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Mechanical Behavior of PVC-U Window Elements Under Static Loads

Zlatka Geshkova*, Veselin Iliev, Petranka Naydenova

University of Chemical Technology and Metallurgy, Sofia, Bulgaria

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ABSTRACT

In the present work the results, obtained from a study on the mechanical behavior of the casement and sash window elements, made by unplasticized polyvinyl chloride (PVC-U), are presented. The study was conducted with three and five chamber profiles according to the EN 514:2018 standard. The results show that the fracture take a place by the cracks of mixed type - initiate at the welding and propagate in the material. A conclusion for the breaking force and deformation is presented for various values of the heating temperature and melting time. The results can be used for model selection and its parameters identification during numerical modeling of the fracture of the corner joints of the window frames.

Keywords: mechanical testing, window frames, corner joints.

INTRODUCTION

The properties that make unplasticized polyvinyl chloride (PVC-U) particularly suitable for the production of primary and secondary structure elements are its high stiffness, high strength and improved environmental resistance. Some values of the basic mechanical properties of this material can be found in the reference books and scientific and applied articles [1, 2]. However, the mechanical properties of unplasticized polyvinyl chloride change during the manufacturing process. The specific additives that are used by each manufacturing company, such as modifiers and stabilizers (anti-aging agents), make each particular material unique in terms of its mechanical properties [3 - 7].

In order to carry out the numerical experiments necessary to solve the set tasks and obtain reliable results, validation of the used models must be carried out [8, 9]. For this purpose, the model mechanical characteristics, assumed in the numerical experiments, must be the same as those of the real materials used in the laboratory experiments. This requires the preliminary

**Correspondence to: Zlatka Geshkova, University of Chemical Technology and Metallurgy, 8 Kliment Ohridski blvd., 1797 Sofia, Bulgaria, E-mail: geshkova@uctm.edu*

determination of the mechanical characteristics of the used materials by standard laboratory experiments [10].

In the present work, the products (window elements - casement and sash) of Weiss Profil Ltd.-Bulgaria, manufactured in the period 2019 (five-chamber casement and sash) and 2020 (six-chamber casement) were used as the basis of the numerical experiments. For these a detailed study of the mechanical behavior under static loads, caused by the conditions of service or of transport and storage, was carried out.

EXPERIMENTAL

For the purpose of the numerical experiment, a laboratory experimental study of the mechanical behavior of corner joints of the window elements was carried out. The examined elements were the case and the sash, made of unplasticized polyvinyl chloride (PVC-U) under a load causing dissolution of the joint with a positive bending moment. The study was conducted with three and five chamber profiles according to the EN 514:2018 standard. The test machine was a „soft“ type, in which the loading force is set by means of a hydraulic system and the deformation obtained in the specimen is taken into account. Twenty-seven specimens were used of frame and wing welded under different conditions (heating temperature and melting time). The experimental process consists of preparation of test specimens, loading to failure and analysis of the obtained results. The aim of the research is to establish the load under which cracking starts in the element and the ways of propagation of the crack. To measure the load, the machine is only equipped with a manometer, registering the pressure (in bar) creating the applied vertical force. This creates some difficulties because to compare the results of these laboratory experiments with the results of numerical experiments, the load needs to be recorded as a force measured in newtons. This requires the pressure gauge to be additionally tared. This was done by conducting a test in which the applied pressure was simultaneously read by the manometer and the force - by the force meter (1, Fig. 1). It was found that in the operational area of the machine a pressure of 0.2 bar registered on the manometer corresponds to a force of 1 KN. The general view of the test machine is given on Fig. 2. Welded sample 2 is placed on supports 3, which can move in a horizontal direction. The load is applied to the edge of the welded specimen by mandrel 4, which moves vertically downwards. In addition, the displacement of the mandrel is measured using a rod 5.

RESULTS AND DISCUSSION

Twelve welded specimens of three chamber casement and nine three-chamber sash specimens, welded at different heating element temperatures

Fig. 1. Force meter.

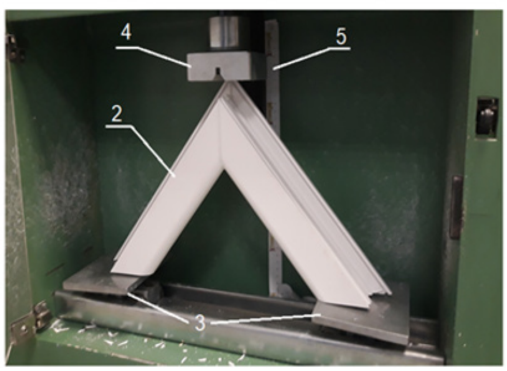

Fig. 2. Test machine.

(235°C, 240°C, 245°C and 250°C) and at different melting times (18 s, 20 s, 24 s), were investigated (Fig. 3). Additionally, three welded five-chamber casement specimens and three five-chamber sash specimens (Fig. 4) were tested at three different heating element temperatures (240°C, 245°C and 250°C) and at two different melting times (18 s and 20 s).

In Figs. 5 - 8 are shown the tested specimens loaded to fracture. From the obtained results, it can be concluded that the fracture proceeds by the formation of cracks. Most often, these cracks initiation at the welding point, starting along the weld seam and then propagation in the profile material (mixed type). Therefore, in the numerical modeling of this process, it is appropriate to use a "smart crack" type model. In the rare cases, as in three-chamber sash, the crack propagates along the weld seam until complete fracture. In this case, debonding models are suitable for describing the process. Numerical results for the deformations and applied forces at specimen fracture are presented in Tables 1 - 3. These results can be used to identify the parameters of the models used in the numerical modeling of the fracture of the corner joints of the window frames.

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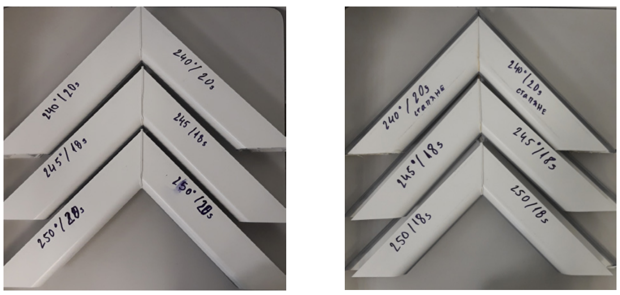

Fig. 3. Three-chamber casement and sash.

Fig. 4. Five-chamber casement and sash.

Fig. 5. Three-chamber Casement.

Fig. 6. Three-chamber Sash.

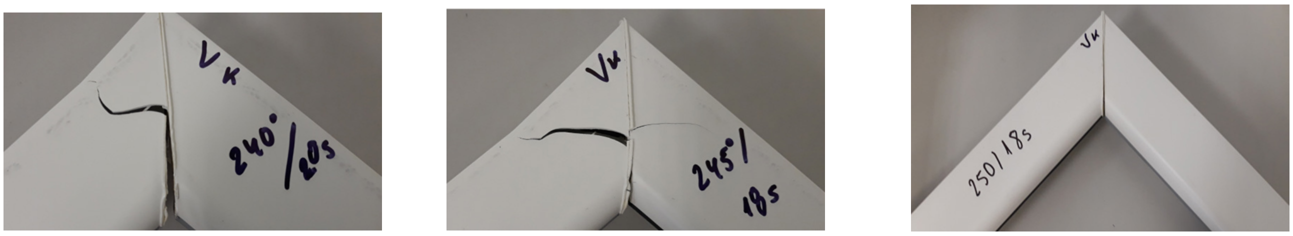

Fig. 7. Five-chamber Casement.

Fig. 8. Five-chamber Sash.

Table 1. Three chamber casement.

Temperature / Time	235°/18s			235°/24s			240°/20s	240°/24s			245°/18s	250°/18s
Number of tests	1	2	3	1	2	3	1	1	2	3	1	1
Report – start, mm	60	58	65	59	60	60	85	58	60	56	83	87
Report – end, mm	80	75	80	80	78	80	108	80	78	75	100	104
Displacement, mm	20	17	15	21	18	20	23	22	18	19	17	17
Pressure, bar	17	14	15	10	15	18	16	19	16	16	15	15
Force, KN	3.4	2.8	3	2	3	3.6	3.2	3.8	3.2	3.2	3	3

Table 2. Three chamber sash.

Temperature / Time	235°/18s			235°/24s			240°/20s	245°/18s	250°/18s
Number of tests	1	2	3	1	2	3	1	2	3
Report – start, mm	60	60	60	58	62	60	84	89	89
Report – end, mm	80	82	78	75	78	79	95	92	105
Displacement, mm	20	22	18	17	16	19	11	3	16
Pressure, bar	19	20	18	17	15	14	14	15	17
Force, KN	3.8	4	3.6	3.4	3	2.8	2.8	3	3.4

Table 3. Five-chamber casement and sash.

	Casement			Sash		
Temperature / Time	240°/20s	245°/18s	250°/18s	240°/20s	245°/18s	250°/18s
Number of tests	1	1	1	1	1	1
Report – start, mm	80	87	85	84	86	87
Report – end, mm	95	105	102	98	95	118
Displacement, mm	15	18	17	14	9	31
Pressure, bar	19	21	10	26	15	29
Force, KN	3.8	4.2	2	5.2	3	5.8

CONCLUSIONS

The results, obtained from test specimens loaded to fracture, show that the fracture take place by the formation of cracks. The cracks are of the mixed type - initiate at the welding and propagate in the material. The numerical results don't show large deviations for the breaking force and the breaking strain at different values of the weld characteristics. Differences are observed between the results for three-chamber and five-chamber window frames. With the three-chamber window frame, the breaking force is around 3.5 KN. With the five-chamber window frame, the breaking force at the casement reaches 4.2 KN and at the sash reaches 5.8 KN. The results can be used for model selection and its parameters identification during numerical modeling of the fracture of the corner joints of the window frames.

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