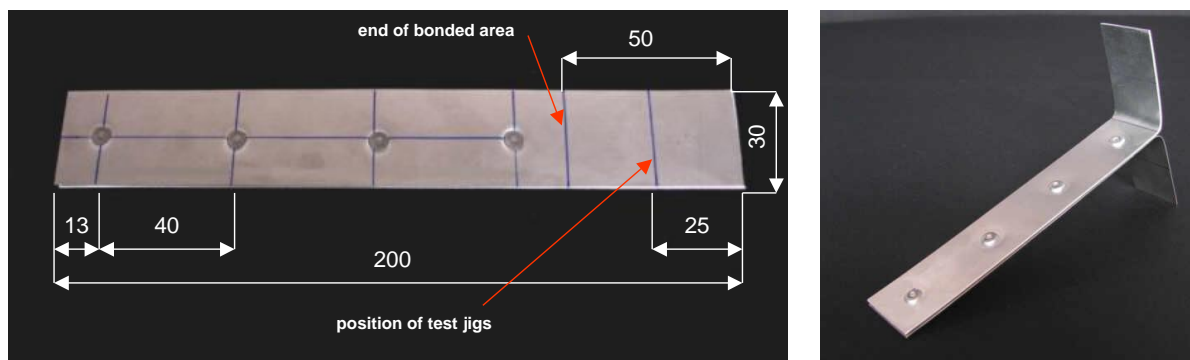


Figure 2: Preparation of the hybrid T-peel specimens (all measures in mm)

Before testing the specimens made with acrylic pressure sensitive tape, a dwell time of 72 hours was maintained. The samples prepared using the structural bonding tape were cured at 150 °C for fifteen minutes in a convection oven. Table 1 illustrates the combinations of parameters that were considered in this study. Purely mechanically

or adhesively joined non-hybrid joints in this matrix served as a reference to be able to evaluate the added value of the hybrid joints.

	<i>mechanical joint</i>	<i>structural bonding tape</i>	<i>acrylic pressure sensitive tape</i>	<i>mechanical joint</i>	<i>structural bonding tape</i>	<i>acrylic pressure sensitive tape</i>
<i>peel rate:</i>	<i>500 mm/min</i>			<i>5 mm/min</i>		
<i>mechanical joint (self piercing rivet)</i>	x			x		
<i>structural bonding tape</i>	x	x		x	x	
<i>acrylic pressure sensitive tape</i>	x		x	x		x
<i>mechanical joint (clinchng)</i>	x			x		
<i>structural bonding tape</i>	x	x		x	x	
<i>acrylic pressure sensitive tape</i>	x		x	x		x

Table 1: Variation of experimental parameters

## Results

Figure 3 illustrates the debonding of the joints during the t-peel test. The comparison of the pure pressure sensitive joint (left) and the hybrid-joint using half hollow self-piercing rivets reveals how the local debonding characteristic of the adhesive is influenced by the presence of the mechanical joint. The results of the peel tests were quantified according to the progression of peel force and dissipated peel energy for different peel rates.

The differences in peel behavior for both the acrylic pressure sensitive tape as well as the structural bonding tape is compared in Figure 4 on the basis of representative peel diagrams. The data of the total peel energy in Figure 5 has been calculated as an average of three individual tests.

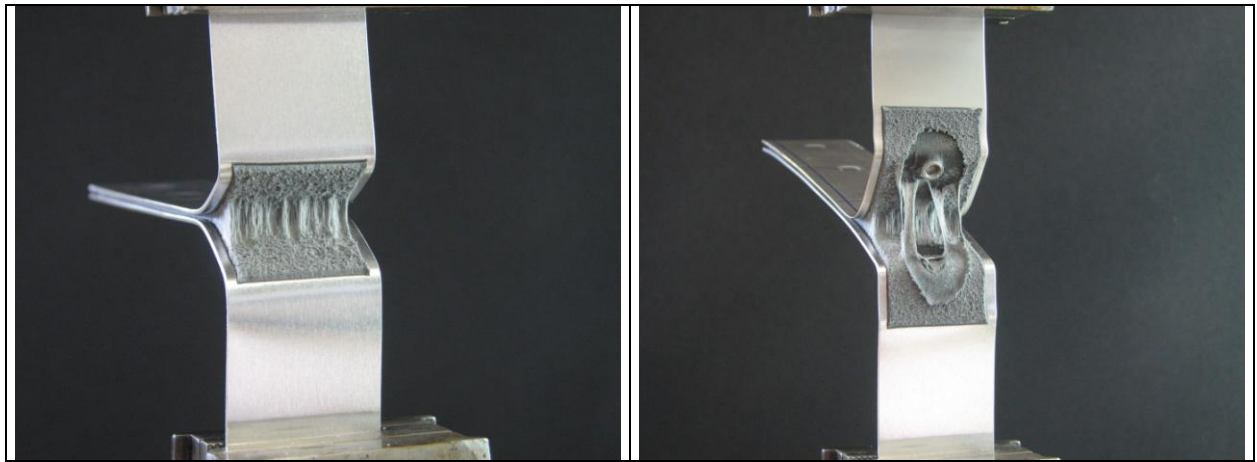


Figure 3: Debonding of T-peel specimens bonded only with acrylic pressure sensitive tape (left) and hybrid-jointed using self-piercing rivets

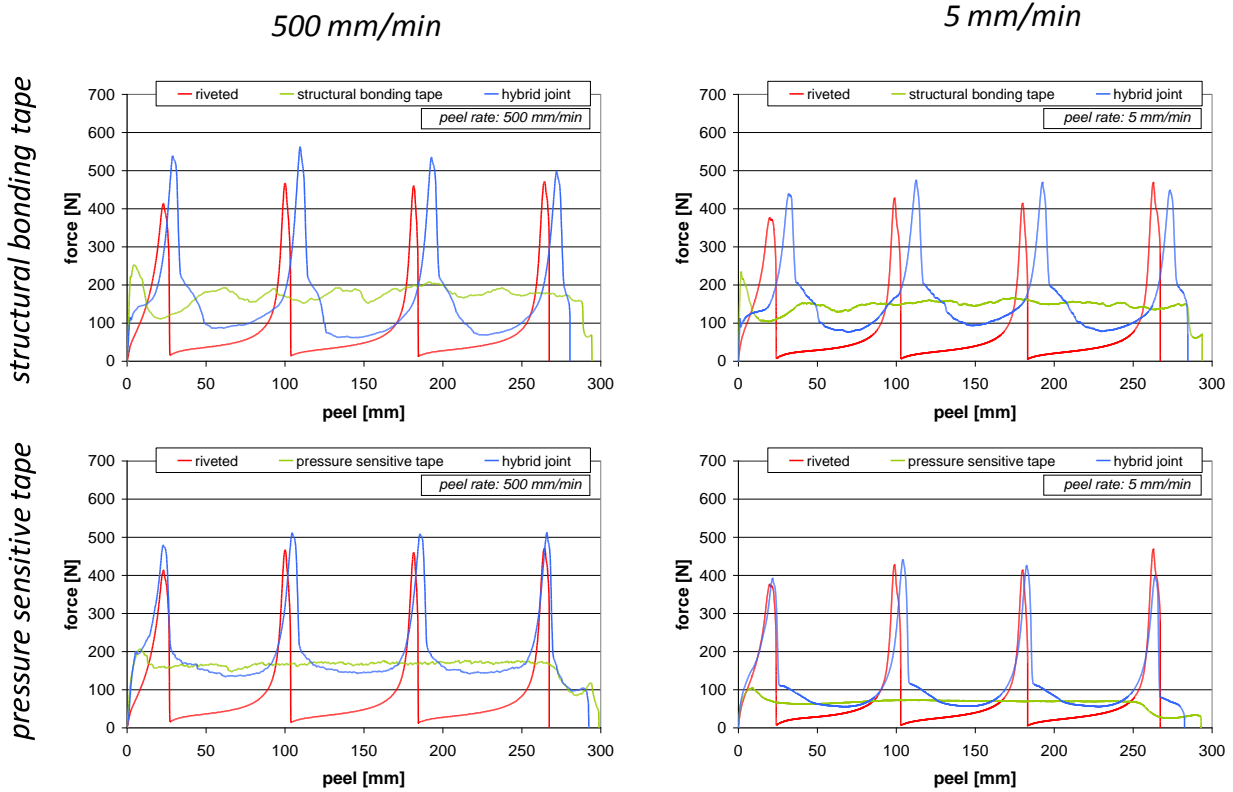


Figure 4: Peel resistance of reference specimen and hybrid-joints with self-piercing rivets at different peel rates, aluminum (AlMg3) to stainless steel (1.4571)

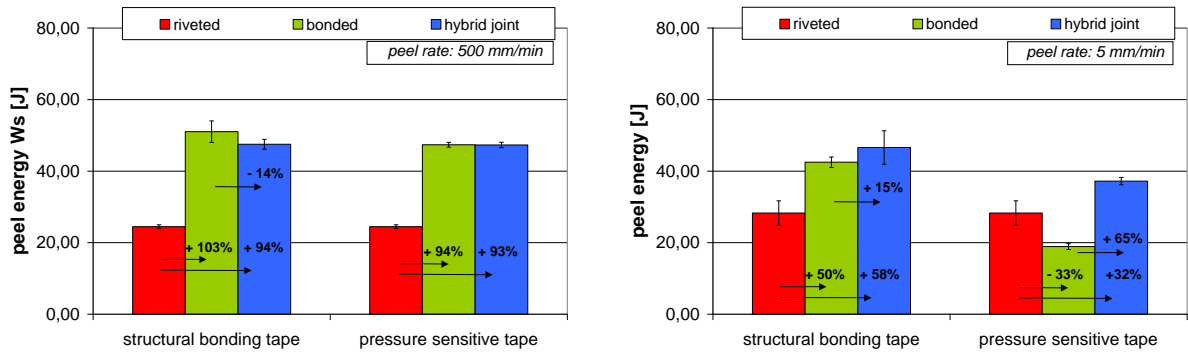


Figure 5: Overall peel energy at different peel rates, aluminum (AlMg3) to stainless steel (1.4571), self-piercing rivets and adhesives

The specimens bonded only with double face acrylic pressure sensitive adhesive naturally exhibit a high peel rate dependency of the peel resistance. The peel rate dependency is less pronounced in the case of the structural bonding tape. In hybrid joints, even at low peel rates the acrylic pressure sensitive tape contributes significantly to the overall dissipated peel energy. At high peel rates the overall peel energy of hybrid joints is more than twice as high as for the purely mechanically joined reference samples.

The image of the cross section of the hybrid joint in Figure 6 provides evidence that the formation of the undercut-geometry of the half hollow self-piercing rivet during the setting procedure is not influenced by the adhesive tape.

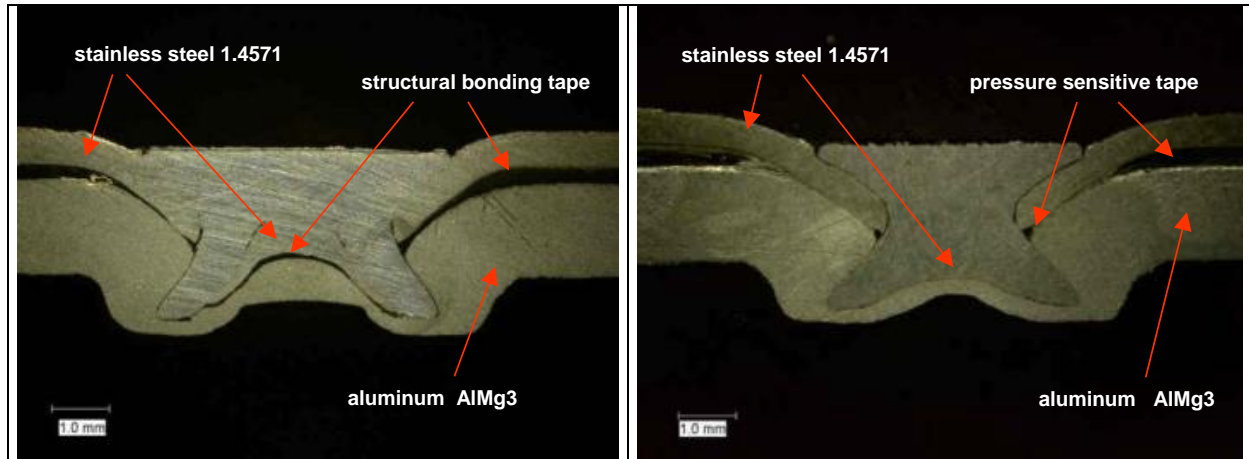


Figure 6: Combination of self piercing rivets with structural bonding tape (left) and acrylic pressure sensitive tape (right)

In the hybrid combination of bonding and clinching however, the presence of the 1.0 mm pressure sensitive tape as well as the 0.5 mm structural bonding tape strongly disturbs the interlocking of the mechanical joint (Figure 7).

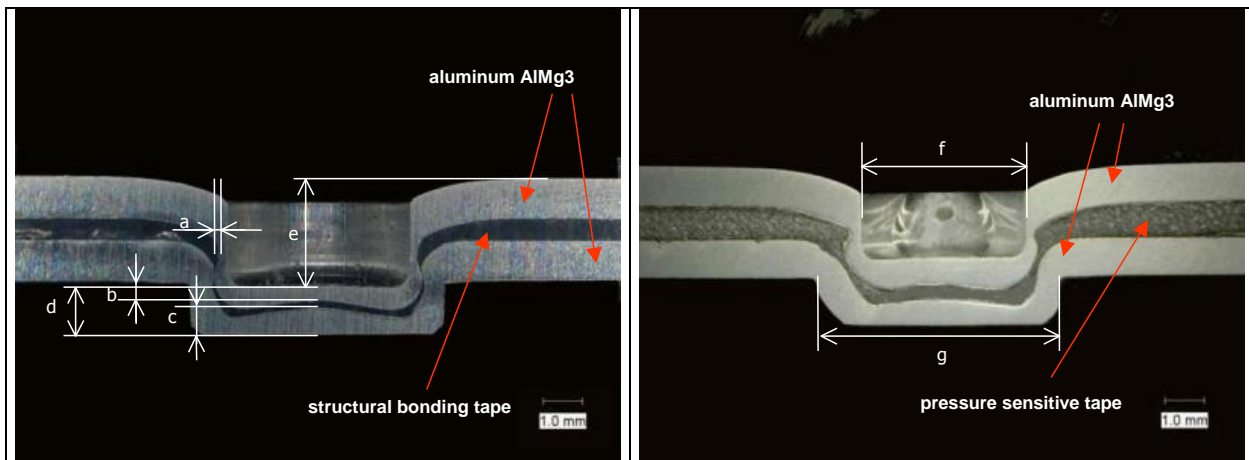


Figure 7: Combination of clinching with structural bonding tape (left) and acrylic pressure sensitive tape (right)

Correspondingly, neither in the peel diagrams in Figure 8 nor in the comparison of overall peel energy in Figure 9 was a significant contribution observed from clinching the hybrid joint in combination with acrylic pressure sensitive tape. The mechanical properties of the only adhesively bonded joint are similar to those of the clinch-bonded hybrid joint.

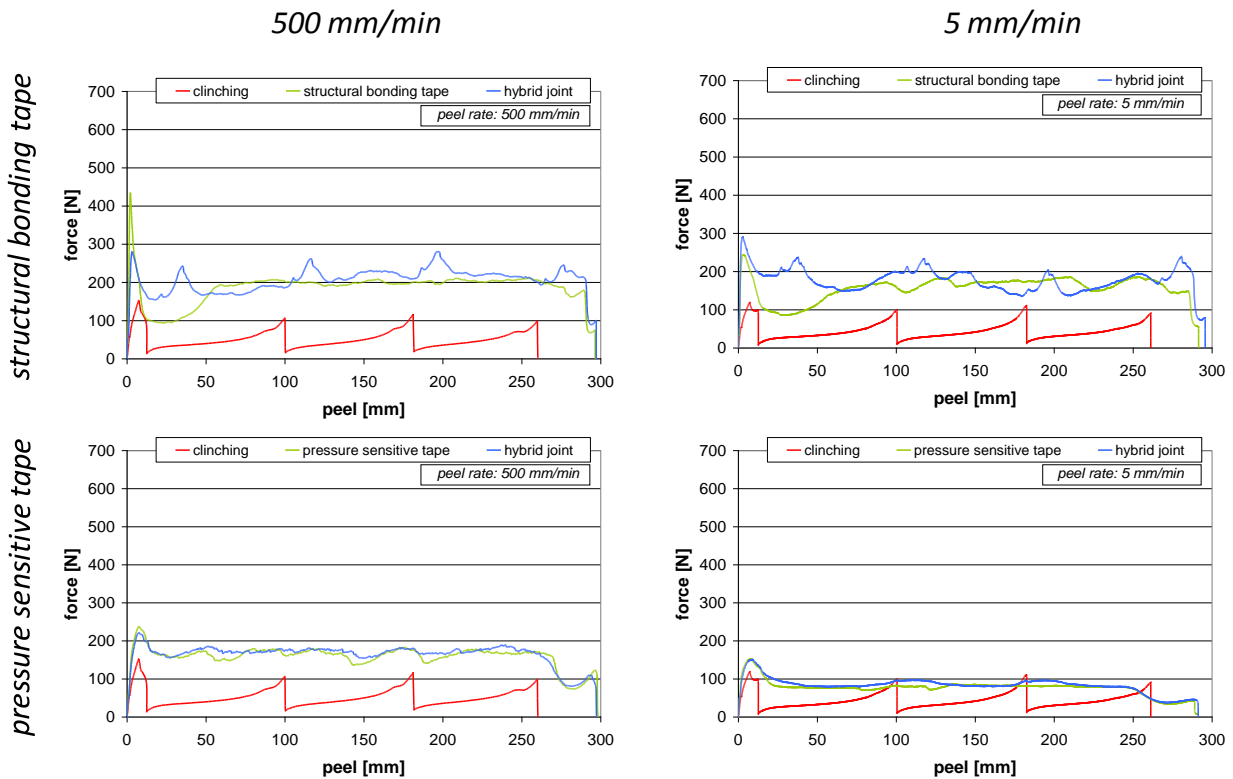


Figure 8: Peel resistance of reference specimen and clinched hybrid-joints at different peel rates, aluminum (AlMg3) to stainless steel (1.4571)

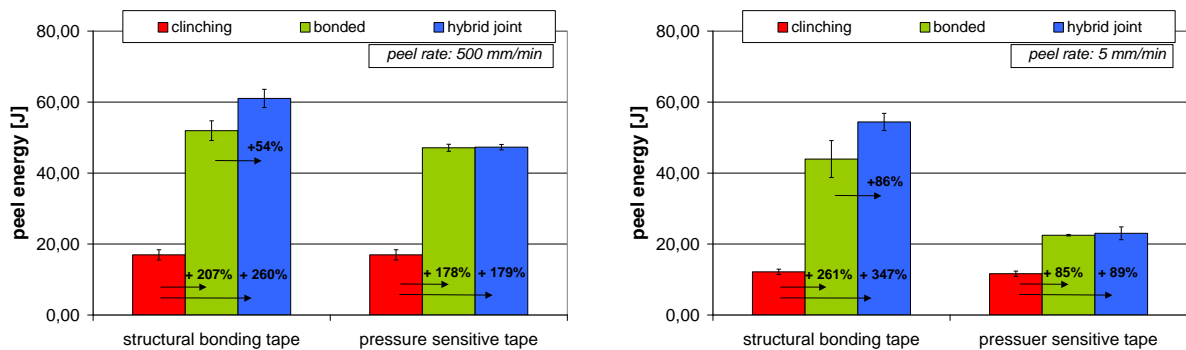


Figure 9: Overall peel energy at different peel rates, aluminum (AlMg3) to stainless steel (1.4571), clinching and adhesives

Due to the more viscous flow characteristics of the structural bonding tape compared to the acrylic pressure sensitive tape, the hybrid joining in combination with clinching gives slightly better results, exceeding the adhesive reference value by about 15 % to 20 %. This effect can also be assigned to the observation that the mechanical fixture avoids movement or opening of the adhesive joint in the transition from pressure sensitive properties to structural adhesives in the thermal curing procedure. The hybrid joint with structural bonding tape thus contains fewer defects than the reference adhesive joint and the clinch-joints fail by neck fracture of the clinch punch (Figure 10).



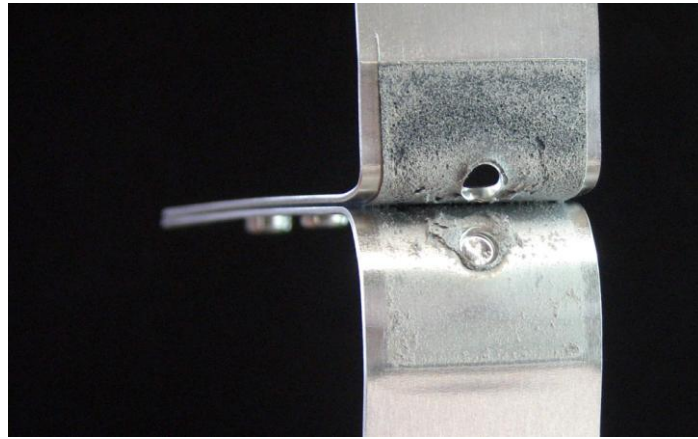


Figure 10: Debonding of clinched hybrid joints with structural bonding tape after curing, 2 x 1 mm AlMg3

### Summary

The discussed results show that hybrid joining using pressure sensitive adhesive tapes or structural bonding tapes with pressure sensitive properties in combination with mechanical joining is possible. Hybrid joints prepared in this manner exhibit superior properties in terms of incipient tear and peel resistance and generally outperform the characteristics of the reference specimens prepared as non-hybrid joints.

However, a negative interference could be observed in the case of clinching the joints in the presence of the pressure sensitive adhesive tape. An appropriate interlocking of the clinch punch could not be achieved. Using a thinner tape or optimizing the shape of the clinch die could possibly avoid this effect.

The mechanical fixture during the thermal curing of the structural bonding tape causes a more homogeneous bondline with fewer defects. Hybrid joints with structural bonding tape in combination with self-piercing half hollow rivets have exhibited the best balance of performance at low and high peel rates.

A challenge in using liquid hot curing adhesives in the BIW-assembly today is to adjust their rheology in such a way, that the washing and passivation treatments followed by cataphoretic painting do not wash out adhesive before the curing in the paint dryer takes place. Since the wash-out resistance of the structural bonding tape compared to liquid structural adhesives is naturally better, this hybrid joining technology can offer additional process-related advantages to the automotive industry.

During preparation of the specimens, the self-fix properties of the acrylic adhesive tapes greatly facilitated the overall hybrid-joining procedure. The combination of acrylic pressure sensitive tape with self-piercing half hollow rivets has led to hybrid joints with an excellent peel resistance at high and low peel rates without the need of a thermal curing process. This practice seems especially suitable in the automotive industry for mounting parts once the body in white has passed the paint drier.

Future work will focus on the shear resistance, crash performance and durability of hybrid joints with pressure sensitive adhesive tapes and their corrosion resistance under detrimental environmental exposure.

## References

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