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THERMAL PERFORMACE AND AESTHETICS OF WOOD-ALUMINIUM WINDOWS FOR PASSIVE HOUSES

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ABSTRACT

The contribution deals with heat and technical characteristics of wood-aluminium windows designed to passive houses. It deals with their shape solution interior wooden part of the structure of the casement. These are compared the properties commonly available profiles with newly designed shape solution.

Profiles of three Slovak producers and one from Poland and one from Germany were compared and modified at the same time. Their construction depth ranged from 112.5–135.0 mm. Four profiles were with additional thermal insulation profile and one in combination with plastic profile with closed air cavities. The aim was to compare and evaluate the impact of the change of shape solutions to window properties compared with commonly available. Shaped solution and its variants are processed on the basis of aesthetic design and functional principles. Calculations of properties and put the final value thermal transmittance of the frame (U_f), according to current STN EN ISO standards.

A comparison of the final results in changing the shape solutions showed that the effect of having an average of 0.24%, and compared the results of rounding under conditions specified in STN EN ISO values are unchanged. Shape changes are mainly aesthetic appreciation of the window construction and the thermal performance of their impact is negligible.

Key words: wood-aluminium windows, passive house windows, thermal performance of windows, design.

INTRODUCTION

Passive buildings are the future of the construction as confirmed by the legislative changes effective from January 2016 also. "Thermal transmittance U is included in the desired properties of building structures. It is used to calculate the heat loss of the building to heat transfer that will affect the fulfilment of the mandatory criteria of the energy performance of buildings" (JOCHIM 2016). "Building satisfy the energy requirements if specific heating demand $Q_{H,nd} \leq Q_{H,nd,N}$ [kWh/(m^2·year)]." (BÚRYOVÁ, SEDLÁK 2016). "Where $Q_{H, nd}$ is the specific heat demand provided by STN 73 0540-2 in kWh/(m^2·year) and $Q_{H, nd, N}$ is standardized heating demand, it is also called setpoint also taking into account building form factor" (BÚRYOVÁ 2014).

This value for windows (U_w) is composed of two values U_g - thermal transmittance of glazing and the U_f - thermal transmittance of the window frame also. The window to the passive house is a usual rule in our climate region, that value does not exceed U_w value of

0.8 W/m^{2}K with glazing with U_g = 0.7 W/m^{2}K (PASSIVHAUS INSTITUTE 2016). Window frame constitutes about 25% of the total area of the window (PUŠKÁR *et al*. 2000). Therefore U_f value should be also remain below 0.8 W/m^{2}K. According GUSTAVSEN *et al*. (2007), the value U_f of passive windows with a simple structure, and the window glazing U_g = 0.7 W/m^{2}K is in the range 0.63 up to 0.82 W/m^{2}K.

Wood-aluminium windows in the comparison to conventional wooden windows have added value in terms of life and use, this is due by the exterior aluminium cover cladding. Manufacturers are not very imaginative and originally in the field of the relating to the aesthetic side of interior design. All windows on the inside part have a close to rectangular type of shape the casement (Fig. 2). This may not satisfy every time to more demanding aesthetic requirements to design of the interior.

This is usually, among other things, that works of research and scientific institutions devoted to wood-aluminium windows (CARDINALE *et al*. 2015, PALKO *et al*. 2012, GRÜLL *et al*. 2006, GRÜLL *et al*. 2005, and others) are not concentrated on solving their shape and influence the design of the window to U_f as well.

THEORETICAL – EXPERIMENTAL PART

Calculation of thermal transmittance through window frame was made and based on EN ISO 10077 Thermal performance of windows, doors and shutters — Calculation of thermal transmittance. Part 1: General a Part 2: Numerical method for frames. It has been done by simulation in computer program THERM (HUIZENGA *et al.* 2015). The individual results of the various structures window frames make them comparable, so the calculation was conducted under identical conditions, stationary and with the same parameters of the material and with the declared values such as the relevant standards.

Boundary conditions for the calculation: (EN ISO 10077-2):

Reference temperature:
- internal: θ_i = 20 °C
- external: θ_e = 0 °C

Reference surface resistance:
- internal: R_{si} = 0.13 m^2·K /W
- increased surface: R_{si} = 0.20 m^2·K /W
- external: R_{se} = 0.04 m^2·K/W

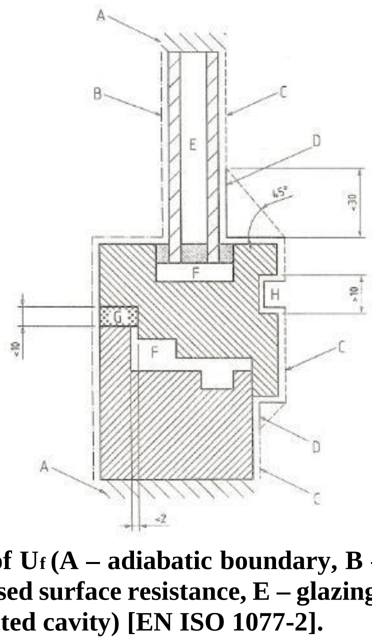


Fig. 1 Division of reference boundary conditions for the calculation of U_f (A – adiabatic boundary, B – external surface resistance, C – internal surface resistance, D – increased surface resistance, E – glazing, F – unventilated cavity, G – slightly ventilated cavity, H – well ventilated cavity) [EN ISO 1077-2].

To calculate the U_f it were used materials in thermal conductivity (λ [W/m·K]) according to the Tab. 1. The values are taken from STN EN ISO 10077-2:2012 which gives us the characteristics of the materials most commonly used for production of windows.

Tab. 1 Coefficient of thermal conductivity of frame materials.

Material	Thermal conductivity (λ [W/m·K])
ethylene propylene diene monomer (EPDM)	0.25
steel	50.00
Picea Abies (L.)	0.11
polysulfide	0.40
silicone	0.35
alloy aluminium	160.00
polyvinylchloride (PVC)	0.17
acrylonitrile butadiene styrene (ABS)	0.20
highly resistant PS-foam*	0.04
Equivalent thermal conductivity (λ_{eq}) air cavities has been determined according to the algorithms in the software program THERM, modelled using the ISO 15099 (Thermal performance of windows, doors and shading devices – Detailed calculations) cavity Model	
* COMPACFOAM: CF 150, from COMPACFOAM GmbH, Porzellangasse 22/1/11, 1090 Wien	

Tab. 2 List of researched frames.

No.	Frame	Mark	Country of origin
1.	Wood-aluminium with additional and integrated PS-foam	MW	Slovakia (SR)
2.	Wood-aluminium with additional PS-foam	MR	Slovakia (SR)
3.	Wood-aluminium with additional PS-foam	MN	Slovakia (SR)
4.	Wood-aluminium with additional PS-foam	AL	Poland (PL)
5.	Wood-aluminium with plastic profile	WG	Germany (DE)

It has been selected five wood-aluminium window profiles intended for passive houses for comparison between geometric change and subsequent change of heat transfer coefficient of the window frame (U_f) (see Tab. 2). The four sections are the additional thermal insulation of the highly-resistant PS-foam (MH, MR, MN, AR) and one of the additional plastic profile (WG) (see Fig. 2).

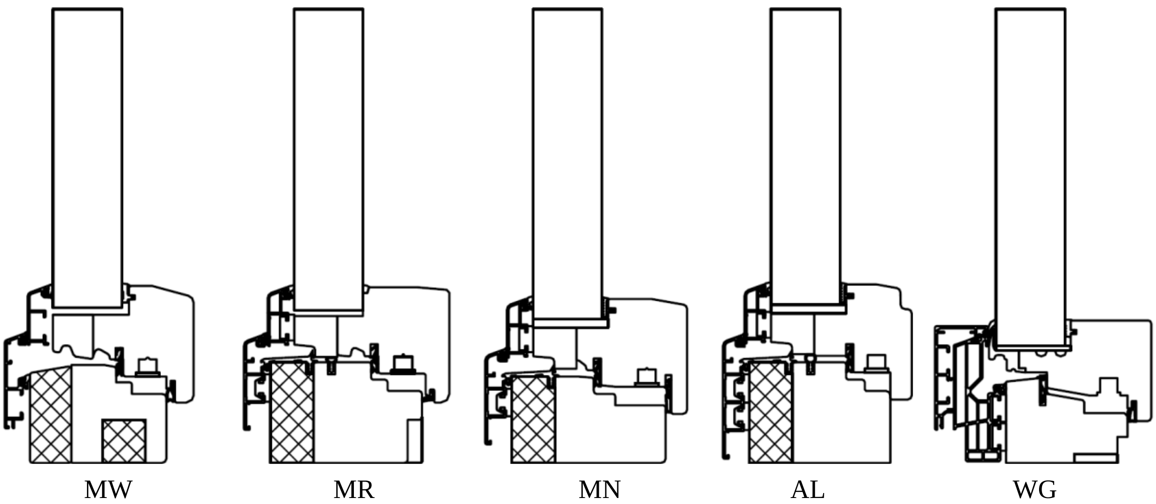


Fig. 2 Profiles of wood aluminium windows with marks.

Geometry changes concerned mainly to the inner side of the wooden sash. They were designed three variants (V1, V2, V3). These variants have been processed design approach, with emphasis on the aesthetic aspects of the sash (Fig. 3 and 4.). These are reflected the course of the isotherms to the original window profiles here. The design options are equal by design modifications to all the various types of profiles each. Variant V1 was processed according to the gentle curves of the Art Nouveau period. V2 is a variant to variant V1 as opposites. It is characterized by inside sharpened broken line. Variant V3 is connection of sharp chamfer with a concave curve.

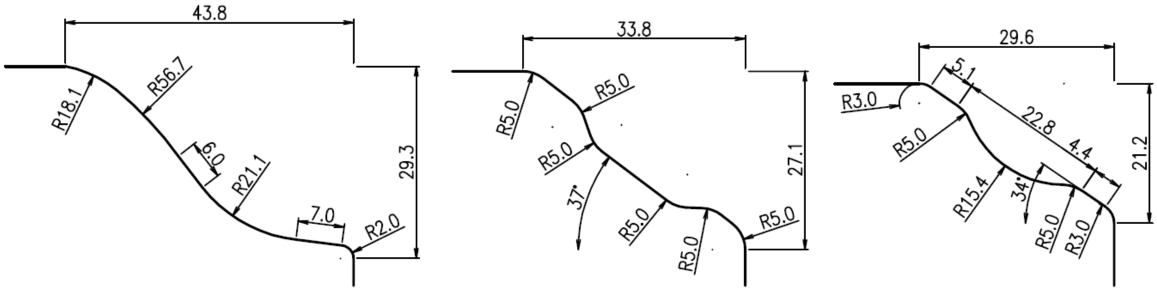
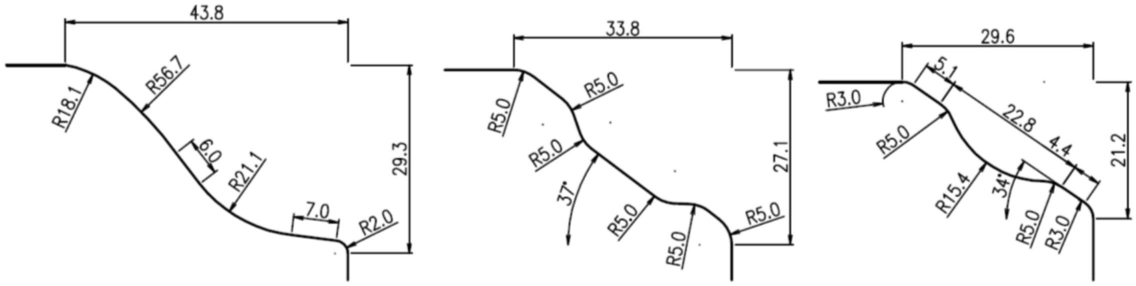


Fig. 3 Geometry of modifications.



MN V1 MN V2 MN V3

Fig. 4 Modified of MN profiles.

RESULTS AND DISCUSSION

Significant impact on the overall terms of the coefficient of thermal transmittance window frame has a total construction ponder and window profile too. It has already been confirmed in the works of various authors several times (PANÁČEK, PUŠKÁR 2016, NÔTA 2016, PUŠKÁR 2012, and others). The total thickness of the wooden part, additional thermal insulation as well as the total depth of the profile in studied structures are shown in Tab. 3. The percentage values of the area of each material in the cross section of window profiles are given in Tab. 4.

Tab. 3 Geometric and thermal properties of windows frames.

profile	profile high [mm]	Al dimension [mm]	insulation dimension [mm]	wood dimension [mm]	overall building depth of profile [mm]	U_f [W/m^{2}K]*	U_f [W/m^{2}K] by STN EN ISO*
MW	123	17	30+30**	85	131.5	0.7254	0.73
MR	122	18	30	95	143	0.6987	0.70
MN	114	18	30	92	140	0.7085	0.71
AL	124	17	30	83	131.5	0.7221	0.72
WG	100	14.5	35***	101	150.5	0.7374	0.74

* U_f values has been calculated by software program THERM, ** additional insulation is located also in fixed part of frame in window profile, *** it is insulation due by plastic 3-chamber profile

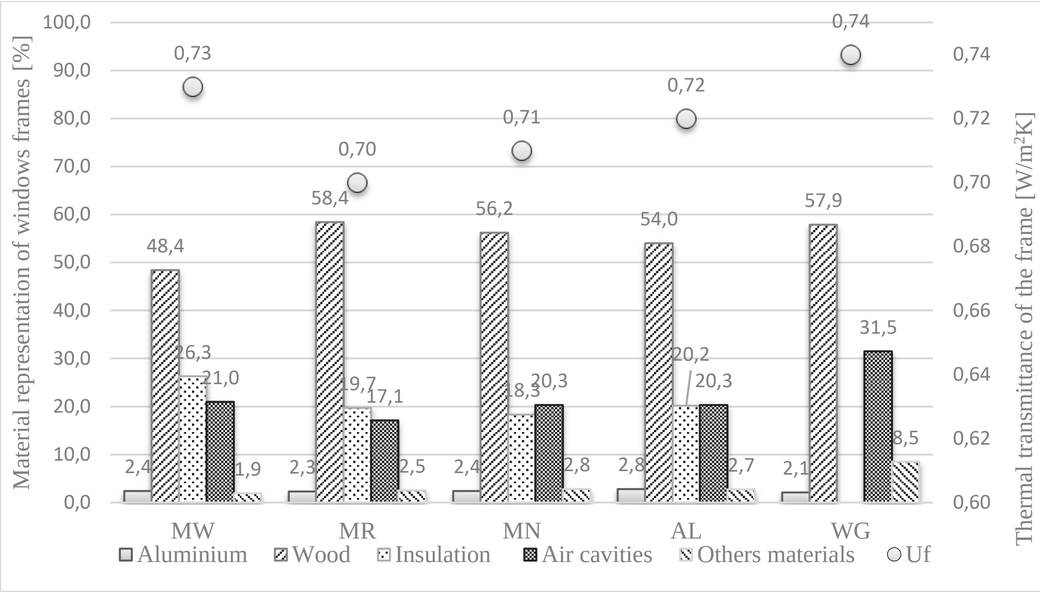


Fig. 5 Representation of materials on the value U_f.

The most significant impact on the value of thermal transmittance of the window frame is caused by wood material in comparison to the original window profiles like shown in the graph in Fig. 4. The proportion of aluminium at all profiles is comparable and does not affect to change thermal properties fundamentally. Mutual combination of wood and insulation does not have a significant impact on improving the value U_f which is visible to the profile "MW", this is the highest recovery rate at the expense of the share of wood but achieves U_f value of 0.73 W/m^{2}K. This makes it to fourth in the list. From all of this we can assume that proper placement of insulation material in the window profile has an impact on the total value of heat transfer coefficient. The profile "WG" has a higher proportion of wood, although it does not provide insulation from high insulating material and the U_f value is on the end of the compared profiles.

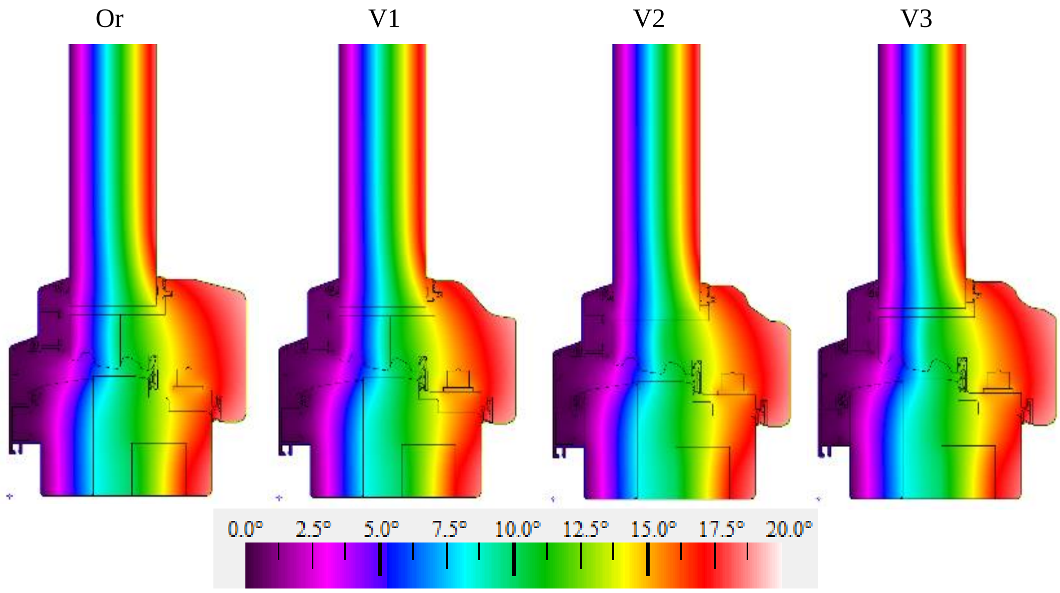


Fig. 6 Colour infrared results modified of MW profiles.

Tab. 5 is showing the U_f values for original profiles as well as profiles after changing shape of the profile geometry of the casement.

Tab. 4 Thermal properties of original and modified profiles.

profile	U_f [W/m²K]	ΔU_f [%] to origin	U_f [W/m²K] by STN EN ISO
MW Or*	**0.7254**		**0.73**
MW V1	0.7275	−0.29%	0.73
MW V2	0.7283	−0.40%	0.73
MW V3	0.7270	−0.22%	0.73
MR Or	**0.6987**		**0.70**
MR V1	0.7012	−0.36%	0.70
MR V2	0.7000	−0.19%	0.70
MR V3	0.6992	−0.07%	0.70
MN Or	**0.7085**		**0.71**
MN V1	0.7119	−0.48%	0.71
MN V2	0.7105	−0.28%	0.71
MN V3	0.7097	−0.17%	0.71
AL Or	**0.7221**		**0.72**
AL V1	0.7233	−0.17%	0.72
ALV2	0.7238	−0.24%	0.72
AL V3	0.7227	−0.08%	0.72
WG Or	**0.7374**		**0.74**
WG V1	0.7406	−0.43%	0.74
WG V2	0.7389	−0.20%	0.74
WG V3	0.7379	−0.07%	0.74

* Or – origin profile

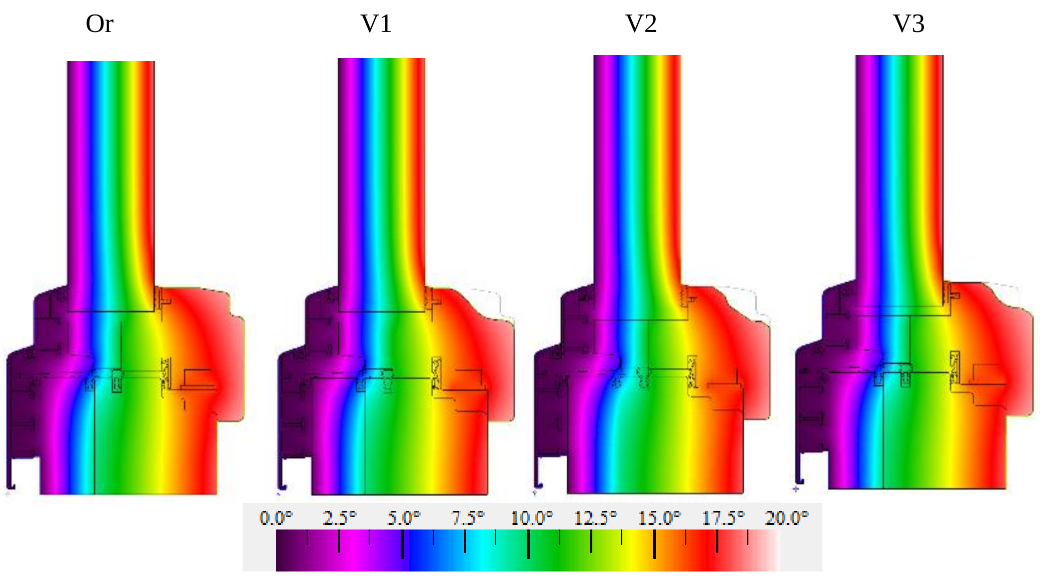


Fig. 7 Colour infrared results modified of AL profiles.

The value of thermal transmittance has been aggravated in the range of 0.22% to 0.40% for profile produced MW. Profile AL was in the range of 0.08% up to 0.24%. However, these values do not correspond to the estimated value of the losses of wooden mass. It is therefore necessary to do deepen its analysis of the results, which is not consistent with the purpose of aim of this article.

For profiles from MN, MR and WG was visible deterioration of thermal transmittance factor (MN 0.48% – 0.17%, MR 0.07% – 0.36%, WG 0.07% – 0.43%). It was dependent linearly caused by loss of wooden mass in windows casement. That is coinciding with assumptions.

However, it is clear that the change in the temperature field of the casement profile has changed minimally at least, see Fig. 6. – Fig. 10.

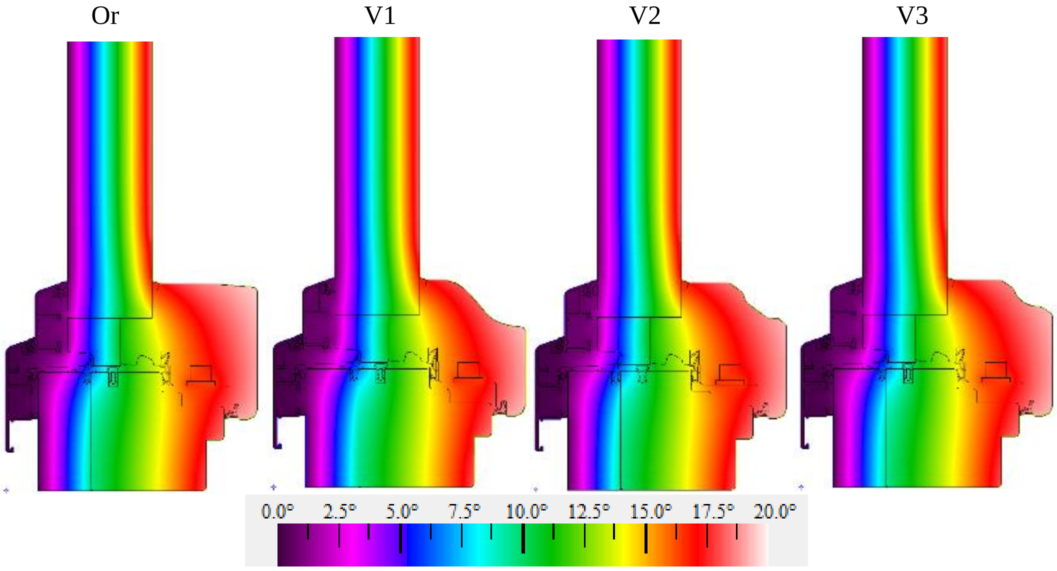


Fig. 8 Colour infrared results modified of MR profiles.

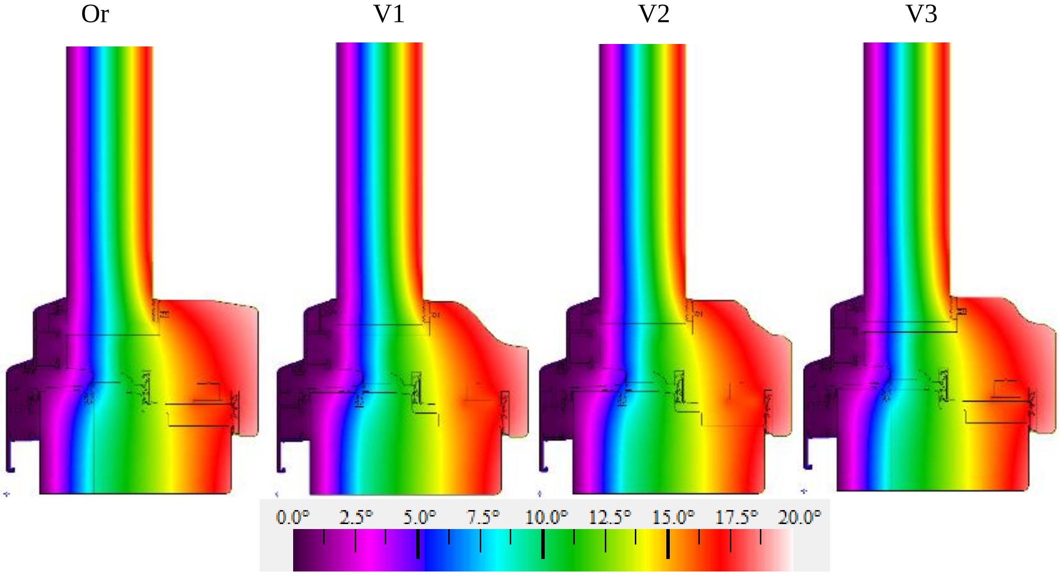


Fig. 9 Colour infrared results modified of MN profiles.

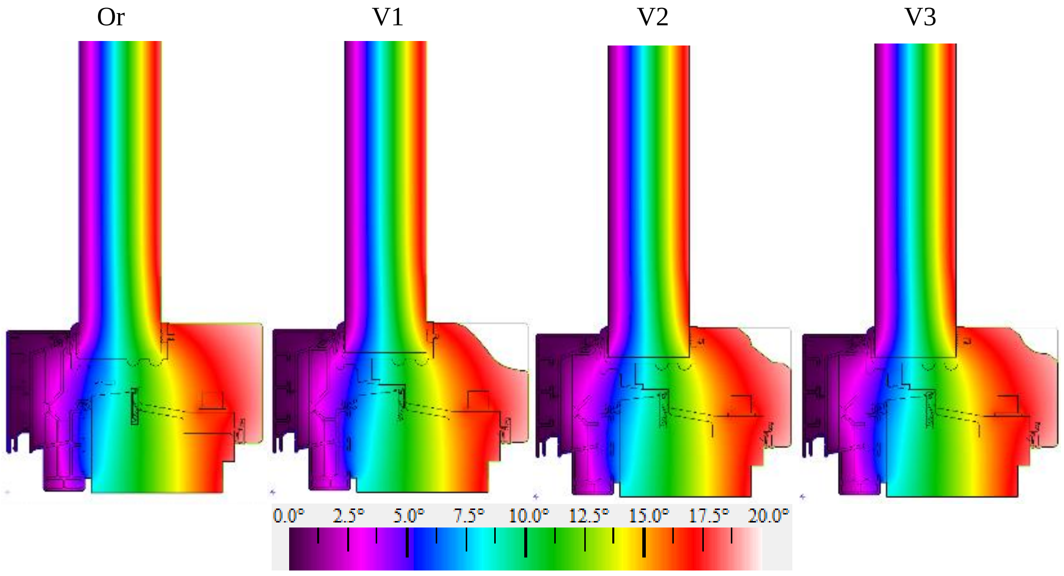


Fig. 10 Colour infrared results modified of WG profiles.

CONCLUSIONS

The average value coefficient of heat transfer in window frame has worsened after design change of the shape solutions, it was agreed and based on the assumption. That is due by removal of timber in window profile. This deterioration is varied in the range of –0.07 up to –0.48%. While the sanding of wood mass has been ranged in between 5.11% to 19.81%. On average, it represented values $\phi\ \Delta U_f = 0.24\%$ and $\phi\ \Delta A_{cf} = 10.72\%$[1]. However these changes do not constitute any effect to express its overall values coefficient of heat transfer according to current standards, for individual profiles (see Tab. 5.). STN EN ISO 1077-2:2012 article *7.4 Results* indicated: The total thermal transmittance of the frame section shall be given to two significant figure, i.e. to two decimal places if less than 1.0.

We have confirmed through simulations our assuming that editing the shape of window construction profile, which is based on the loss of timber in windows up to value about 20% of the area its window casement, its thermal performance worsen in the order of just tenths of a percent. In the context of the overall results of rounding that deterioration it is negligible and does not have any significant affect the properties window presented by thermal-technical site in the final result. Just that it brings added value in terms of modern architecture and aesthetics. Larger variation of frames allow to architects use with the window as a full-fledged component of interior. This element fits into the overall concept with its expression. This can be achieved by simply a seemingly form of edge and the window frame too. These basic modifications may serve as a guide to subsequent possibilities of change. The ideas can be applied to the requirements of the architect or designer without significantly affecting into quality of the window then.

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[1] A_{cf} – Area of casement frame

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