Review Article

THE INFLUENCE OF WELDING DEFORMATION TYPES OF HYBRID NODE ON ASSEMBLY SUITABILITY

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ABSTRACT

The article presents welding deformation types identified in a hybrid node. The hybrid node is a new structure element. Its implementation requires solving many problems, especially those related to the technology. The most important problems in this field are welding deformations arising at the prefabrication stage of a node fabrication. Welding deformations influence the quality of prefabricated section and cause an increase of manufacturing costs. Therefore, a definition of influence of each deformation type on assembly suitability is a significant problem. The expert method presented in the article makes it possible to define this influence.

Keywords: innovative constructional element, sandwich panel, hybrid node, welding distortions.

INTRODUCTION

In order to specify the issues discussed in the article the following terms are used:

- Welding deformation – a change of measurements or shapes of construction elements which are caused by welding heat cycle [1].
- Hybrid node – a specific fragment of large-size steel construction in which two different elements, in terms of construction and technology, connect (in the analysed example: innovative construction element – panel sandwich and conventional construction element – stiffened plate. Both construction fragments are combined with a joining element [6, 8].
- Assembly suitability – the ability of construction or its element to connect to other construction, or its fragment, without any additional corrective measures [6, 7].

Hybrid node can be used whenever sandwich panels are used [2, 5, 6]. The analysed node is presented in Fig. 1.

The definition of the influence that is exerted by a given deformation on assembly suitability is extremely significant from the perspective of the costs of correction measures. The most common method of removing welding deformations in large-size constructions is straightening. The operation generates additional costs related to its labour intensity. Straightening thin-walled constructions is particularly laborious (such elements construct a hybrid node). It is estimated that labour intensity of this operation is as high as 30% of total labour intensity for the whole construction [2, 3].

THE TYPES OF WELDING DEFORMATIONS IN THE HYBRID NODE

The types of welding deformations in the analysed hybrid node are presented in Table 1, whereas, selected types were presented in Fig. 2.

In order to locate the specified welding deformations in the hybrid node were assigned to a specific weld (see, Fig. 1).
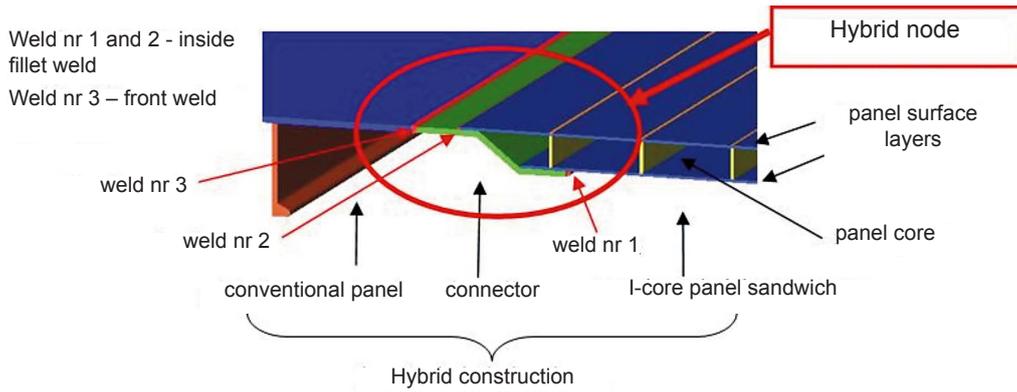
Weld nr 1 and 2 - inside fillet weld

Weld nr 3 – front weld

Hybrid node

panel surface layers

weld nr 3

panel core

weld nr 2

weld nr 1

conventional panel   connector   I-core panel sandwich

Hybrid construction

Fig. 1. Hybrid node [6, 8]

Table 1. Types of welding deformations distinguished in the hybrid node [6, 7]

Item	Hybrid node weld	Form of weld deformaion	Symbol of deformation form
1	weld nr 1	transverse deformation of pannel plating (surface wavyness)	DPP1
2	weld nr 1	longitudinal deformation of pannel plating (deflection)	DWP1
3	weld nr 1	angular deformation of connector	DKL1
4	weld nr 1	longitudinal deformation of connector (deflection)	DWL1
5	weld nr 2	transverse deformation of pannel plating (surface wavyness)	DPP2
6	weld nr 2	longitudinal deformation of pannel plating (deflection)	DWP2
7	weld nr 2	angular deformation of connector	DKL2
8	weld nr 2	angular deformation of connector (deflection)	DWL2
9	weld nr 3	transverse shrinkage at groove weld	SP3
10	weld nr 3	angular deformation at groove weld	DK3
11	weld nr 3	plating deformation at groove weld	ZP3
12	weld nr 3	longitudinal deformation at groove weld (deflection deflection)	DW3
13	weld nr 3	straight line at free edge of conventional plating	PWK3
14	weld 3	relocation of free edge of the conventional plating in transverse direction	PRK3
15	welds 1,2,3	transverse deformation of hybrid node (deflection)	DPWH

conventional cover panel

100

DK3

SP3

connector

ZP3

3

DKL2

2   DPP2

end-to-end joint

1

DKL1

DPP1

1, 2, 3 – number of weld

DPP1, DPP2, DKL1, DKL2, DK3, SP3, ZP3 – types of deformations, in accordance with Table 1
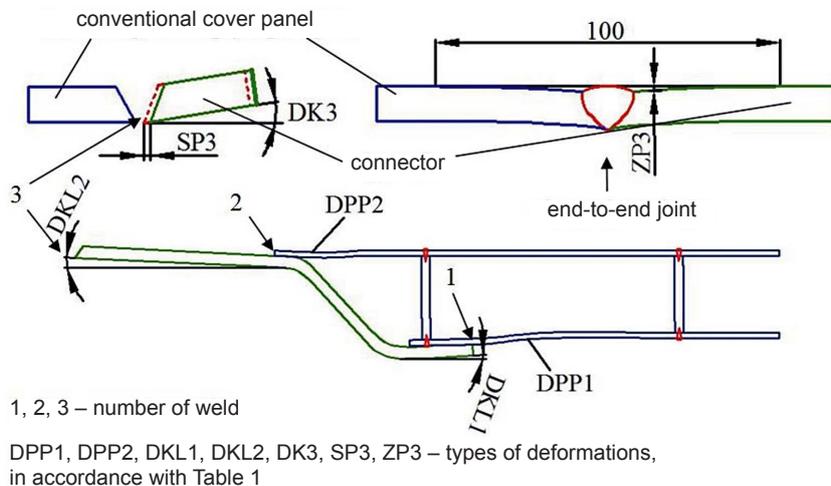
Fig. 2. Selected types of welding deformations distinguished in the hybrid node [6, 7]

THE ANALYSIS OF DEFORMATION INFLUENCE ON ASSEMBLY SUITABILITY

The aim of the analysis is to identify the types of welding deformations and their influence on assembly suitability. The evaluation was made on the basis of a multiple (multi-factor) expert method. The method is based on the following steps:
- Defining the aim of the analysis and the evaluated objects.
- Forming the criteria that define the required set of features that define given objects.
- Defining the method of evaluation on the basis of the criteria.
- Conducting the evaluation for each of the analysed objects and the selecting of the best of them.

The evaluated objects are the types of deformations presented in Table 1. To evaluate the types of deformations, eight criteria presented in Table 2 were selected. In author's opinion the criteria allow obtaining the aim of the present analysis.

The selected types of deformations were evaluated independently according to the criteria (Table 2) in the point scale from 0 to 5. The higher mark, the better properties, i.e. lower influence on assembly suitability. All the criteria were brought to the dimensionless form by dividing them by the largest number of points that can be attributed to a given criterion, i.e. by 5.

For each of 8 analysed forms of deformation parameter a radar graph was prepared. The graph surface is the generalised criterion to evaluate the influence of deformation form on the assembly suitability of the hybrid node. In the ideal case, each of the 8 criteria has a dimensionless value equal to 1. The surface of the radar graph for the ideal object is 2.827. The evaluation of the influence of deformation from on assembly suitability in relation to surface "p" of the radar graph was presented in Table 3.

Table 3. Influence of a deformation type on assembly suitability of the hybrid node depending on a radar graph area [6]

Item	Influence of a deformation type on assembly suitability	Area surface for the radar graph [-]
1	insignificant	$2,121 < p$
2	moderate	$1,414 < p \leq 2,121$
3	large	$0,707 < p \leq 1,414$
4	very large	$p < 0,707$

The results of the multi-criteria evaluation for the analysis are presented in Table 4 and illustrated in Fig. 3 and Fig. 4. Fig. 3 presents a set of

Table 2. Criteria of influence assessment of welding deformation types of the hybrid node on its assembly suitability [6]

Item	Name	Description
1	Dependability criterion	Concerns the influence that the analysed type of deformation exerts on other elements (i.e. on one or more types of deformations)*.
2	Self-dependency criterion	Concerns the influence of the analysed form of deformation on further assembly of the hybrid node*.
3	Reductiveness criterion (preventability)	Concerns the possibility to minimise a given form of deformation while making a hybrid node, e.g. by using the right welding technique or initial deformation of welded elements**.
4	Faultiness criterion (acceptability)	Concerns the level of accepted forms of deformations, as a failure of construction geometry fragment.
5	Correctness criterion (technical)	Concerns the technological possibilities of deformation correctness (i.e. straightening operation).
6	Correctness criterion (technological)	Concerns the level of difficulties in straightening related to weld accessibility, place of straightening, etc, and required operator's qualifications**.
7	Instrumentality criterion (tool)	Concerns the necessity to make specialist tools for straightening operations, i.e. the number of tools and their level of advancement**.
8	Prognostic criterion	Concerns the possibility to predict (a'priori) orientation (e.g. roughing) value of the analysed type of deformation.

Comments:

* – one should remember that despite clear influence of the analysed shape of the deformed item on others, it may not have the influence on further assembly of the hybrid node, and the opposite,

** – because the evaluation may differ depending on the stage of large-size steel construction development, where hybrid node is monitored; in order to balance the evaluation, more difficult assembly option was assumed, i.e. assembling the node in the open space (e.g. on a ramp in case of ship's hull construction).

Table 4. Influence of a deformation type on assembly suitability of the hybrid node (on the basis of [6])

Item	Evaluation criteria	Ocena w skali punktowej (od 0 do 5) dla poszczególnych postaci odkształceń węzła hybrydowego														
		DPP1	DWP1	DKL1	DWL1	DPP2	DWP2	DKL2	DWL2	SP3	DK3	ZP3	DW3	PWK3	PRK3	DPWH
1	Dependability	3	3	3	3	3	2	2	2	1	3	3	3	4	5	4
2	Self-depen-dency	5	4	5	4	5	3	0	1	5	5	5	5	5	5	5
3	Preventability	3	2	3	2	3	2	4	3	4	4	3	3	2	1	3
4	Acceptability	3	2	1	1	2	2	1	1	3	2	2	1	3	2	2
5	Correctability (technical)	1	1	4	4	2	2	4	4	0	4	4	4	5	5	3
6	Correctability (technological)	1	1	1	1	2	2	2	2	4	1	3	3	4	0	0
7	Instrumentality	1	1	5	5	2	2	4	4	0	4	4	4	5	5	3
8	Predictability	2	2	4	4	3	3	4	4	4	4	4	4	2	4	2
9	Radar area, [-]	0,735	0,508	1,103	0,947	0,891	0,565	0,678	0,735	0,579	1,230	1,357	1,258	1,541	1,159	0,862
10	Share of graph surface influence to the surface of the ideal surface [%]	26	18	39	34	31	20	24	26	20	43	48	44	54	41	30
11	Technological hierarchy *	10	14	6	7	8	13	11	10	12	4	2	3	1	5	9

Comments:

* Technological hierarchy of welding deformations, due to their influence on assembly suitability, ordered according to increasing influence (from 1 to 14).
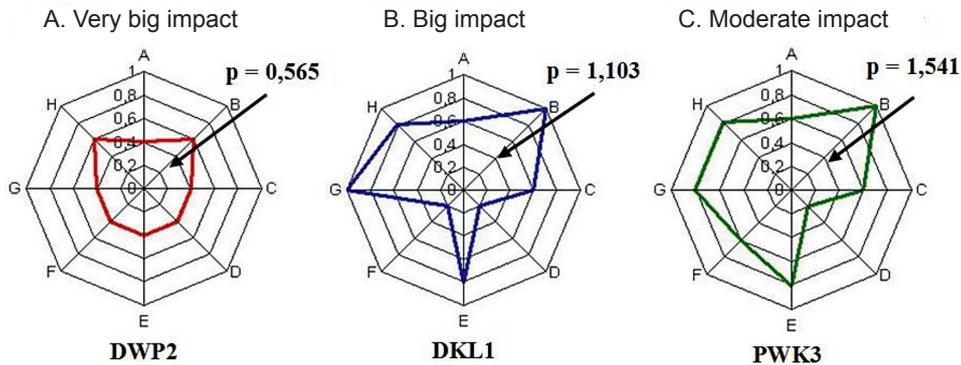
Criteria for evaluation:
A – dependence, B – auto-dependence, C – thrift, D – permissiveness, E – corrective (technical),
F – corrective (technological), G – instrumental, H – predictability

p – surface area of the radar chart

DWP2, DKL1, PWK3 – types of deformations, in accordance with Table 1

Fig. 3. Set of radar graphs for chosen types of assessed deformations (on the basis of [6])

radar graphs for selected representative research objects illustrating all states of the evaluation (Table 4). Fig. 4 presents a set of values of the radar fields describing the state of assembly usefulness of the evaluated hybrid node forms.

On the basis of the obtained results it was stated that:

- Most types of deformations of the hybrid node (i.e. c.a. 67%) have a large influence on assembly suitability,

- c.a. 27% forms of deformations have very large influence on assembly suitability,
- c.a. 7% forms of deformations have moderate influence on assembly suitability,
- there are no forms of deformations that have insignificant influence on assembly sustainability.

The conducted expert analysis allows introducing the so called technological hierarchy of hybrid node deformations that facilitate ordering
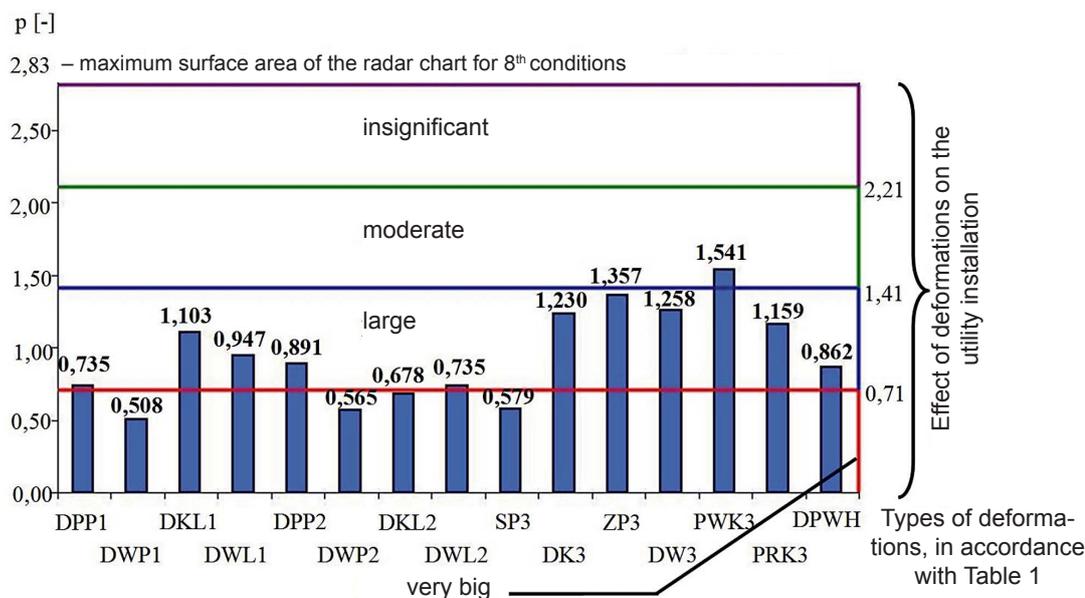
Fig. 4. Set of radar graph areas values describing assembly suitability of assessed welding deformation types of the hybrid node (on the basis of [6])

specific forms of deformations from the least to the most significant in terms of their influence on assembly suitability. At the same time it is possible to select the most significant forms from the whole array of deformations.

It was observed (see, Table 4 and Fig. 4) that in the area that is defined as significant for assembly suitability of the hybrid node there are different types of deformation, both vertically and longitudinally to the node. The differences between the share of radar graph surface for different deformation types to the surface of the ideal graph are insignificant for the first four deformation types, i.e. at the level of 2÷6 % (line 10, Table 4). This process that there is no primary deformation type and the first four (DWP1, DWP2, SP3, DKL2) can be treated as equal.

Another two forms in the technological hierarchy (DWL2 oraz DPP1) that have the same radar graph surface are only 2% behind DKL2 (according to line 10, Tab. 4). This fact proves that the boundaries between specific areas that define the influence of deformation on the assembly suitability should be treated flexibly and considered with regards to a particular situation that is related to assembly technology and quality requirements.

Moreover, one should remember that deformation types are correlated with one another (particularly the neighbouring ones) and have influence on each other, what increases the deformation activities (e.g. ZP3 and DK3 depend on SP3).

CONCLUSIONS

Large size steel constructions are characterised by high technical and construction repeatability. Therefore, deformations of similar size and range are expected in such products. Thus, it is advisable to create a technological hierarchy that systematises deformation forms. It is particularly important with regards to innovative construction elements.

The expert method discussed in the article allows defining the influence of a given type of welding deformation on assembly suitability in a given hybrid node and designing the above-mentioned technological hierarchy.

For the types of deformations that have largest influence on assembly suitability it is justified to design predicative models. The models can facilitate the technological control over the construction at the production stage.

REFERENCES

1. Ferenc K., Ferenc J.: Konstrukcje spawane. Połączenia, Wydanie trzecie. WNT, Warszawa 2006.

2. Kubera S.: Odkształcenia spawalnicze i zasady ich usuwania w okrętowych konstrukcjach cienkościennych. Rozprawa doktorska. Politechnika Gdańska, Gdańsk 1964.

3. Metschkow B.: Współczesna technika utrzymania wysokiej jakości konstrukcji okrętowych. X Konferencja: Laboratoria technologiczne – aspekty utrzymania wysokiej jakości wyrobu. Wydawnictwo Uczelniane Politechniki Szczecińskiej, Szczecin 1999.

4. Pyszko R.: Zastosowanie stalowych paneli typu sandwich w konstrukcjach okrętowych i oceanotechnicznych. Rozprawa doktorska. Katedra Technologii Okrętu, Systemów Jakości i Materiałoznawstwa, Wydział Oceanotechniki i Okrętownictwa Politechniki Gdańskiej, Gdańsk 2006.

5. Urbański T., Graczyk T.: Application of innovative materials in waterborne transport means – identification of technological problems. International Conference on Innovative Materials and Technologies for Surface Transport (INMAT 2005), Gdańsk, Poland, 7-8 November, 2005.

6. Urbański T.: Metoda prognozowania odkształceń spawalniczych węzła hybrydowego na podstawie badań eksperymentalnych. Rozprawa doktorska. Zakład Konstrukcji, Mechaniki i Technologii Okrętów, Wydział Techniki Morskiej, Zachodniopomorski Uniwersytet Technologiczny w Szczecinie, Szczecin 2009.

7. Urbański T.: Węzeł hybrydowy – technologiczność wielkogabarytowych konstrukcji spawanych – wprowadzenie. Przegląd Spawalnictwa, 11, 2010, pp. 21-25.

8. Urbański T.: Węzeł hybrydowy – prognozowanie odkształceń spawalniczych panelu I-core na podstawie planowanego eksperymentu dwuwartościowego, Przegląd Spawalnictwa, 3, 2012, pp. 16-22.