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EVALUATION OF DEFORMATIONS OF THICK-LAYER GLUED JOINTS APPLIED IN CONSTRUCTION OF RAIL VEHICLES

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Abstract: *This paper presents the measurement results of deformations of glued joints applied in construction of rail vehicles. The joint materials and technology of making used were the same as in the technological process used in the manufacturing of such vehicles. The specimens prepared were divided into eight groups and subjected to different types of aging according to guidelines specified in regulations for examinations obligatorily performed by rail vehicle manufacturers. Measurements of deformations during shearing test of glued joint were performed. The results obtained exhibited the existence of impact of the way the glued joint ages on its properties. Different types of aging of specimens effect in the loss of joint strength and its deformability.*

Keywords: Glued joint, Rail vehicle, Aging of glued joints, Deformation of glued joints.

1. Introduction

Glued and welded joints are currently commonly applied in the construction of rail vehicles. The gluing technology has a number of benefits compared to welding or riveting. It allows to join elements made of different materials, of entirely different physical properties, shape, as well as of large differences in size. Gluing permits obtaining joints in which no installation stresses occur, which lowers internal tensions in large-size rail structures, including, among others, rail car bodies. One of the more frequent application of gluing technology in presently manufactured rail vehicles is fixture of external plastic or metallic plating to metal frame, and installation of internal equipment of cars. When fixing skin plates to the car framing, the glued joint must perform several functions. The primary function is stable and reliable joining of the elements. Another function is eliminating inaccuracies in making of the car framing, and adequate mutual amortization of the glued elements, so that any tensions from the framing occurring while driving are not transferred onto the car plating. For this reason, thick-layer glued joints are applied in framing-plating type connections. The joint obtained must feature adequate elasticity in order to correctly perform its functions. During operation of the vehicle, these types of joints are exposed to variable load, and to the effect of variable atmospheric conditions, including temperature, humidity, saltiness, sunlight. Therefore, the glues applied for these types of joints must feature resistance to the factors mentioned. Thus, the aim of this paper is to evaluate the elasticity of think-layer glued joints subjected to aging in conditions simulating real-world conditions to which these types of joints are exposed in rail vehicles. The paper presents the results of examinations of joints made of materials applied in constructing rail vehicles according to the technology used by their manufacturer.

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2. Methods

The material glued was a sheet of 1.6 mm thickness made of X2CrNi12 steel (PN-EN 10027-1: 2007). The shape of the specimen resulted from the guidelines of Standard PN-EN 1465:2009. Strips of length 100 and width 20 mm were cut from the sheet. The strips were ground with fine-grained sand paper (granulation 180), and then degreased (BETACLEAN 3350 degreaser) at the area to which the joint will be applied. Subsequently elements were cap by the primer BETAPRIME 1707B. Then, they were degreased BETACLEAN 3350 again. For gluing, the strips were placed in a special shape that ensures proper positioning of the plates relative to each other, and thus the required shape and dimensions of the joint (according guidelines of DVS 1618:2002). BETAMATE 7120 glue was used for gluing. Gluing was performed in strictly controlled conditions, i.e. 20 ºC temperature and 23 % humidity. Then, the specimens were left to dry for 7 days in the same conditions. The shape of a ready specimen is presented in Fig. 1. After aging, the specimens were kept for 2 hours in ambient temperature (DIN 54457), after which the tests were performed.

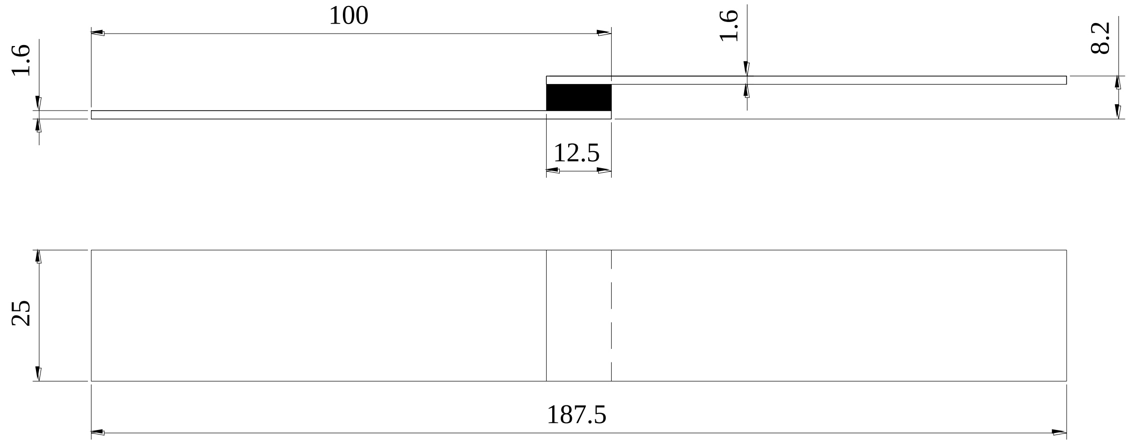

Fig. 1: Shape and dimensions of the specimen.

The specimen were aged according to the guidelines specified in DIN 54457 and DIN EN ISO 9142. Specimens aging methods are specified in Tab. 1. The specimens made were divided into eight groups. Five specimens were tested in each group.

Tab. 1: Specimens aging method.

Group number	Aging method	Number of specimens
G1	Specimens not aged	5
G2	Specimens stored for 1 week in water in 20º C temperature	5
G3	Specimens stored for 2 weeks in water in 20 ºC temperature	5
G4	Specimens stored for 3 weeks in water in 20 ºC temperature	5
G5	Specimens stored for 4 weeks in water in 20 ºC temperature	5
G6	Specimens stored for 1 week in water, and then for 1 day in 80 ºC temperature	5
G7	Specimens stored for 1 week in water in 20 ºC temperature, then tightly closed (using foil not permitting air and humidity) in 70 ºC temperature (so-called cataplasma test)	5
G8	Specimens stored for 1 week in water in 20 ºC temperature, and then for 1 day in -30 ºC temperature	5

Shearing test was performed on the joint using Instron E3000 testing device. Temperature during the test was 20 ºC, humidity 23 %. Test performance speed was set at 10 mm/min, based on the results of preliminary test on specimens of the same properties. Washers of adequate depth were used when fixing the specimens to the machine holders, to ensure action of the force along the joint. Force increases and elongation were registered at 10 Hz frequency.

3. Results

Fig. 2 presents average diagrams of the tested specimen groups (average diagram for the given group was equivalent to the averaged diagram for all specimens in the group). Tab. 2 presents average results for F_{max}(Av) force and elongation obtained for tensioning the specimens ΔL(Av) in individual groups, and values of standard deviation and relative standard deviation.

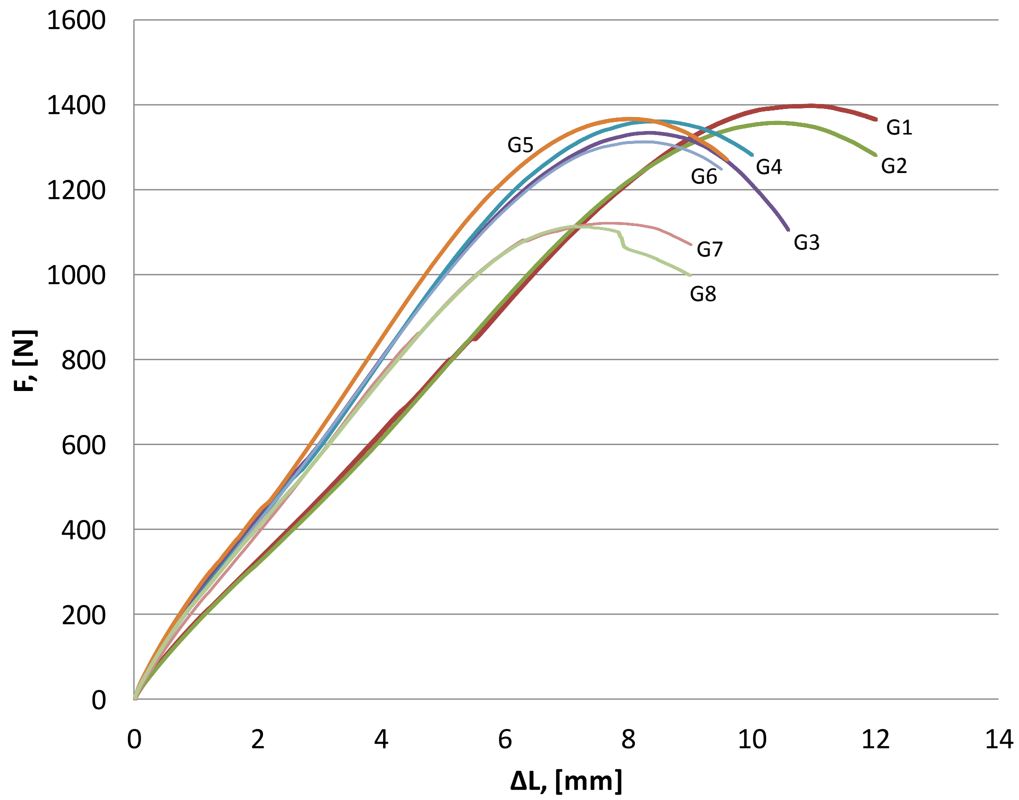

Fig. 2: Groups of specimens average diagrams.

Tab. 2: Average values of force and elongation obtained from tension test.

	G1	G2	G3	G4	G5	G6	G7	G8
F_{max}(Av)	1401.6	1361.5	1337.9	1365.1	1370.6	1316.5	1125.4	1118.7
SD	156.3	126.3	106.3	145.2	158.9	126.7	138.2	119.2
RSD	11.1	9.3	7.9	10.6	11.6	9.6	12.3	10.7
ΔL(Av)	10.968	10.395	8.332	8.518	7.989	8.289	7.604	7.129
SD	0.892	1.123	0.865	0.623	0.834	0.916	0.876	0.8125
RSD	8.1	10.8	10.4	7.3	10.4	11.0	11.5	11.4
SD – standard deviation, RSD – relative standard deviation								

4. Conclusions

The experimental tests performed on joints glued with BETAMATE 7120 glue in monotonic-variable stress conditions indicate that the aging process has an impact on the change of F_{max}

maximum force value and ΔL elongation. The highest value of forces occurs for those joint specimens that were not subjected to aging. The value of forces decreased in response to increasing the aging process time and changing its conditions. The lowest stress force value amounts to 79.8 % of the force value obtained for specimens not subjected to aging. For ΔL elongation, the highest value was obtained for groups 1 and 2 (the test results were similar). For the remaining specimen groups, ΔL values amounted to 65.0 % to 77.6 % of the deformation value for the glued joint specimens not subjected to aging.

It must also be noted that F = f(ΔL) correlation graphs for the specimens from group 1 and 2 exhibit different tension curve slope. The value of longitudinal elasticity modulus (Young's modulus) is lower than for the other specimens. The result obtained may be caused by absence of the aging effect on the glued joint. The changes identified may be important for performing numerical calculations for the strength of these types of joints.

The lowest values of breaking forces and elongation were obtained for specimens from groups 7 and 8. These results effect from the aging process leading to degradation of the glued joint in the area where the highest destructive stress occurs. Lap joints feature a complex stress condition resulting from shearing and tensioning loads.

The results obtained confirm the existence of an impact of ambient conditions on the elasticity of the glued joint examined. It its therefore necessary to limit the effect of those conditions on the glue joint. This is partly practicable. The joint may be covered with a layer of glue or paint, which protects it from the effect of humidity and sunlight. Also, adequate design of the glued joint may significantly limit the effect of those factors on the joint. It is more difficult to ensure proper temperature protection, however. The temperature difference outside and inside the vehicle, especially in winter conditions, may amount to tens of degrees, and lead to additional thermal stress on the joint. The joint will thus be exposed to overall stress resulting from movement of the vehicle, temperature differences, and - to a lesser degree - other factors.

The measurement results obtained will constitute basis for evaluating cyclic resistance of the joints tested. Based on the diagrams obtained, stress levels at which cyclic tests are to be performed will be determined in the next examination stage. The purpose of this examination will be to determine fatigue life of a joint subjected to different aging methods at different stress levels. Further examinations will conducted according to the requirements of PN_EN_15190-2009 standard: „Glues for structural joints. test methods for evaluating long-term fatigue life of glued structural joints of metals".

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