Empirical Safety Assessment of Double-Sided Adhesive Tapes

A new approach based on multiparametric fracture analysis evaluates the adhesive safety of double-sided adhesive tapes. As different test parameters create different test winners, it is necessary to define a well-thought-out evaluation concept that takes these inconsistencies into account.

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In the ever-changing world of industrial production, material innovations take center stage to meet the ever-increasing demands. A key element of this progress is double-sided adhesive tapes, which are increasingly establishing themselves as indispensable components in various industries. Traditionally, mechanical joining methods such as screws, rivets, and welding have played a central role in construction. However, with the advent of lighter materials, more complex designs and the desire for more efficient manufacturing processes, adhesive tapes have come to the fore.
Industrial double-sided adhesive tapes have proven to be a versatile solution to permanently bond materials while providing an aesthetically pleasing finish. In the automotive, electronics, aerospace, and many other sectors, companies are increasingly turning to these adhesive solutions to reduce weight, shorten assembly times, and improve the overall performance of their products. There are many reasons for this trend. Firstly, adhesive tapes allow stresses to be distributed evenly across the entire joint, resulting in improved stability. Secondly, they offer greater design flexibility as they facilitate the joining of materials with different properties. They also contribute to noise insulation and vibration reduction, which is particularly important in the automotive sector.
In view of this development, it is crucial to evaluate the performance of adhesive tapes. This requires new test methods in the adhesives industry. These have already been presented and discussed in detail in past publications [1-13].

Traditional test methods with limitations

In the area of suitability testing of double-sided adhesive tapes, manufacturers always emphasize the decisive role of peel strength tests [14,15]. It is argued that this method, together with the adhesive tensile strength [16] and shear strength [17-20], is sufficient for determining minimum adhesive properties. The focus is on speed and cost minimization. However, considering that the above-mentioned test methods have been on the market for a very long time and new innovative methods exist, it is necessary to evaluate the effectiveness and reliability of the established test methods. Fracture Analytics has for the first time applied a testing and evaluation methodology to double-sided adhesive tapes from the companies 3M and Tesa. *Table 1* summarizes common test methods using Tesa as an example.

- Peel tests [14,15] assess the adhesion properties by peeling off the adhesive tape on one side at a constant speed. The disadvantages of this test are the fixation on pure maximum values and the ignoring of other types of load that can occur simultaneously in real applications. Likewise, neither the complex failure mechanisms in the interface are described, nor the expansion of the plastic process zone characterized.
- Tensile adhesion tests [16] are similar to peel tests, except that the adhesive tape is bonded on the face side and pulled off uniaxially on both sides at a constant test speed. The result is the so-called adhesive tensile strength, which represents a mechanical stress in [MPa] at which the bond is separated. The disadvantages of this test are the same as for the peel test.
- Tensile shear tests [17-20] measure the maximum shear stress of the adhesive

Method:	Peel test	Dynamic tensile test	Dynamic lap-shear test	Static lap-shear test	Temperature resistance
Standard:	ASTM D3300	ASTM D897	ASTM D1002	ASTM D3654	TESA Internal
Value:	Force per unit width	Mechanical tension stress	Mechanical shear stress	Mechanical shear stress	Temperature
Unit:	N/mm Uncommon: N/cm	MPa (N/mm^2) Uncommon: N/cm^2	MPa (N/mm^2) Uncommon: N/cm^2	MPa (N/mm^2) Uncommon: Gram g, Weight time min	°C

Table 1 > Overview of classic test methods in the adhesive tape industry.

Tape ID:	3M VHB 060	3M VHB 160	3M VHB 4912	3M VHB 4991	TESA ACX 7074	TESA ACXplus 7815	TESA ACX 7078
Tape Thickness [mm]	0.6	1.6	2	2.3	1	1.5	2
Peel Resistance [N/mm][1]	2.5	3.4	3	3.5	3	3.5	4
Peel-Off Strength [MPa][2]	0.38	0.24	0.29	0.19	0.09	0.16	0.07

Table 2 > Overview of the results of test methods using different products depending on the adhesive tape thickness ([1] Data from the manufacturer, [2] Own measurements from Fracture Analytics).

bond by applying a shear force at a constant test speed until the bond fails. The disadvantages of this test are the same as for the peel test.

Although all of these methods are still widely used, they have significant drawbacks as they ignore the complex interactions in the interface that are critical to the necessary evaluation of bond performance and bond reliability. Therefore, this article uses a proven test method from Fracture Analytics to overcome these limitations of the above methods. It is called the MCT method [21] and allows all common load types (crack opening, longitudinal shear, transverse shear) to be tested either in pure form or as a superposition. However, the most important unique feature of this method is its ability to record stable test curves, even if the material is brittle. This distinguishes it from all other common test methods on the market. There are also more extensive possibilities for evaluation that are not covered by traditional test methods [14-20]. The MCT method is already part of the standard test protocol at Fracture Analytics.

Extensive evaluations using multiparametric fracture analysis

The use of and adherence to traditional standard test methods [14-20] on the part of manufacturers often has historical reasons. Cost minimization and the doctrine of minimum effort often dominate the testing policy here. The use of scientific test methods with higher requirements is often not a necessary priority in this cost-dominated industry, as the focus is on selling products and there is often a lack of understanding of the added value of new innovative test methods.

A correlation analysis was carried out by Fracture Analytics to demonstrate to the reader the distorted contradictions and impressions that the previous measurement methods lead to. The adhesive tape thickness was compared with the peel strength and the adhesive tensile strength. The results are quite surprising and lead to the conclusion that the sole use of peel tests is not expedient. *Table 2* shows the results of the correlation analysis from a recent study by Fracture Analytics on various Tesa ACX and 3M VHB adhesive tapes.

Looking at the peel strength and the adhesive tape thickness, there is a positive correlation factor of 0.72. This shows a direct correlation between these parameters and one might think that adhesive tapes lead to higher peel resistances with increasing adhesive tape thickness. However, this is not the case. In fact, the level of peel resistance is in the range of 3.4 N/mm and therefore the correlation with the

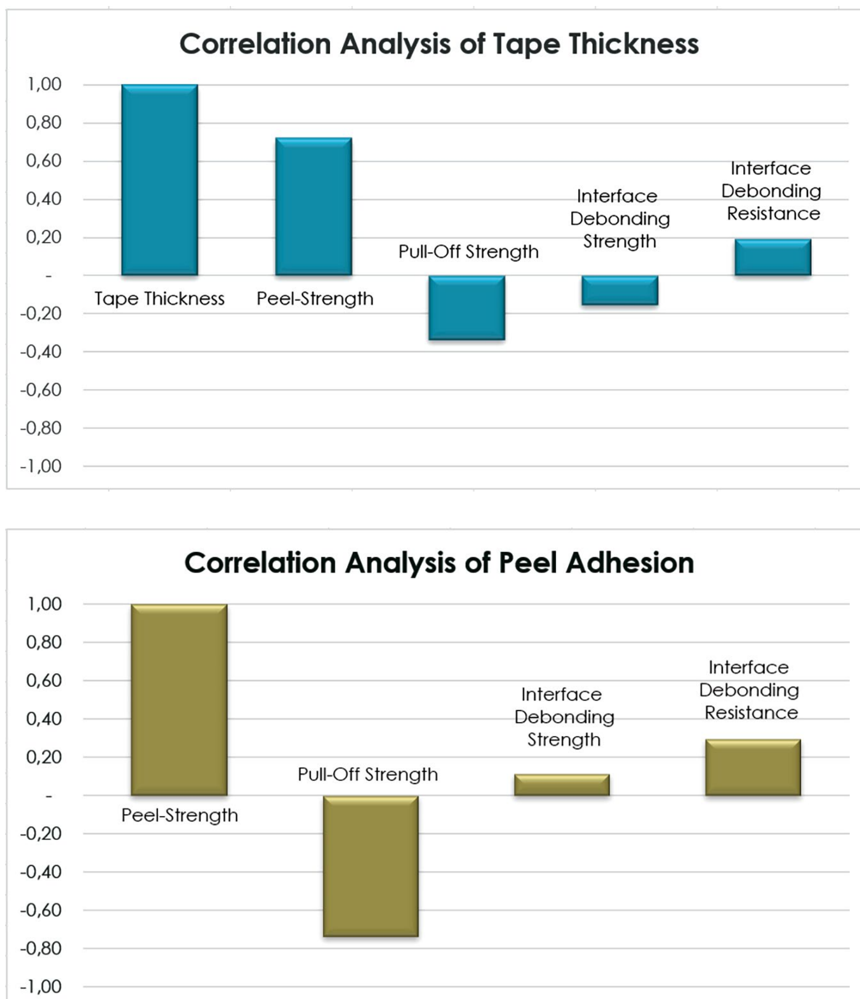
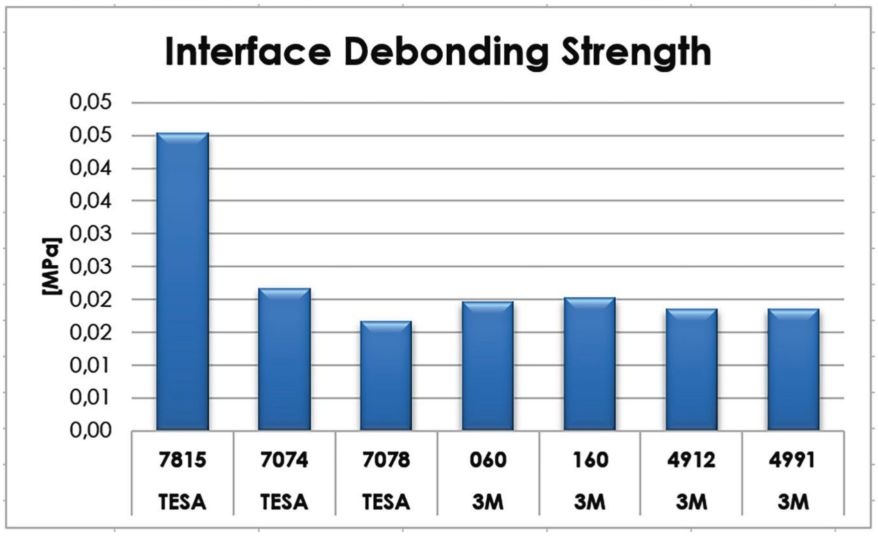


Figure 1a+b Compilation of the correlation of different test parameters as a function of the adhesive tape thickness and the peel resistance.



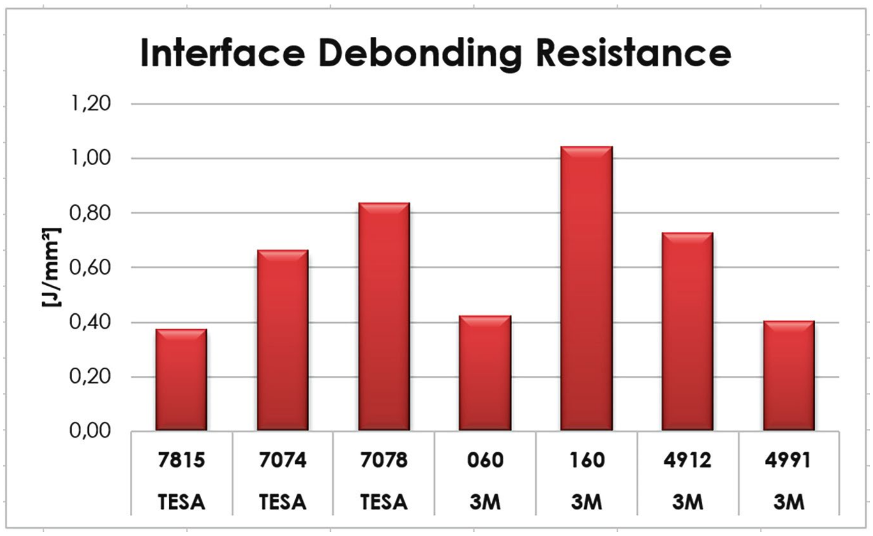


Figure 2a+b Compilation of the evaluation parameters "interface debonding strength" and "interface delamination resistance" using the example of 3M and TESA test candidates.

tape thickness is not clear. Other factors are therefore required.

These can be found in the adhesive tensile strength, which was measured directly by Fracture Analytics and has an average value of 0.20 MPa. If this is compared with the adhesive tape thickness, a completely different picture emerges than with the peel strength. The correlation factor turns negative and results in a value of -0.33. This means that the adhesive tensile strength does not reflect the peel strength trends.

The situation is different in direct comparison with two new parameters from multiparametric fracture analysis, the interface debonding strength σ_c and the interface delamination resistance G_F. Both values that have not yet been used for adhesive tape evaluations, as these methods are not available to the manufacturers.

Figures 1a (left) and 1b (right) summarize the correlations of all test parameters as a function of the adhesive tape thickness and the peel resistance.

Empirical key figures for the adhesive safety assessment of adhesive tapes

For the assessment of adhesive safety, Fracture Analytics uses a total of seven specially developed empirical key figures based on multiparametric fracture analysis which are determined using the MCT method [21]. The situation is comparable to that of a pilot who carries out a purely visual flight in fair weather, with no wind, and during daylight (shell strength test) or a night flight in, rain, and crosswinds with the aid of extensive flight assistance systems (MCT test method). Since a detailed explanation of the key figures would go beyond the scope of this article, two of the eight key figures are presented here:

1. Interface Debonding Strength σ_c

The interface debonding strength σ_c enables the evaluation of the cohesive debonding stress in the interface during crack propagation and debonding under different types of load. Unlike the pure adhesive tensile strength, this parameter measures fracture-analytical detachment processes in the two interfaces between the adhesive tape and the substrate (interface fracture mechanics). As the failure processes there are much more complex and better reflect real processes, this method is preferable to simple peel tests.

2. Interface Debonding Resistance G_F

The interface debonding resistance G_F is an energetic evaluation parameter from non-linear plastic fracture mechanics. It measures the crack resistance of a material under load for the crack formation, crack initiation, and crack propagation phases. Mathematically, it is the area under a stable test curve from the load-displacement diagram in relation to the ligament area of the fracture surface of a test specimen. In the case of the current study, load mode I (crack opening) was selected, which corresponds to the international test standard. In comparison to the pure peel resistance – which only provides a maximum value – the delamination resistance determines an empirical material law in the form of an individual test curve. Furthermore, this key figure is an independent material property and therefore provides a higher quality of information. It is therefore clearly preferable to peel resistance tests [21].

Adhesive safety assessment of adhesive tapes

Figure 2 illustrates the course of the measurement results for different adhesive tapes of the brands Tesa ACXplus 7815, ACX 7074 and ACX 7078 as well as 3M VHB 060, VHB 160, VHB 4912 and VHB 4991.

The findings can be summarized as follows:

Figure 2a (left) shows the development of the interface debonding strength σ_c. It is noticeable that Tesa ACXplus 7815 has twice as high values as the rest of the group, whose values are in the range of 0.02 MPa. These are around a power of ten lower than the adhesive tensile strengths. The reason for this is that the samples for the fracture analysis test are already precracked before the test begins. This allows controlled crack formation to be initiated and propagated until complete fracture.

Figure 2a (right) shows the course of the delamination resistance G_F. Tesa ACXplus 7815 now brings up the rear. This means that, at around 0.4 J/mm², it has the lowest delamination resistance of all the tapes tested. In practice, this means that in the event of a fracture in the interface due to defects and external stress, this tape has the lowest fracture resistance and therefore the highest probability of peeling. In this case, candidate 3M VHB 160 should be preferred, as it has 2.5 times higher fracture resistance than ACXplus 7815.

Summary and Outlook

The results of the present adhesive safety evaluation of double-sided adhesive tapes of the brands Tesa ACX and 3M VHB show that the limitation to peel resistance and tensile strength does not lead to a satisfactory picture of performance. The different correlations of the currently used test parameters of the manufacturers [14-20] with those of Fracture Analytics [21] lead to the necessity of further in-depth investigations. The results showed that the peel strength as a suitability parameter does not lead to a sufficient evaluation and thus a reliable selection of double-sided adhesive tapes.

For this reason, the MCT method from Fracture Analytics was applied in Mode I to seven different products from two well-known manufacturers. It was noticed that the investigation of the interface of adhesive tapes creates different test winners, depending on which test parameter is used. It is therefore necessary to define a well-thought-out evaluation concept for double-sided adhesive tapes that takes these inconsistencies into account. Further details will be available in the upcoming study by Fracture Analytics from fall 2024. //

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