PAPER • **OPEN ACCESS**

Strength analysis of welded corners of PVC window profiles

To cite this article: P. Postawa *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **225** 012003

IOP Conf. Series: Materials Science and Engineering **225** (2017) 012003 doi:10.1088/1757-899X/225/1/012003

Strength analysis of welded corners of PVC window profiles

P. Postawa [1], **T. Stachowiak** [2], **A. Gnatowski** [3]
Production Editor, *IOP Conference Series: Materials Science and Engineering*,
IOP Publishing, Dirac House, Temple Back, Bristol BS1 6BE, UK

E-mail: postawa@ipp.pcz.pl, stachowiak@ipp.pcz.pl, gnatowski@ipp.pcz.pl

Abstract. The article presents the results of researches which main purpose was to define the influence of welding parameters on strength of welded corners of PVC window profile. PVC profiles of a branded name GENEO® produced by Rehau Company were used for this research. The profiles were made by using a co-extrusion method. The surface of the profile was made of PVC mixture with no additives. Its main task was to get a smooth surface resistant to a smudge. The use of an unfilled polyester provides an aesthetic look and improves the resistance of extrudate to water getting into inner layers. The profile's inner layers have been filled up with glass fibre in order to improve its stiffness and mechanical properties. Window frames with cut corners used for this research, were produced on technological line of EUROCOLOR Company based in Pyskowice (Poland). The main goal of this analysis was to evaluate the influence of the main welding parameter (temperature upsetting) on hardness of welds we received in whole process. A universal testing machine was used for the research.

1. Introduction

The welding process is one of the main technologies of combining elements made of polymers or metals used very often in many industrial branches. This technology is basically being used in combining sheets of metal during car production and also elements made of sheet steel. The last few years show more wider use of polymers in mechanical engineering and devices. Also, it seems more common to replace metals with polymers in motorization and building industry and to produce household goods. Processing parameters affecting the properties of the products are also important. Therefore the welding method of plastics is getting more popular and is being more enthusiastically used on the industrial scale [1-13].
It gives an opportunity to produce elements with more complicated shapes and also empty inside like fuel tanks, AdBlue products. Furthermore it allows quick merging of plastic elements with various technologies (profile's, sheet's amd foil's extrusion, etc.) [14-32].
Because of different properties received products of combined polymers and various characteristics of received welded joints we distinguish a dozen or so variety of plastic weldings. They vary with primary physical elements of generating heat in connecton with welding joint and welded accessories being used.

The strenght of welded joint depends on a vary factors like:
- surface preparation
- properties of welded materials (the differences between the melting temperature or softening temperature values)
- the adequate selection of combined materials,
- and other factors depending on method and type of combining materials.

The main purpose of this researches was to determine an influence of welded window profiles parameters on the endurance of received joint. The window profile was made of PVC and the researches was based on PN-EN 514: 2000 norm. Starting point to this deliberation was welding temperature (temperature of welded sheets used in the process) that was equal 250 ºC. The usage of the lower temperature would have allowed saving electric energy and to save teflon linings of heating units. Each interference into the main technological parameter would need to be confirmed during independent tests. The reason for that is to make sure in the future it wouldn't decrease the endurance of assembled window frames. An additional difficulty would be the usage of glass fibre filler in the examined profile which could lead to deacrease the welding of combining elements.
The window corners made of PVC during coextrusion process were the subject to an observation and strenght tests. The received corners were coextructed firstly and and then were welded while using various temperature values with different clamp strenght (depending on the material's fluidity). Received this way probes for the researches were cut accordingly to the norm's dimension and then its mechanical properties were analysed [14-32].

2. Materials and the methodology of researches

In the researches a part of window frame corner of GENEO® profile type made by Rehau company was used. That particular profile was made of thermoplastic amorphous PVC during the coextrusion process. Usage of plastics with a glass fibre with the trading name RAU-FIPRO leads to receiving completely new characteristics that haven't been known in window industry before. It allows gaining very good heat insulating parameters which reduces energy usage. It allows giving up any additional steel reinforcements widely used until now, but also it may caused some difficulties during welding process. The external layer of the profile was made in coextrusion process from mixture of PVC with no extras (only with glass fibre). Its main task was to get high chemical endurance, the color stability and high quality of the surface. The inner layer was made of mixture of PVC filled in 15% of glass fibre.
Process of windows' corners preparation included technological operations listed below:
- a trim of 4 profiles lenght 600 cm each to a 90 cm lenghts segments at the angle of 90o
- the frames' welding at the welding station
- conditioning of welded frames (3 hours time)
- a split of each frame into 4 window corners used for strenght tests
- transport of ready frames into the lab
- frames' conditioning in the lab (24 hours time)
- conducting strenght tests.

2.1. The process of preparation the frames components' fractions made of PVC

For this researches four of windows' profiles of GENEO® type made of PVC marked P1, P2, P3,P4 were used. Six frames (R1-R6) were made of these four profiles. Before starting the welding process all profiles were submitted to conditioning process, which was conducted in the production hall within 48 hours and with temperature equal 20 oC and the humidity eqaul 50%. After that time cutting out process of the frames components started.

2.2. The welding parameters and frames arrangments for the strenght tests

The next step was to arrange profiles to be transported to a welding station where frames for testing were created. The welding process was taking place while conducting the semi-automatic procedures. It means that the value of the upsetting temperature was only changed by an attendant. The rest of the parametres were selected automatically in a way to achieve destined parameters (i.e. 900mm x 900mm). The time of the fusion process as well as time of the welding process were selected automatically by the programme of the welding device.

An indication of particular frames are consecutively presented in the Table 1. Table includes details like frame number and the upsetting temperature (that is a temperature that sheet fusing-in the profile's part was heated to before welding it).

Table 1. Indicatios of individual frames and its welding temperatures

Frame number	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**
Upsetting temperature ºC	**230**	**220**	**240**	**250**	**210**	**210**

2.3. The scheme of a welding station

Earlier arranged profiles were welded into frames with 900x900 mm dimensions. The welding process was conducted at the industrial welding station equipped in four heating sheets with an air operated drive, positioning lay out and clamp system. Figure 1 presents the profile positioned in the machine before welding process. As the standard upsetting temperature (used up to nowdays) temperature of 250 ^{o}C was accepted (frame number R4). In order to minimalise the energy-consumption during welding process all the tests were conducted in the temperature lower than 250 ^{o}C reducing it every 10 ^{o}C. Because the tolerance of a welding machine within the upsetting temperature was in range of ±2 ^{o}C there was no point of changing the temperature in the range lower than 10 ^{o}C.

Figure 1. The view of welding station presenting the arrangements of the components before starting the process

The machine is fully automated and therefore some of the parameters were selected automatically until the preset parameters were achieved. These parameters are: the clamp force of the profiles towards sheets during fusion process, time of fusion process and upsetting time (welding time). The estimated technological allowance for the upsetting and welding processes was in total equal 6mm. It means that

nominal dimension of the frame is 6mm smaller that each partical dimension of profile's parts prepared for the welding process. Both processes, fusing-in and welding process, are presented adequately on Figures 2 and Figure 3. Once the window frames were ready they were a subject to a three hours conditioning process in the production hall's conditions. The reason for that was to reduce own stress left after the welding process and to reduce the eventual deformation. Following that, from each frame four window's corners were cut according to the scheme presented on the Figure 5. These window's frame will be used in the strenght tests. After the cut the lenght of the external part of the profile should be equal 385mm.

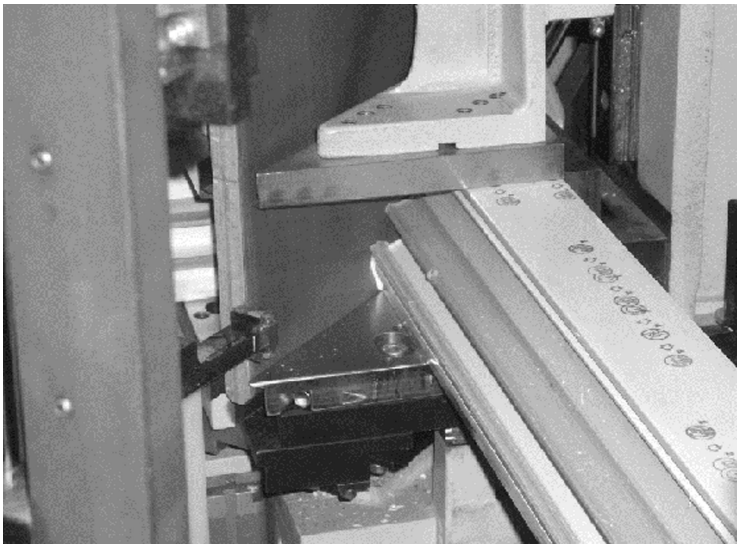

Figure 2. Fusing-in the profiles' edges before welding process

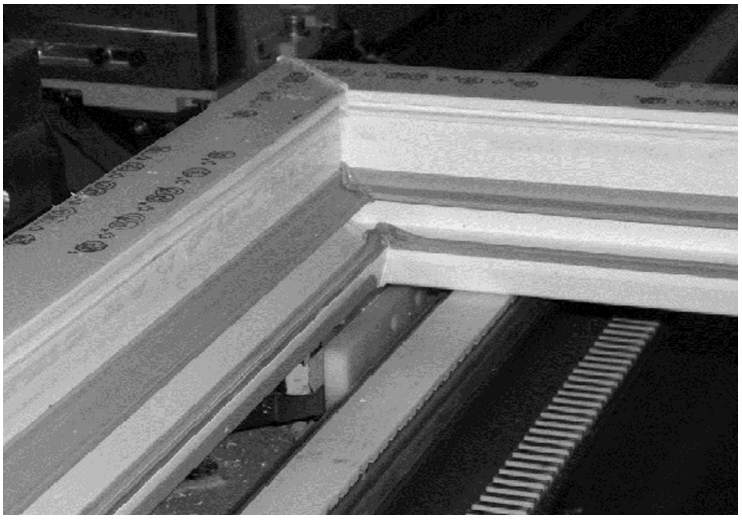

Figure 3. Corners received in welding process

Received windows' corners were reffered to a further researches in the lab of the Department of Polymer Processing at Czestochowa University of Technology.

3. The results of the research and comments

Before start of these researches the probes were reffered to go through a conidtioning process in the lab's compartment for the duration of 48 hours. The temperature in the lab was equal 22 °C and relative humidity around 45%.

According to PN-EN 514:2000 norm the probes for the endurance tests of the joint weld should be taken from the window corners in a way that the lenght of the external profile's segment should be equal 385 mm. The probe needs to be allocated on two trolleys that would allow the probe to drift during the axial load applied on the edge of weld. The usage of the handcarts protect from side forces' occurance which are connected with ground's friction. The window corner is loaded only by the axial force which is being transmitted onto its arms. Between the trolleys there is a spring or other springly material, which casues the come back of the trolleys after the load demise.

The scheme of the research station with the probe and the point of applied force is presented on the Figure 4.

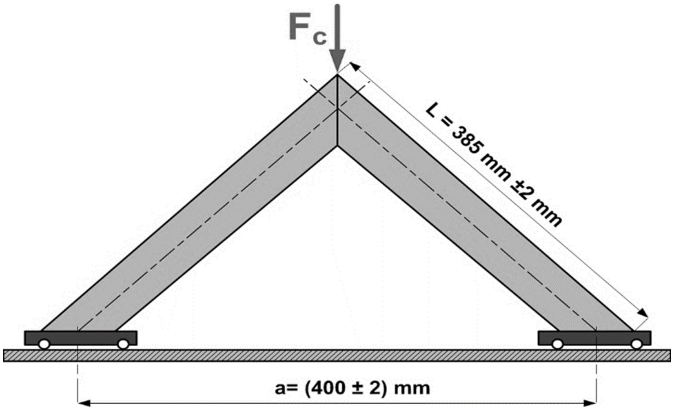

Figure 4. The scheme of measuring system and corner's load during testing

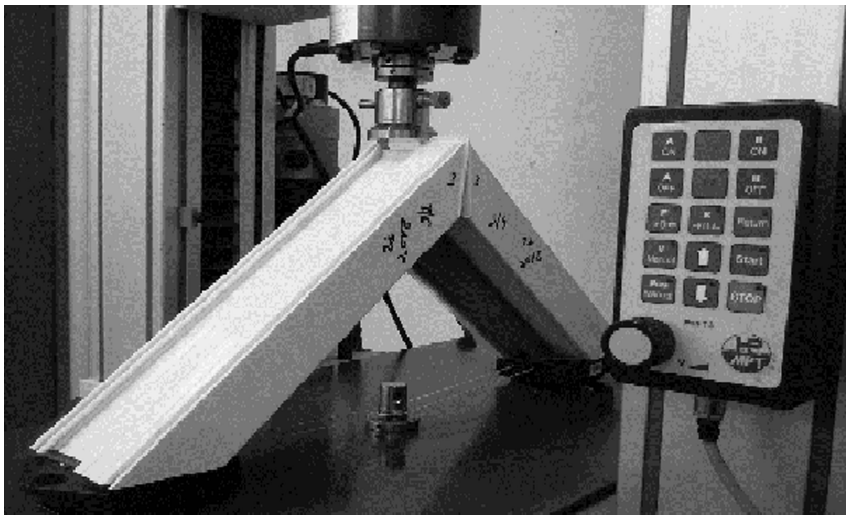

Figure 5. The view of the test bench with set corner

For the reseraches the universal strenght machine was used with the maximum force of 20 kN. The machine was equipped with the measuring head and the registration lay out of the force changes

according to swapping traverse. The tested window corner was reinforce on the two movable trolleys. The reason for that was to eliminate friction between the the ground and the tested profile. By using handcarts it was possible to load the welded joint with bending tension and in a minimal tighten stage. Table 2 presents the general tests results of each frame, welded in a different temperatures. For each frames we received four results (each of window's corners).

Table 2. General Tests results

Frame number	Upseting temperature, ^{o}C	Window corner number	Max force gained during test	Targetted fusin-in time	Way of the weld cracked *
			N	**s**	**-**
R1	230	R1-1	5381	37	Z
		R1-2	5896		Z
		R1-3	6180		Z
		R1-4	5844		P
R2	220	R2-1	4752	50	Z
		R2-2	5063		Z
		R2-3	5646		Z
		R2-4	5290		Z
R3	240	R3-1	5031	39	P+Z
		R3-2	5244		Z
		R3-3	5512		Z
		R3-4	4955		Z
R4	250	R4-1	4882	30	P
		R4-2	5467		P+Z
		R4-3	5160		P
		R4-4	5020		Z+P
R5	210	R5-1	4500	51	Z
		R5-2	4902		P+Z
		R5-3	4560		P+Z
		R5-4	4795		P
R6	210	R6-1	4036	51	Z
		R6-2	4499		Z
		R6-3	4634		Z
		R6-4	-		-

*The characteristics of the crack – crack with the weld Z, crack with the profile P (there is a possibility of mixture Z+P – when the crack started from the weld and then propagated on the profile, or the other way round P+Z)

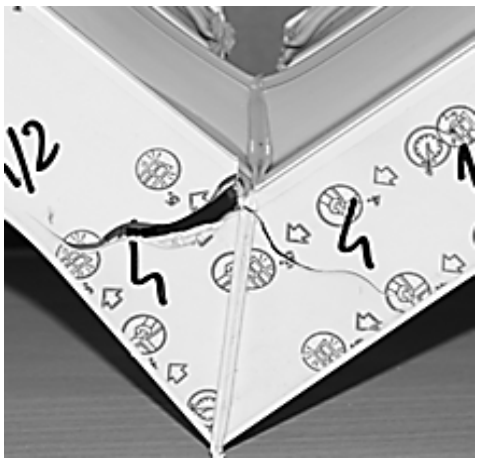

Figure 6. Corner R1 – temp. 230 °C

Figure 7. Corner R2 – temp. 220 °C

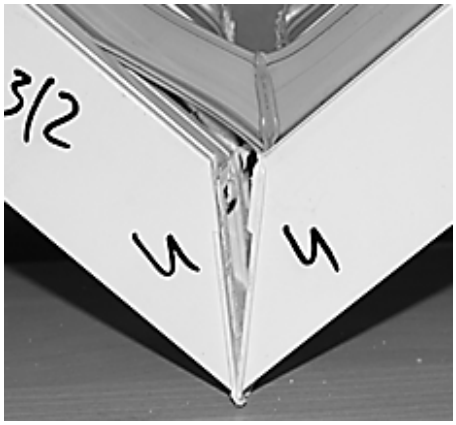

Figure 8. Corner R3 – temp. 240 °C

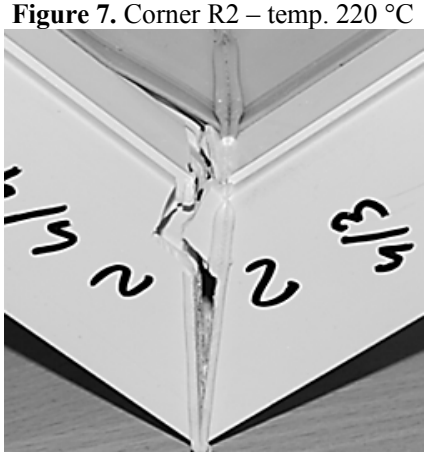

Figure. 9. Corner R3 – temp. 250 °C

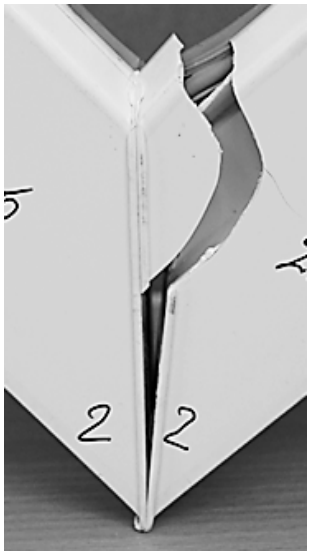

Figure 10. Corner R5 – temp. 210 °C

4. Conclusions

During the welding process four different profiles were used. Each of profiles was under different conditions. The basic parameter was the upsetting temperature (plasticise). It determined all the other parametres of the process presset automatically by the machine including clamp force and welding time.

Using the default temperature of the process leads to gain the crash time of welding and the minimal value of the force of short circuit profiles.

Along with the welding temperture reduction under 250 °C the time needed for plasticise the plastics is increasing and the value of the clamp force of profiles increases during the weld.

It was proven that while using the weld temperature equal 210 °C the mechanical properties of the worsening. The value of the gained maximum destruction force of the joint is lower about 10%.

Very important is also the crack's character of welded profiles (Figure 8). Depending on the weld temperature of the profiles we can point different character of the crack propagation. Within the temperature range of 220 – 240 °C the crack starts where the weld joint is located. In the event of extreme temperatures like 210 °C and 250 °C we can observe more likely the crack of the profile itself. It means that the joint has a better strenght than profile's material itself.

For the profiles welded in the temperature of 250 °C it is closely connected with the high temperature used during the welding. What happens is a partial joint material's melting and its thermodynamic homogenization as well as material homogenization. It allows on gaining the solid joint which often leads to fault of combining profiles.

For the profiles welded in the temperature of 210 °C gaining a solid joint is leading to a fault of the profile. It is conneceted with the plasticise time and the clamp force of combining elements.

In the second part of this article we'll present the results of the microscope researches as well cross sections of the welds as its fracture gained during the destructive tests. It will allow to expand and complete presented in this conclusion the thsesis in regards to PVC upsetting temperature and its impact on the strenght of window frames.

5. Acknowledgement

Special thanks to the owners of the EUROCOLOR company, who agreed on the conducging the researches and enables on creating this publication.

6. References

[1] Sattari-Far I., Javadi Y. 2008 *International Journal of Pressure Vessels and Piping* **85** 265–274
[2] Jasiulek P. 2006 *Łączenie tworzyw sztucznych metodami spawania, zgrzewania, klejenia i laminowania* (Wydawnictwo i Handel Książkami „KaBe" s.c., Krosno)
[3] Postawa P. Szarek A. Stachowiak T. 2010 *Composites* **3** 266-269
[4] Kwiatkowski D. 2010 *Composites* **4** 344-347
[5] Gnatowski A., Gnatowska R. 2016 *Edukacja dla Bezpieczeństwa. Przegląd Naukowo-Metodyczny* **1**, 1799-1805
[6] Gnatowski A., Gnatowska R. 2016 *Edukacja dla Bezpieczeństwa. Przegląd Naukowo-Metodyczny* **1**, 1669-1675
[7] Kwiatkowski D., Nabiałek J. 2007 *Composites* **3** 160-162,
[8] Gnatowski A., Ziewiec A., Gnatowska R. *AIP Conference Proceedings* 1648, 850127
[9] Kaczmar J.W. 2013 *Wytwarzanie, właściwości i zastosowanie elementów z materiałów kompozytowych* (Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław)
[10] Wróbel G. 2008 *Polimery i kompozyty konstrukcyjne* (Wydawnictwo Politechniki Śląskiej, Gliwice)
[11] Wróbel G., Wierzbicki Ł., Siódmok Ł., Nowakowski K. 2015 *Przetwórstwo Tworzyw* **163** 61-64

[12] Wróbel G., Wierzbicki Ł., Szymiczek. M. 2002 *Achievements in mechanical and materials engineering* 621-624
[13] German J. 2001 *Podstawy mechaniki pękania* (Politechnika Krakowska, Kraków)
[14] Bilici M. K., Yükler A. I. 2012 *Materials and Design* **33** 145–152
[15] Bilici M. K., Yükler A. I. 2012 *Materials and Design* **33** 545–550
[16] Dashatan S. H., Azdast T.,. Ahmadi S. R, Bagheri A. 2013 *Materials and Design* **45** 135–141
[17] Amanata N., James N. L., McKenzie D. R. 2010 *Medical Engineering & Physics* **32** 690–699
[18] Qiu J., Zhang G., Asao M., Zhang M., Feng H., Wu Y. 2010 *International Journal of Adhesion & Adhesives* **30** 729–734
[19] Tsujino J., Hongoh M., Tanaka R., Onoguchi R., Ueoka T. 2002 *Ultrasonics* **40** 375–378
[20] Ch. Ageorges a, L. Ye a, M. Hou 2000 *Composites Science and Technology* **60** 1191-1202
[21] Bang H.-S., Bang H.-S., Joo S.-M.,. Kim J.-M and Chang W.-S. 2003 *Science and Technology of Welding and Joining* **5**
[22] Sánchez H. T., Sánchez P., Estrems M. 2009 *Int J Adv Manuf Technol*. **40** 84–94
[23] Stavrov D., Bersee H.E.N. 2005 *Composites Part A: Applied Science and Manufacturing* **1** 39–54
[24] Don R.C., Bastien L.,. Jakobsen T.B, Gillespie Jr J.W. 1990 *Fusion bonding of thermoplastic composites by resistance heating (*SAMPE J, Jan–Feb 59–66)
[25] Ageorges C., Ye L., Hou M. 2000 *Compos Sci Technol*, **60** 1027–1039
[26] Xiao X.R., Hoa S.V., Street K.N. 1992 *J Compos Mater*. **26** 1031–1049
[27] Stavrov D., Bersee H.E.N.2003 *Proceedings of ASME Summer Heat Transfer Conference. Las Vegas* 47222
[28] Hou M., Friedrich K. 1992 *Compos Manufact*. **3** 153–163
[29] Stavrov D., Bersee H.E.N., Beukers A. 2003 *Proceedings of ICCM-14 Conference San Diego* ID-1581
[30] Hou M., Yang M., Beehag A., Mai Y.W., Ye L. 1999 *Compos Struct*. **47** 667–672
[31] Ageorges C., Ye L., Yiu-Wing M., Hou M. 1998 *Composites Part A*, **29** 899–909
[32] Ageorges C., Ye L. 2001 *Composites: Part A* **32** 1603–1612