

Subsequent Mounting Of Brackets To Coated And Uncoated Surfaces Using Adhesives

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ABSTRACT

As part of a nationally-funded German research project, a new mounting procedure for maritime and offshore environments using adhesives has been developed and tested in laboratory and field applications.

Based on a benchmark study, suitable adhesive materials and surface preparation methods were evaluated. Furthermore, representative loading cases and environmental conditions were determined. Loading scenarios included tensile tests, shear tests, torsion tests, creepage, and fatigue tests. Specimens were tested under unaged conditions and aged conditions, whereby the aging procedures included temperature changes, humidity, and neutral salt spray tests. Six different metals/coating materials were tested as substrates for adhesive application. Metals included construction steel, stainless steel, and aluminum, whereas the coating materials covered epoxy, polyurethane, and polysiloxane.

The paper reports the details of testing and the results obtained for the different testing scenarios.

Keywords: adhesives, coating, corrosion, marine, offshore, shipbuilding

INTRODUCTION

Welding for subsequent mounting of brackets onto fully coated surfaces (for example repair purposes, modification of equipment or subsequent fittings) raises a number of problems with respect to surface preparation, coating integrity, post-processing, heat transformation, esthetics, and health and safety. Two examples for subsequently welded holders onto coated surfaces along with the accompanying coating damages are provided in Fig. 1. An option for joining brackets is the use of mechanical fasteners. However, this solution often requires the drilling of pre-holes. This, in turn, leads to sealing problems, risk of corrosion and the reduction of the notch class.¹

In order to reduce costs and working time and not compromise the existing corrosion protection system, a standardized procedure using high-performance adhesives has been developed. Brackets, and any attachments, are mounted directly to the topcoat without harming the coating or substrate. Part of the process is a non-destructive pre-evaluation test that verifies the required adhesion to the particular coating system.

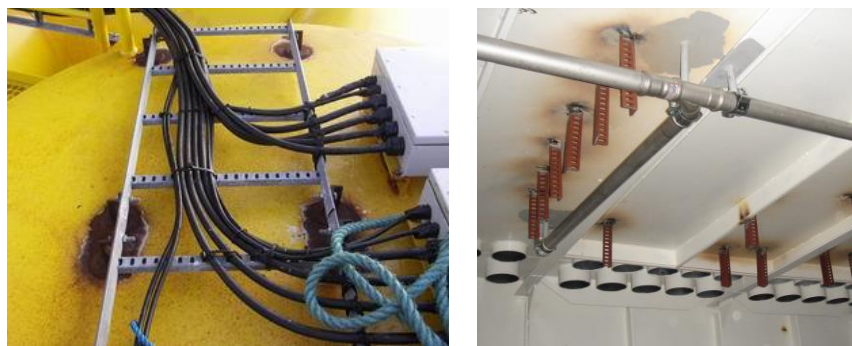


Figure 1: Subsequently welded holders on marine structures (Muehlhan AG, Hamburg)
Left: cable trace on an offshore platform (external); right: fixtures in an engine room (internal)

Long-term stability of adhesives is an important aspect when investigating bondings. Of particular interest is the water/moisture absorption of polymer-based adhesives and the accompanying property modifications. This is one of the main reasons for the failure of adhesive bondings during their lifetime.^{2,3} In addition to water absorption, other factors, such as temperature levels, temperature fluctuations, high humidity, and salts, affect the long-term properties of adhesive bondings in marine environments.⁴

Another aspect is aging and the effect of aging on the performance of adhesive bonds. In order to simulate corrosive aging as a major deterioration mechanism, a neutral salt spray test is recommended. With reference to moisture/humidity as an additional critical exposure mechanism, the climate change test “VW PV 1200” can be used.⁵ Equally important, permanent static loads that cause creeping of the polymer and mechanical static and dynamic loads are of high relevance for the service life of bonded joints.^{6,7}

EXPERIMENTAL PROCEDURE

Requirements

Table 1 lists the requirements of an adhesively bonded bracket system for the application and performance under marine and offshore conditions.

Table 1: Requirements for adhesively bonded bracket design

Attribute	Requirement
Bonding surface	Reproducible
Adhesive film thickness	Reproducible
Injection method	Failsafe, complete surface wetting
Corrosion resistance class (CRC)	CRC III or better (DIN EN 1993-1-4:2015-10) ⁸
Availability	Commercially available
Weldability	Good
Standardized bracket	Easily combinable with a wide range of standard attachments

Materials and sample preparation

For testing, the adhesively bonded brackets were applied to six different substrates. In order to cover typical material combinations for marine services, a number of metal substrates and coating materials were considered (Fig. 2). Metal substrate materials included the following (Fig. 3a):

- construction steel (1.0976);
- stainless steel (1.4571);
- Aluminum (AlMg3).

With respect to coating substrate materials, the following materials were considered (Fig. 3a):

- epoxy (mainly for internal structural parts)⁹;
- polyurethane (typical topcoats for external structures)⁹;
- polysiloxane (alternative topcoats for external structures)⁹.

Unaged coated surfaces were chosen as a worst case scenario for the adhesive application since newly applied coatings often continue to release residues of remaining solvents. These can have a negative impact on the adhesion. For aged coatings this problem is less likely to appear, only the remaining adhesion to the surface has to be ensured through testing prior to the application.

The base plates for all coating substrate samples were 100 x 100 x 5 mm S355MC plates (typical steel for offshore constructions). To account for sufficient mechanical stability during static testing, the material thickness for aluminum was increased to 10 mm. All metal substrates were blast cleaned to Sa 2½ according to DIN EN ISO 8501-1¹⁰. Table 3 provides information on sample design and preparation.

The adhesive material was a soft accelerated 1-component polyurethane; its key properties are provided in Table 2. The thickness of the adhesive layer was 3.0 mm; it was accurately maintained due to the given thickness of the sealer ring. The adhesion-promoting agent was a pigmented solvent-free polyurethane material.

Table 2: Adhesive properties

Parameter	Value
Glass transition temperature in °C	-54.8
Volume change	1.0%
Shore A hardness	55
Elongation	500%
Tensile strength	6.0 MPa
Shear strength	4.5 MPa

The coated samples were cleaned with a solvent-based cleaner. The brackets were applied and fixed using a tape. Finally, the adhesive was injected through one of the injection holes into the adhesive chamber between the substrate and bracket.

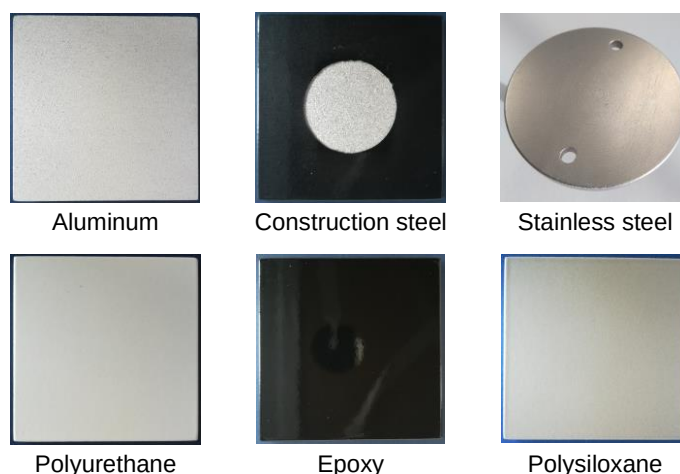


Figure 2: Substrate types investigated in the study

Table 3: Sample design and preparation (see also Fig. 3)

Substrate	Designation	Surface preparation	Interfacial primer	Coating system
Aluminum	Alu	Sa 2½	Yes (epoxy-based)	-
Construction steel	Steel			1. 2 x 125 µm epoxy 2. Partially decoated ¹⁾
Stainless steel	SS			-
Polyurethane	PU			1. 2 x 125 µm epoxy 2. 1 x 60 µm polyurethane
Epoxy	EP			1. 2 x 125 µm epoxy
Polysiloxane	PSX			1. 2 x 125 µm epoxy 2. 1 x 125 µm polysiloxane

¹⁾ See Fig. 2, the upper center image

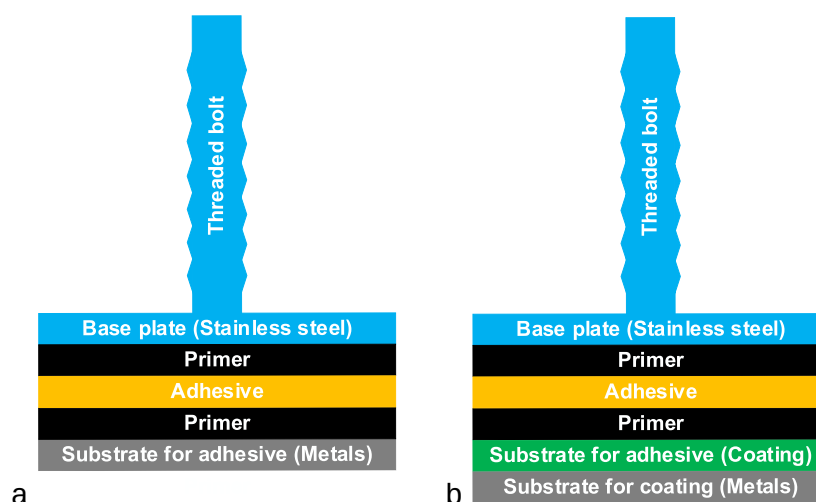


Figure 3: Configuration of the adhesive bond for metal and coated substrates
a) Adhesive bond on the metal substrate; b) Adhesive bond on coating substrate

Figure 3 schematizes the configurations of the two groups of substrates: Figure 3a illustrates the application of the adhesive directly onto metal substrates and Fig. 3b illustrates the application of the adhesive onto coating substrates. An (interfacial) primer was applied in both cases to ensure sufficient adhesion and durability of the adhesive bond.

Thermal-mechanical analyses

To account for sufficient mechanical stability of the coating substrate materials also during aging testing with temperatures exceeding norm conditions, Differential Scanning Calorimetry (DSC) was applied (DIN EN ISO 11357)¹¹. DSC is a thermo-analytical technique in which the difference in the amount of heat required to increase the temperature of a sample with respect to a reference is measured as a

function of temperature. The glass transition temperature is one important parameter derived from the results.

In order to receive further information about the adhesive material, Dynamic Mechanical Analysis (DMA) was performed (DIN EN ISO 6721)¹². DMA is a rheological method used to measure the viscoelastic performances of polymeric systems. A thin wafer of adhesive is placed between two metal shafts. During the analysis, the bottom shaft oscillates slightly while the top shaft measures the amount of energy transmitted through the sample.

Static tests

The following static tests were performed:

- tensile strength testing (DIN EN ISO 4624)¹³;
- shear strength testing;
- torsion testing;
- creep testing (DIN EN 15336)¹⁴.

Because the complete bracket configuration was supposed to be tested as a whole (see highlighted sections in Figure 4), modified testing procedures, partly based on existing testing guidelines, were developed. The setup for tensile testing and shear strength testing can be seen in Figure 4. The bracket configuration was loaded until failure occurred to one of the components (substrate, adhesive, bracket). The pull-rate was set to 10 mm/min with a pre-load force of 100 N. Samples were tested at room temperature with six replications each to ensure a conclusive statistical analysis.

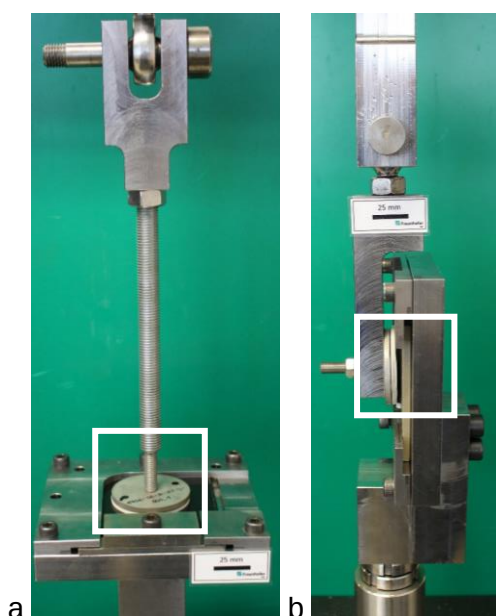


Figure 4: Test setups for static testing (bracket configuration is highlighted)

a) Tensile strength testing; b) Shear strength testing