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SIMULATION MODELS OF BONDED JOINTS AND THEIR EXPERIMENTAL VALIDATION

SIMULAČNÍ MODELY LEPENÝCH SPOJŮ A JEJICH EXPERIMENTÁLNÍ VALIDACE

Abstract

The identification method of adhesives material properties for numerical simulation (MSC.Nastran) is described in this article. There result of experimental validation for different test samples is also described. There is also described some physical appearance of bonded joints which is difficult to simulate in current software.

Abstrakt

Tento příspěvek popisuje postup, jakým lze určovat materiálové konstanty lepidel používaných v automobilovém průmyslu pro numerické simulace (v MSC.Nastran). Jeho součástí jsou výsledky validací na různých typech zkušebních vzorků i přehled jevů, které lze jen obtížně simulovat.

1 INTRODUCTION

The motivation of this project was to find easy method for obtaining material properties of the adhesives used in the automotive industry. Simulation models of different bonded joints geometry were designed and validate with realized experiments.

There were realized 3 different groups of the sample geometry:

1) Test sample suitable for obtaining material properties and for tuning nonlinear material model
2) Test sample suitable for model validation with experiments
3) Test sample not experimentally realized or unable to simulate

2 USED TEST SAMPLES

2.1 Samples for material properties identification

- Tensile test according to EN ISO 527-1 (Dog bones)

There is pure tensile loading by this test. It's easy to specify Young's modulus (E), yield stress and tensile strength, stress-strain curve or Poisson's ratio (μ).

Homogeneity of specimens is important for correct specifying of tensile strength. Bubbles cause local stress concentration and early destruction, especially near to surface.

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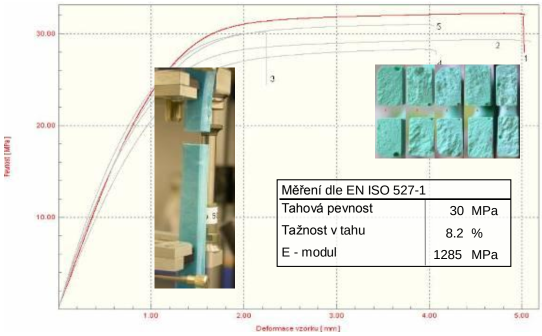

Fig. 1 Tensile Test - Stress strain curve of adhesive Betamate 1496V

- Shear test – torsion of tubular cylinders.

This specimen was designed to achieve pure shear loading of the adhesive. It was used for multiparametric nonlinear material model tuning above all. It's important to reflect stiffness of substrate (metal tubes) by evaluation.

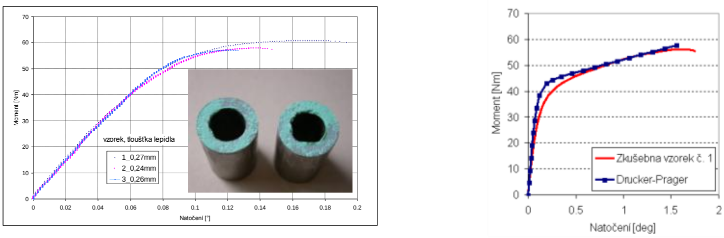

Fig. 2 Tubular cylinders. Torque – angle characteristic for BM 1496V, Experiment/Simulation results

2.2 Samples for simulation models validation

- Tensile test according to EN 26922 – rigid shafts

There is homogeneous 3-axial stress in most volume of the adhesive. Only on the border of bonded area is combined loading. Tests on the specimens with small thickness (less then 1 mm) haven't good repeatability. Measurement of deformations on these samples could be inaccurate because of high stiffness of specimen.

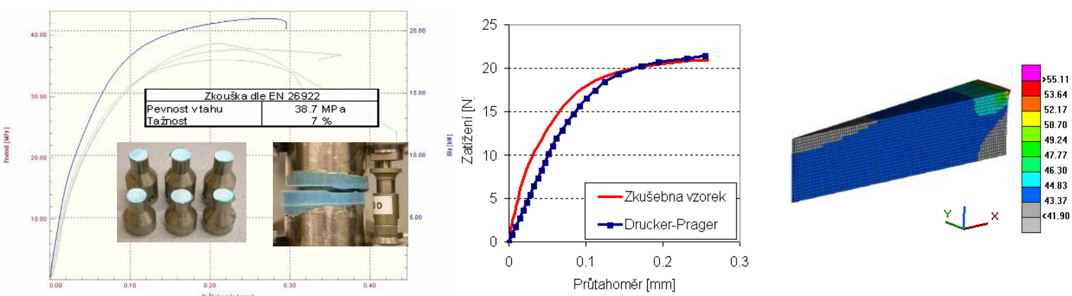

Fig. 3 Stress strain curve for rigid shafts specimen, Experiment/ Simulation results

Shear test according to EN ISO 1465

There were more variants of shear tests on overlap joints specimens according to EN ISO 1465:

With stiff substrate (Docol DP1200) - There was achieved satisfactory congruence of measurement and simulation in linear part, but the simulation model doesn't satisfactorily describe behavior behind yield point. It could be caused by disagreement of simulation model and test in stress at front face of adhesive.

With relatively softer substrate (H220 PD+Z) – Correct simulation of nonlinear behavior of substrate lead to satisfactory congruence of whole specimen.

The double overlap joint – it doesn't satisfy expectations. Measured stiffness wasn't twice higher then by common specimen despite of double bonded areas. It could be caused by imperfect symmetry of the specimens.

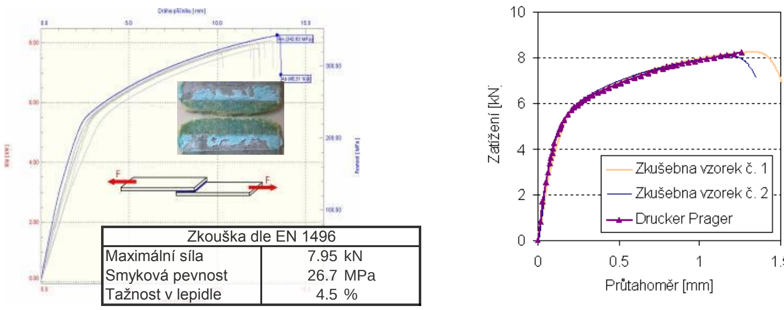

Fig. 4 Overlap joint. Stress strain curve Betamate 1496V . Experiment/Simulation results

2.3 Test sample not experimentally realized or unable to simulate

- Cup samples

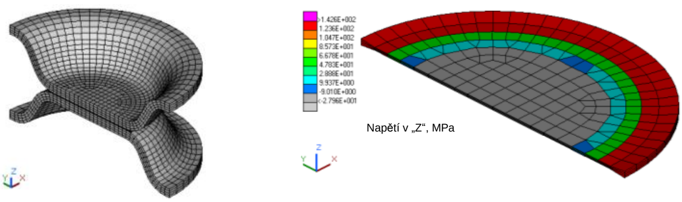

Fig. 5 Cup samples – shape of simulation models

These specimens were not realized because of complicated preparation. Simulations show that there isn't pure loading and it would be possible to use them only for simulation models checking.

- Tensile test – cross joint according to ČSN EN 14272

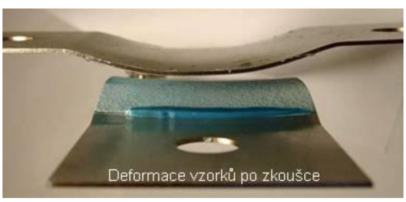

Fig. 6 Tensile cross joint – experiment sample after the test

Crack propagation from corners to middle of bonded area is typical for this test and it's impossible to simulate this test without model of failure. The tests were done without the extensometer so we miss the data for comparison behaviour before crack initialization.

- Peeling test on T-joint according to ČSN EN 14173

Simulation was not successful because of the same reason like by cross joint.

3 CONCLUSIONS

Tab. 1 Overview of strength limit for different type of loading and different samples

Type of samples – description		**BM1496 V** [MPa]	**BM 5103_2** [MPa]
Tensile test (dog bones)		30	40
Tensile test (rigid shafts)	Bonded joints thickness 0.6 mm	41.6	-
	Bonded joints thickness 5 mm	38.7	-
Shear test (single overlap joints)	samples Docol DP1200, 4 mm overlap	34.3	-
Shear test (double overlap joints)	samples Docol DP1200, 4 mm overlap	26.1	-
Shear test (tubular cylinders)	*Maximal nominal stress*	34.7	34.7
	Theoretical stress on the outside fibre	41.7	41.7
Shear test (overlap joints) Samples H220 PD+Z , 1mm	Overlap 12.5 mm	26.7	-
	Overlap 4-20 mm	40 - 18	-
		26 - 16	-
	Overlap 8-70 mm	-	20 - 7

The tested adhesives have similar strength for miscellaneous loading, if stiffness of substrate is sufficient; although the computed strengths are influenced by local stresses concentrates and their influences are different for each type of specimen. The test specimens with softer substrate have lower strength because importance of local stress concentrations is higher. It's obvious by tests of overlap joints with miscellaneous length of overlapping.

For simulation of bonded joints was chosen Drucker-Prager model from available material models in MSC.Nastran. Its parameters were tuned for 2 glues – BETAMATE 1496 V and BETAMATE 5103_2. There was achieved satisfactory congruence of measurement and simulation for some test specimen's.

The primal aim - to successfully simulate all possible loading of glues with tuned material model - wasn't realized. One of reasons could be fact, that simulations don't include important properties of glues like influence of strain rate or repetitive loading. On the other side tuned Drucker-Prager material model gives significant improvement in comparison with common Von Mises model.

Reviewer: MSc. Zdeněk PORUBA, Ph.D., VŠB - Technical University of Ostrava