OPTIMIZATION OF SURFACE TREATMENT PARAMETERS IN ADHESIVE BONDING TECHNOLOGY

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Abstract. A bonding technology is developed and is improved forever thanks to the technical scientific progress. This technology distinguishes itself as well as other technologies of connecting for many advantages but at the same time for negative and limiting factors, too, which can influence a trouble-free use of adhesive bonds. When deciding whether the bonding technology use or not it is necessary to review particular pros and cons, which the bonding offers compared with other methods of connecting. The strength of the adhesive bond is determined by an adhesion between adhesive and contacted surfaces and also by cohesion of an adhesive layer. A surface of metal substrates are often covered with an oxides layer which is necessary to be removed mechanically e.g. by grinding or blasting. Without these treatments we cannot reach good bond not even we use the best adhesives.

Keywords: adhesive bond, optimization, roughness, surface pre-treatment, testing.

Introduction

Thanks to unremitting technical-scientifical progress the bonding technology is still developed and improved. This technology as other technologies of connecting is noted for many advantages, but at the same time for negative factors, which can influence the trouble-free use of adhesive bonded joints. When deciding of the use of bonding technology it is necessary to review pros and cons, which the bonding offers compared with other methods of connecting.

The adhesive bond strength is determined by the adhesion between adhesive and part surfaces, but by the cohesion of the adhesive layer after curing, too. Adhesion is influenced by the surface treatment. The surface treatment before the bonding is one of most important operations of the bonded joint creation. The ideal conditions determination for the maximal adherend wettability by an adhesive is the aim of the procedure.

The adhesion is based on the idea of the adhesive penetration in the caverns, pores and surface roughness. In this way the mechanical bond after curing is created. It follows from this idea that the adhesion level depends partially on the bonded surface properties. It is necessary to secure the suitable shape, roughness and surface cleanness. Without the suitable surface treatment the satisfactory bonded joint quality cannot be reached.

The majority of untreated surfaces includes relatively small, in shape unsuitable unevenesses. But already simple ragging is often advantageous. It magnifies the effective surface, it means the surface really wetted by the adhesive. Owing to the ragging the bond strength increases [3].

Further solid impurities, scales, smear, corrosion products and other substances must be removed. They reduce the joint quality. The surface must be without all substances, layers and unevennesses which worsen the adhesion. Generally the surface treatment can include physical of chemical operations, whose number is countless.

The adhesive must fill in the molecular distance of the mechanical treated surface unevennesses of the bonded material. The rate of the by the adhesive covered surface depends on its viscosity, cleanness, shape and slope of unevennesses.

Methods of bonded surface evaluation

The evaluation of the steel (S235J0) and duralumin (AlCu4Mg) surfaces mechanical treatment was the aim of the laboratory tests. The microstructure of steel and duralumin surfaces is shown in Fig. 1 and 2. Table 1 presents the chemical composition of bonded specimens. The tested specimens surface was grinded using the abrasive cloth of grids 40, 100, 150, 240, 320 and 400. The direction of grinding was normal to the tensile force. Before measuring the specimens were rinsed in perchlorethylene.

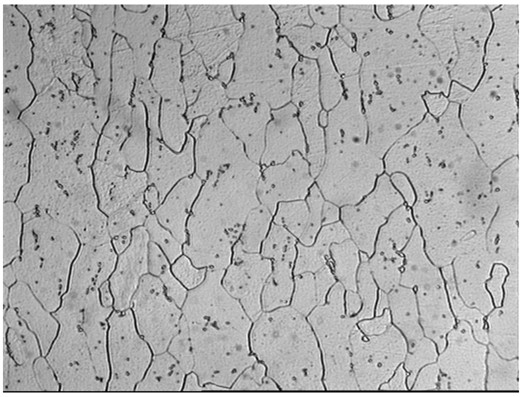

Fig. 1. **Microstructure of the steel specimen:** ferrite with here and there tertiary cemented (Nital 500x magnified)

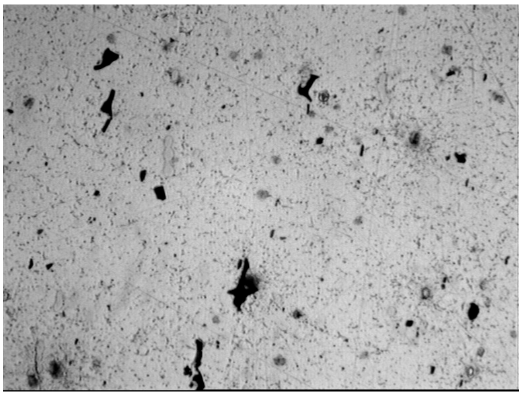

Fig. 2. **Microstructure of the duralumin specimen:** solid solution α with particles of the stiffening phase uAl_2 and with sulfur inclusions – annealed (HF, 500 x magnified)

Table 1

Chemical composition of bonded specimens

Specimen	**C, %**	**Mn, %**	**Cr, %**	**Ni, %**	**Al, %**	**Cu, %**	**Nb, %**	**Ti, %**	**Fe, %**	**Si, %**	**Mg, %**	**Zn, %**
Steel	0.047	0.240	0.076	0.017	0.065	0.039	0.007	0.016	99.500	-	-	-
Duralumin	-	0.510	0.003	0.003	93.197	5.012	-	0.013	0.304	0.350	0.571	0.014

To reach objective values of the bonded surface roughness it is necessary to use above all the stylus instruments. Modern profilometers make possible the easy setting and measuring. For tests the profilometer Surftest 301 was used. The surface texture is detected by the stylus. From the stylus motion the surface texture parameters are computed. For the measuring the use of the correct cut-off value setting is important. The value 0.8 was used as the value most used for heterogeneous materials. The surface roughness was measured in 5 points of each specimen (Fig. 3). Following parameters were determined: Ra – the arithmetic mean of the departures of the profile from the mean line, Rt – the maximum peak-to-valley height within the assessment length, Rz – the average of the maximum peak-to-valley length of five consecutive sampling lengths [6].

After the mechanical treatment of bonded surfaces the specimens were bonded and tested according to the standard CSN EN 1465. The substance of this standard is the determination of tensile lap-shear strength of rigid-to-rigid bonded assemblies. The tensile force acts parallel with the bonded surfaces and with the principal axis of the assembly till to the failure. The test assemblies are made by bonding of two specimens of sizes 100x25x1.5 mm. The recommended lap length is 12.5 mm [4].

Five adhesives were tested: Bison epoxy metal (Bm), Bison epoxy universal (Bu), Lepox (L), Alteco 4 min (A4) and UHU plus sofort fest 2 min (U2). After curing the destructive testing and the bonded joints strength evaluation followed. The tests were carried out using the universal tensile-strength testing machine ZDM 5.

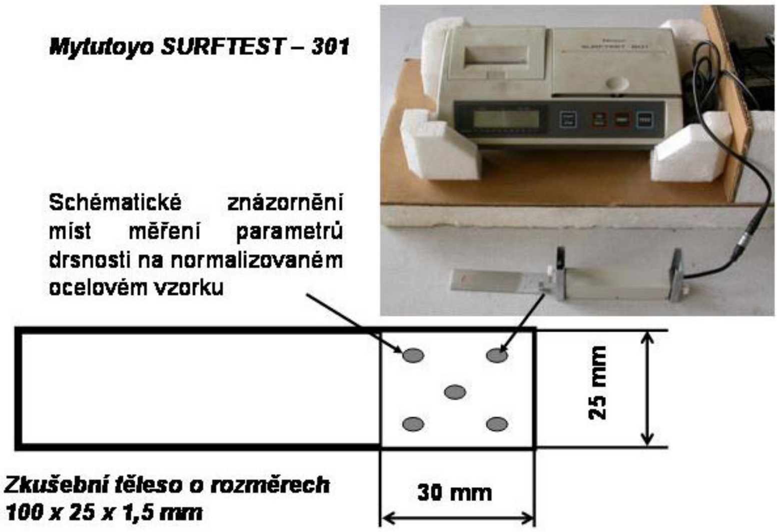

Fig. 3. **Measuring of surface roughness**

Test results

At first the influence of roughness parameters (Ra, Rz, Rt) was watched in dependence on the abrasive cloth grit and on the grinded material. The arithmetic mean of measured values is presented in Table 2. From measured values the considerable influence of the abrasive grit is perceptible. With the decrease of the grain fineness the gradual decrease of roughness parameters occurred.

Table 2

Roughness parameters values

Grit of the abrasive cloth	Average grain size, µm [5]	Steel S235JO			Duralumin AlCu4Mg		
		R_a, µm	R_t, µm	R_z, µm	R_a, µm	R_t, µm	R_z, µm
40	462	2.40	23.41	16.55	5.08	38.13	27.51
100	138	1.27	14.87	9.83	2.12	18.93	13.74
150	98	0.76	8.04	5.73	1.54	14.69	10.78
240	45	0.62	7.91	4.89	1.26	12.46	9.12
320	29	0.59	6.22	4.38	1.17	10.92	8.03
400	17	0.58	4.60	3.23	0.75	7.14	5.29

Roughness parameters values of duralumin are higher in comparison of the ones of steel. The dependence course, shown for Ra in Fig. 4 and for Rt, Rz in Fig. 5 is expressed by the logarithmic function. Next the determination index R2 for the given dependence between the roughness parameters and the abrasive cloth grit is presented.

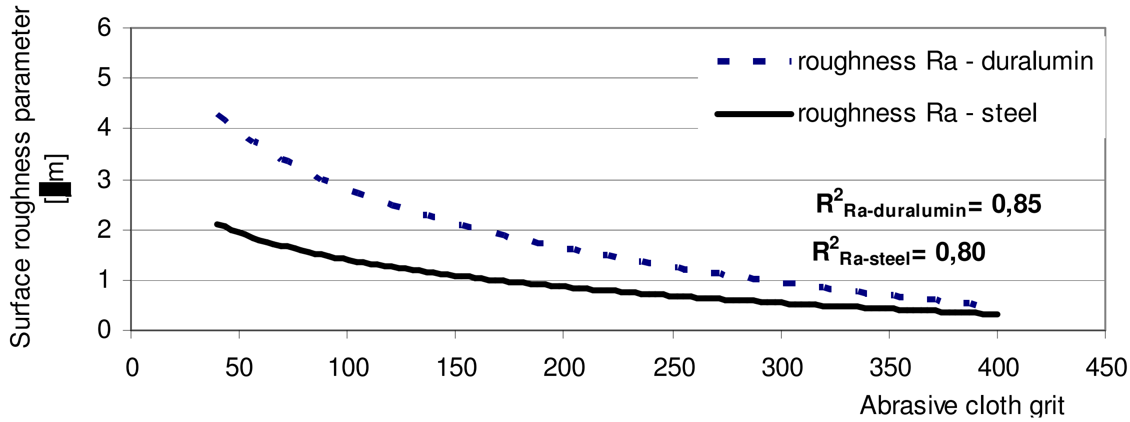

Fig. 4. **Relation between abrasive cloth grit and parameter Ra**

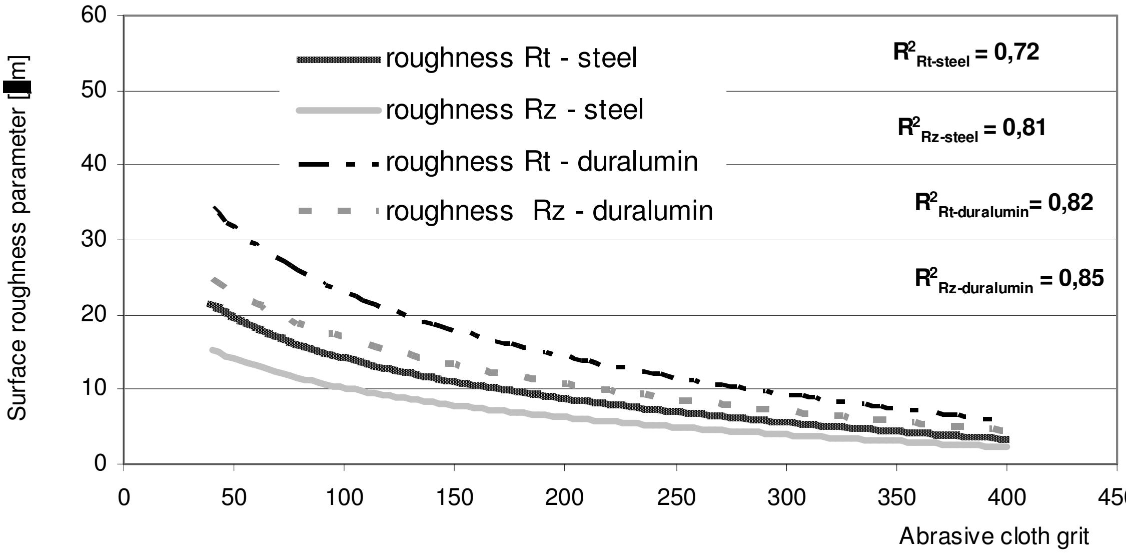

Fig. 5. **Relation between abrasive cloth grit and parameters Rt and Rz**

The bonded joints were destructively tested using the universal tensile-strength testing machine. Tables 3 and 4 present the arithmetic means of the calculated bonded joints strengths. The strength results show the evident influence of the various mechanical treatment of the bonded surfaces.

Table 3

Strength values of single adhesives – steel

Abrasive cloth grit	Steel				
	Symbol of the adhesive				
	Bm, MPa	Bu, MPa	L, MPa	A4, MPa	U2, MPa
40	18.95 ± 1.05	19.91 ± 1.10	8.06 ± 0.73	10.52 ± 0.22	5.99 ± 0.19
100	19.33 ± 0.40	20.05 ± 0.20	9.68 ± 0.62	12.25 ± 0.18	6.16 ± 0.40
150	17.81 ± 0.80	18.07 ± 1.08	9.35 ± 0.65	9.93 ± 0.17	5.04 ± 0.35
240	16.84 ± 0.83	17.62 ± 0.84	8.03 ± 0.56	10.93 ± 0.47	3.74 ± 0.30
320	16.36 ± 0.86	17.18 ± 0.90	9.20 ± 0.55	11.53 ± 0.39	4.41 ± 0.31
400	17.03 ± 0.33	17.08 ± 0.34	9.09 ± 0.49	11.08 ± 0.15	2.94 ± 0.58

Table 4

Strength values of single adhesives – duralumin

Abrasive cloth grit	Duralumin				
	Symbol of the adhesive				
	Bm, MPa	Bu, MPa	L, MPa	A4, MPa	U2, MPa
40	13.52 ±2.05	15.15 ± 0.97	8.24 ± 0.27	6.34 ± 0.36	2.88 ± 0.07
100	15.19 ± 1.04	15.96 ± 1.09	10.14 ± 0.27	5.98 ± 0.31	2.86 ± 0.13
150	18.04 ± 0.86	18.95 ± 0.90	8.81 ± 0.60	6.64 ± 0.25	3.46 ± 0.27
240	18.70 ± 0.58	19.64 ± 0.66	12.36 ± 0.45	7.23 ± 0.18	3.11 ± 0.16
320	18.69 ± 0.49	19.64 ± 0.51	10.27 ± 1.08	6.46 ± 0.37	3.19 ± 0.54
400	16.79 ± 0.92	17.63 ± 0.96	10.36 ± 0.68	6.06 ± 0.73	2.96 ± 0.34

The surface failure was reviewed together with the adhesive bond strength. The cohesion failure occurred in almost all adhesive bonds. The Fig. 6 shows the cohesion surface failure and the distance wire.

Fig. 6. **Cohesion surface failure and distance wire after the perfect curing**

On the Fig. 7 and 8, you can see the influence of optimum and non suitable surface treatment. When using the no suitable treatment, the adhesive bond strength decreases significantly.

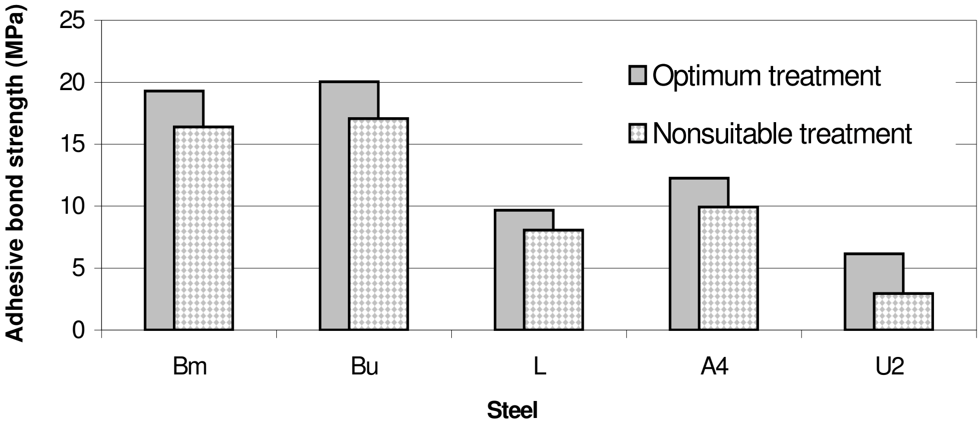

Fig. 7. **Comparing of optimum and unsuitable mechanical treatment of adhesive bond surface**

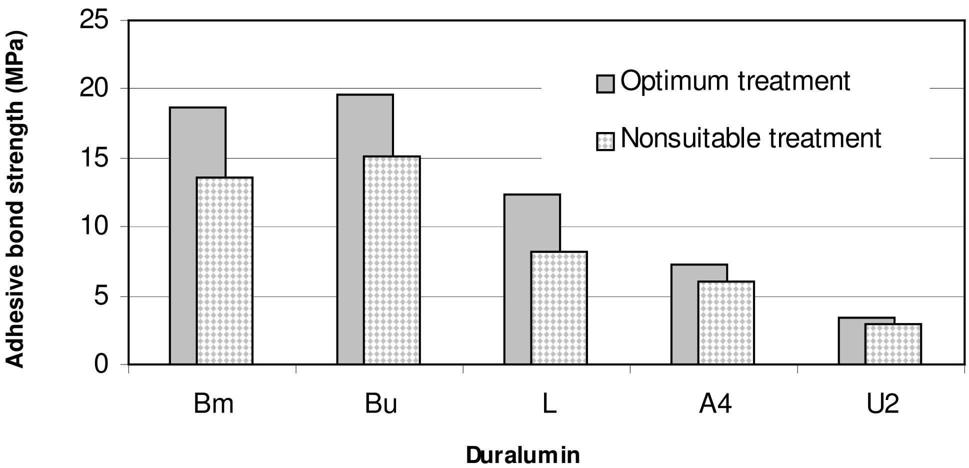

Fig. 8. **Comparing of optimum and unsuitable mechanical treatment of adhesive bond surface**

Conclusions

The bonded surface treatment is one of the specific factors for the bonded joint strength. From tests it is possible to come to a conclusion that it is not possible to determine only a mechanical treatment, but it is necessary to determine the concrete treatment. The use of an occidental abrasive cloth grit for the bonded surface mechanical treatment does not guarantee the optimal bonded joint strength. Using the unsuitable mechanical treatment the loss in tensile strength of steel bonded joints on an average 23.7 %, of duralumin bonded joints 23.6 % occurred.

As the optimal treatment at bonding steel the use of the abrasive cloth of grit 100 was evaluated. The roughness parameters were Ra 1.27 µm, Rt 14.87 µm and Rz 9.83 µm. Bonding duralumin the suitable abrasive cloth grit was 240, only in one case it was the grit 150. Using the grit 240 the roughness parameters were Ra 1.26 µm, Rt 12.46 µm and Rz 9.12 µm. The optimal surface roughness values of steel and duralumin were nearly identical although they were reached using different abrasive cloth grit. It is caused by different mechanical properties of grinded materials. Grinding duralumin higher wear occurred.

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