TALAT Lecture 4702

Factors Influencing the Strength of Adhesive Joints

13 pages, 13 figures

Basic Level

prepared by
Lutz Dorn, Technische Universität, Berlin

Objectives:

– to describe the factors governing the strength of adhesive joints in order to appreciate these factors for the design of adhesively bonded joints, i.e. geometry of joint, stiffness and strength of the adjoining parts, stress distribution in the adhesive layer as well as the effects of humidity and ageing

Prerequisites:

– general background in production engineering and material science
– background in mechanics and polymer science

Date of Issue: 1994

4702 Factors Influencing the Strength of Adhesive Joints

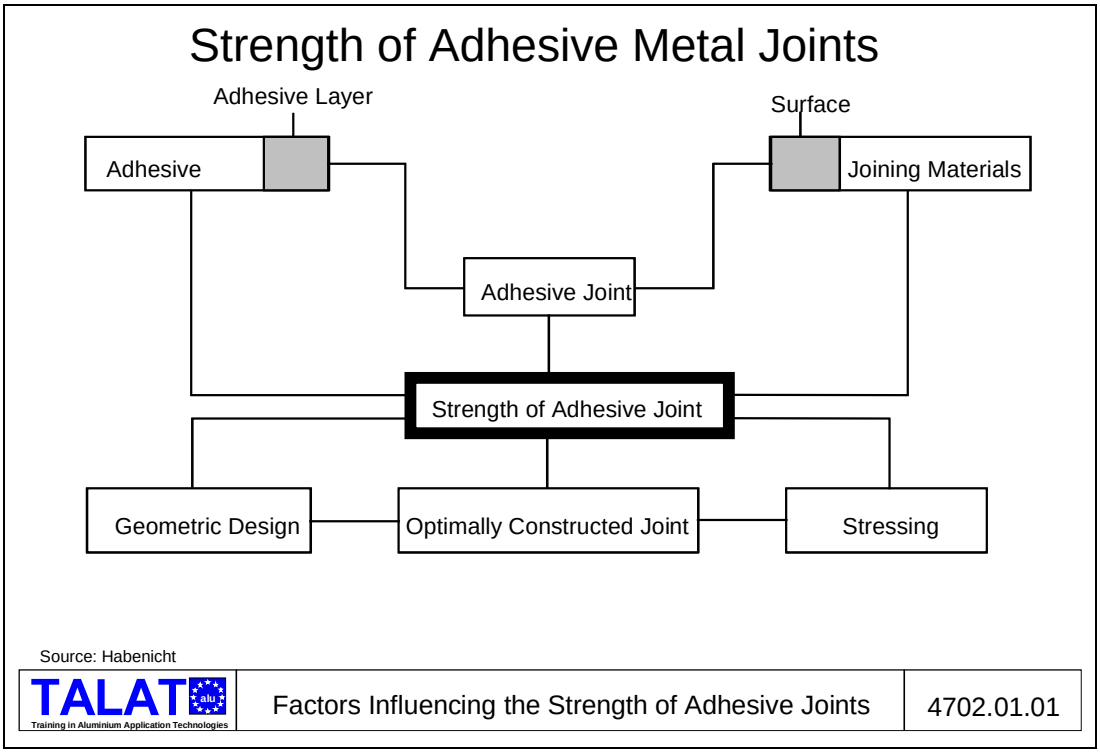
Table of Contents

4702.01 Basic Factors Governing Strength of Joints

- Interdependence of material and design factors
- Loading factors
- Summary of influencing parameters

Interdependence of material and design factors

The peculiar behaviour of the strength of adhesively joint metals is a result of the fact that the joint system is not homogeneous but consists instead of a composite system in which the resulting properties are a combination of the individual properties of the parts to be joint, the adhesive layer and the interface layers (**Figure 4702.01.01**).

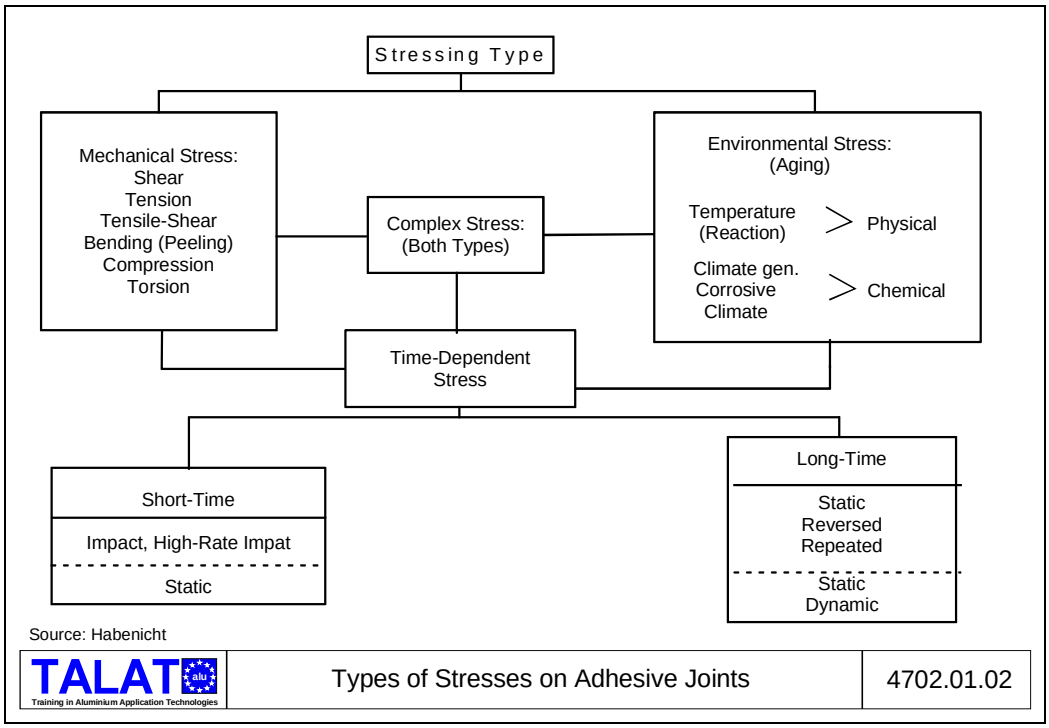


The specific properties of the adhesive joint are a result of the strengths obtained due to the geometrical and material design.

The following statement can serve as a basis for assessing the behaviour of adhesive joints in metals and consequently in dimensioning and designing such joints.

Loading factors

The overall performance of an adhesive metal joint is characterised by the measure in which it is able to withstand loads without any appreciable change in its original strength values (**Figure 4702.01.02**)



Summary of influencing parameters

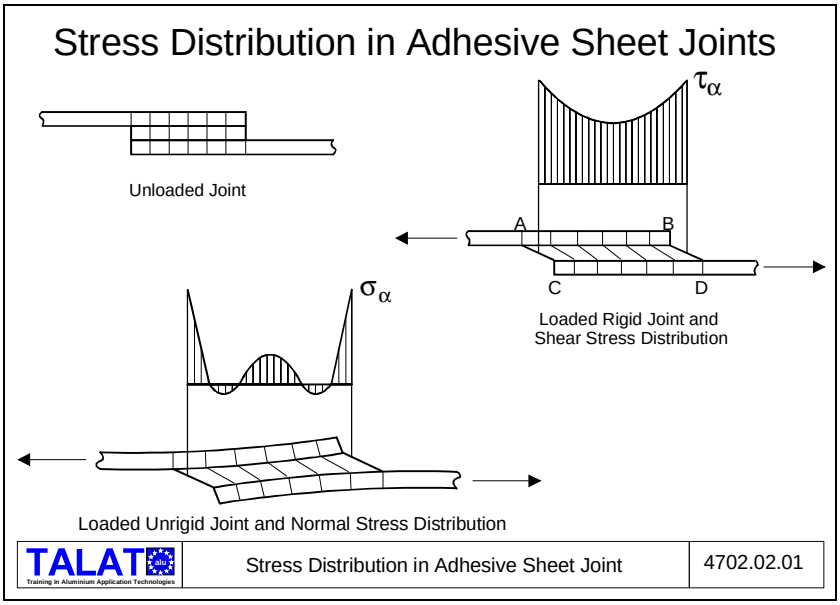
The combined action of the influencing factors and their parameters are the basis for the production of an optimal adhesive joint and govern its attainable strength (**Figure 4702.01.03**).

4702.02 Stress Distributions in Lap Joints

- Load distribution in adhesive sheet joints
- Stress distribution in a brittle and an elastic-plastic adhesive layer
- Distribution of stress during peeling

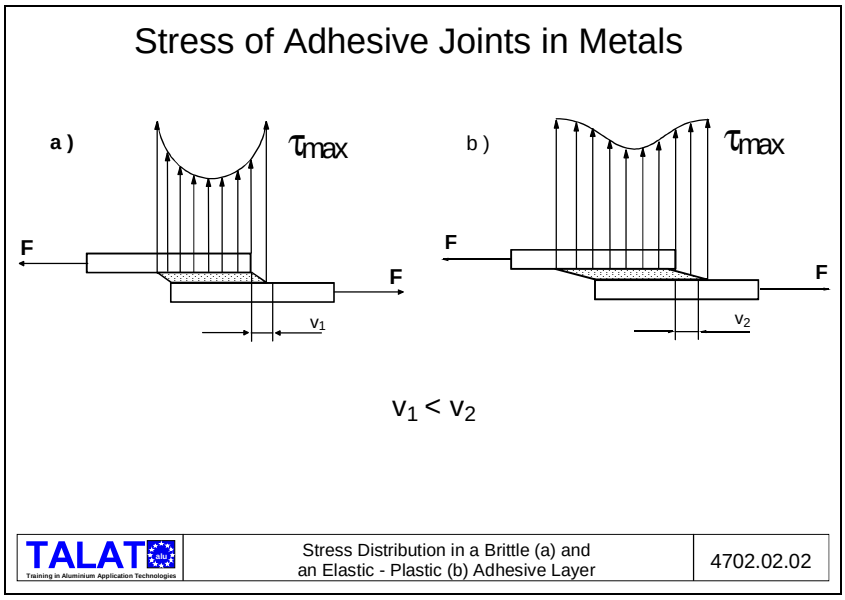
Load distribution in adhesive sheet joints

The load distribution in one-sided lap joints subjected to tensile-shear loading, depends on the stiffness of the joint parts and the deformability of the adhesive layer. The amount of the relative movement of the joint parts is a result of the deformation capacity of the adhesive layer (**Figure 4702.02.01**).



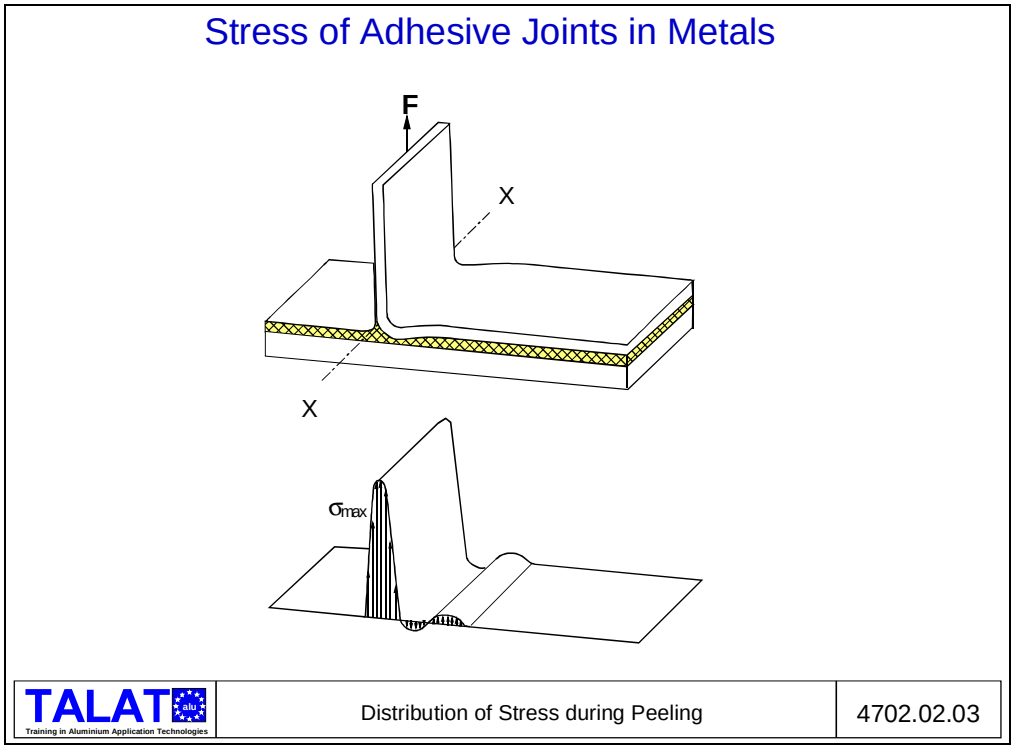
Stress distribution in a brittle and an elastic-plastic adhesive layer

Adhesives of the elastic-plastic type cause only low stress peaks at the overlap ends, in spite of the large relative movements of the joint parts (**Figure 4702.02.02**).



Distribution of stress during peeling

The occurrence of possible peeling stress during loading has a very major influence on the strength of adhesive joints. They occur both in tensile tests conducted on lap joints (due to eccentric loading) as well as in pure peeling tests (with extremely high stress peaks) (**Figure 4702.02.03**).

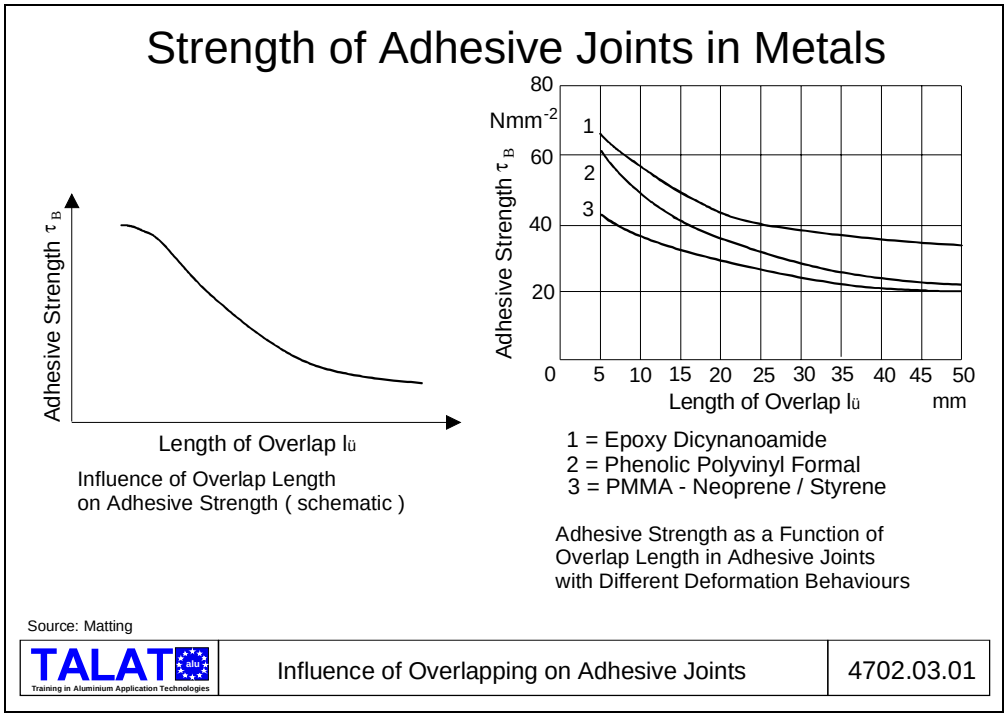


4702.03 Effects of Geometric Parameters

- Influence of overlapping on adhesive joints
- Correlation of overlap length and joining part elongation

Influence of overlapping on adhesive joints

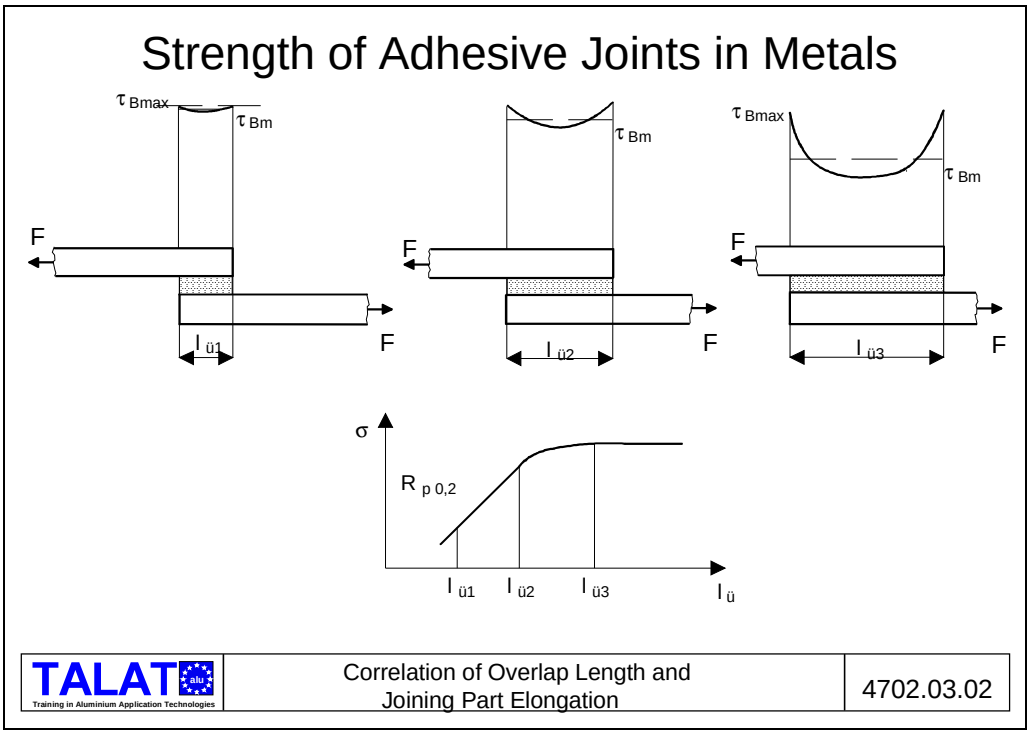
The strength of narrow (≤ 5 mm) overlapped joints is a result of solely adhesion and cohesion forces in the adhesive layer. At overlapping lengths exceeding a certain amount and depending on the geometry and strength of the joint parts and on the deformation capacity of the adhesive layer, stress peaks, in excess of the strength of the adhesive layer, occur at the overlap ends causing the strength to fall (**Figure 4702.03.01**).



Structural materials should not be subjected to stresses exceeding their proportionality limit. In practice, the limiting stress should be lower than the 0.2 % yield strength.

Correlation of overlap length and joining part elongation

Consequently, the optimal overlapping length, l_{o2}, of adhesive joints is so chosen that overloading the structural to more than the limiting stress causes a rupture of the adhesive layer (**Figure 4702.03.02**).



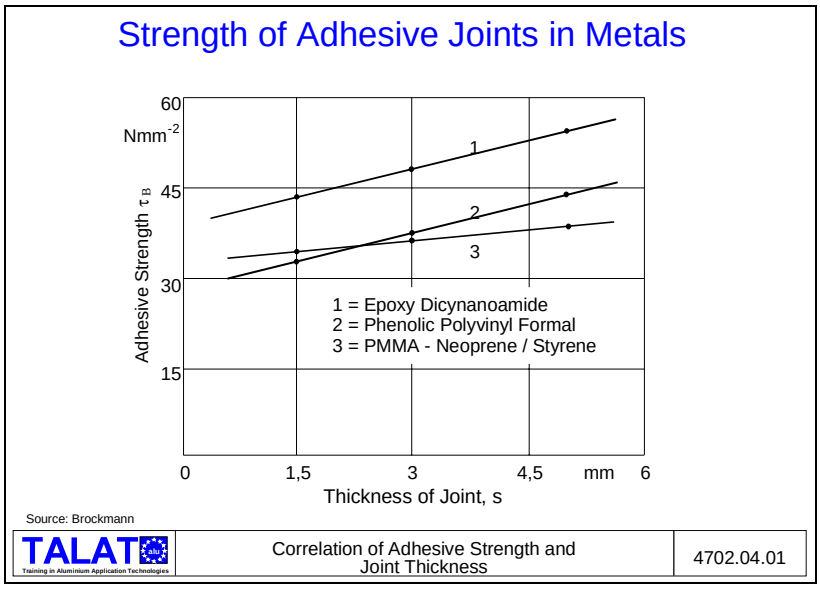
4702.04 Effects of Stiffness and Strength of the Joining Parts

- Correlation between adhesive strength and joining part thickness
- Correlation between adhesive strength and strength of joint parts

Correlation between adhesive strength and joining part thickness

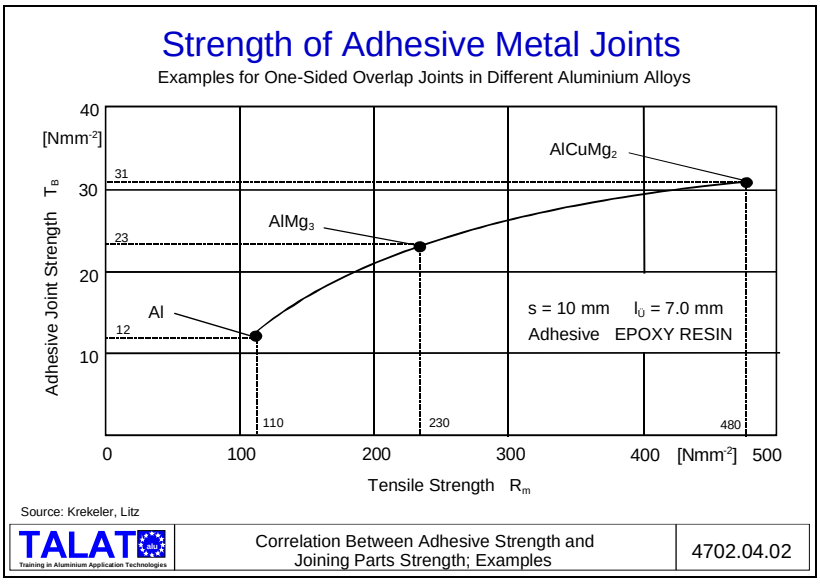
The joint part thickness increases the strength of the adhesive joint by increasing both the stiffness as well as the bending moment of the joint. An increased thickness of the joint parts also increases the adhesive joint strength (**Figure 4702.04.01**).

Stress peaks occurring at the overlap ends are lower for thicker joint parts because the latter leads to a higher rigidity allowing the adhesive layer to accommodate a larger part of the load.



Correlation between adhesive strength and strength of joint parts

These remarks apply in a similar manner to the strength of the joint components (**Figure 4702.04.02**).



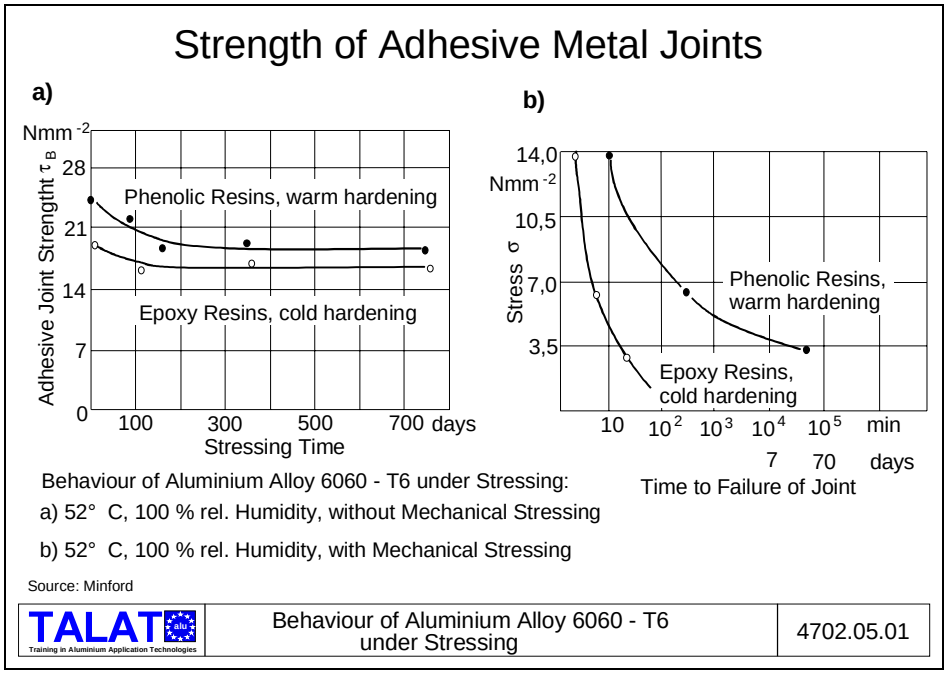
4702.05 Effects of Ageing under Stress and Humidity

- Behaviour of aluminium alloy 6060 - T6 under stressing

Behaviour of aluminium alloy 6060 - T6 under stressing

The strength of an adhesive joint depends on the thermal and mechanical stress as well as on the humidity of the environment.

The combined occurrence of both types of stresses is especially harmful (**Figure 4702.05.01**).



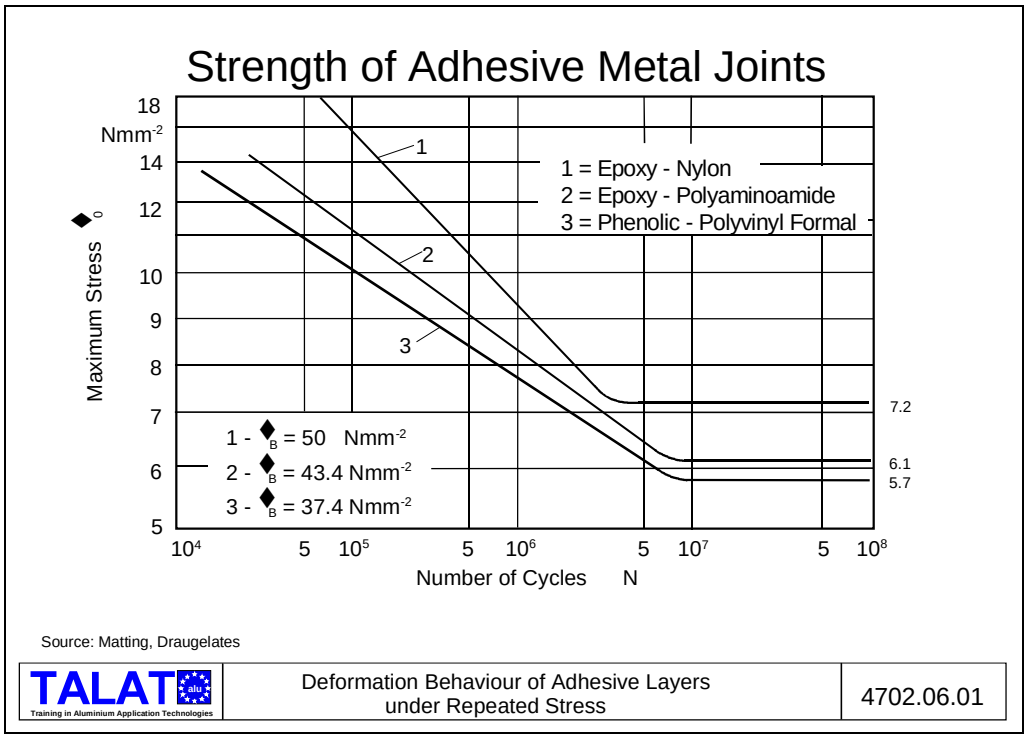
4702.06 Fatigue Behaviour of Adhesive Joints

- Deformation behaviour of adhesive layers under repeated stress
- Correlation between fatigue strength under repeated stress and a number of cycles for different strengths of joining parts

Deformation behaviour of adhesive layers under repeated stress

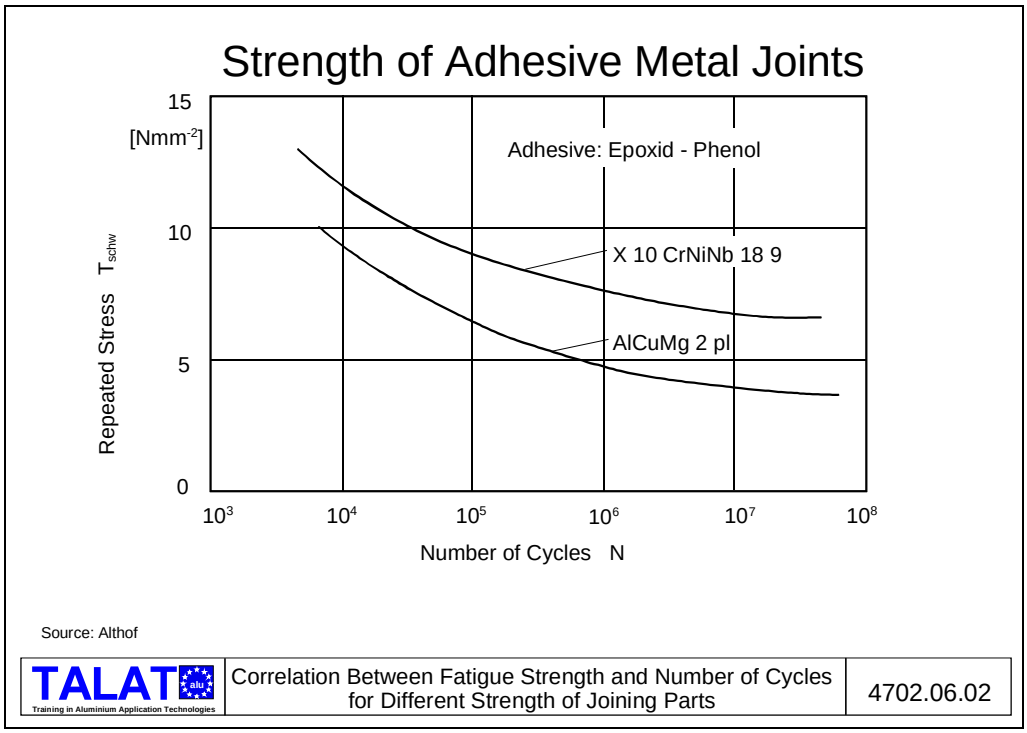
Adhesive joints with sufficient deformation capacity have a longer operational life than those with lower deformability. Fatigue strength increases with the static strength of the adhesive.

At 10^7 cycles, the fatigue strength is equal to about 14 % of the static short-time strength (**Figure 4702.06.01**).



Correlation between fatigue strength under repeated stress and a number of cycles for different strengths of joining parts

High-strength materials, adhesively joint, attain higher life-cycles under dynamic loading due to the slight deformation of the adhesive layer. This means that the stress peaks are lower and the load distribution is more favourable (**Figure 4702.06.02**).



4702.07 Literature/References

1. **Habenicht, G.:** Kleben. Springer-Verlag Berlin-Heidelberg-New York 1990.
2. **Crocombe, A.D**. and **Adams, R.D.:** Influence of the spew fillet and other parameters on the stress distribution in the single lap joint. J.of Adhesion 13 (1981), pp. 141-155
3. **Dorn, L.** and **Liu, W.:** The stress state and failure properties of adhesive-bonded plastics/metal joints. Int. J. Adhesion and Adhesives Vol. 13 (1993), No.1, pp. 21-31
4. **Adams, R.D. , Coppendale, V., Mallick, Al-Hamdan, H.:** The effect of temperature on the strength of adhesive joints. Int. J. Adhesion and Adhesives Vol. 12 (1992), No.3, pp.185-190
5. **Bigwood, D.A.** and **A.D. Crocombe:** Non-linear adhesive bonded joint design analyses. Int. J. Adhesion and Adhesives Vol. 10 (1990), No.1, pp. 31-41
6. **Minford, J.D.:** Adhesives. In: Durability of Structural Adhesives, Applied Science Publishers, New York and London 1983, pp. 135-214
7. **Matting, A.** und **Draugelates, U.:** Die Schwingfestigkeit von Metallklebverbindungen. Adhäsion 12 (1968), H. 1, S. 5-22; H. 3, S. 110-134, H. 4, S. 161-176.
8. **Eichhorn, F.** und **Stockhausen, G.:** Langzeit- und Alterungsverhalten hochwertiger Schmelzklebverbindungen von Metallen. AIF-Abschlußbericht Nr. 5234, Aachen 1984.
9. **Hahn, O.** und **Wender, B.:** Beanspruchungsanalyse von geometrisch und werkstoffmechanisch „unsymmetrischen“ Metallklebverbindungen mit der Finite-Elemente-Methode. Forschungsbericht des Landes NRW, Nr. 3187. Westdeutscher Verlag, Opladen 1984.
10. **Brockmann, W.:** Grundlagen und Stand der Metallklebtechnik. VDI-Verlag, Düsseldorf 1971.
11. **Matz, C.:** Klärung der adhäsiven Bindungsmechanismen von strukturellen Aluminium-Klebverbindungen. Forschungsbericht (LFF 8350 6) des BMFT, 1985
12. **Brockmann, W., Hennemann, O.-D., Kollek, H.** und **Matz, C.:** Adhäsion in Aluminiumklebungen des Flugzeugbaus. Adhäsion 30 (1986) H. 7/8, S. 31-38; H. 9, S. 24-35; H.10, S. 20-35.
13. **Althof, W.:** Festigkeit von Metallklebverbindungen bei schwingender Beanspruchung. DFBO-Mitt. 19 (1968) 5, S. 48-51.

4702.08 List of Figures