Advances in Science and Technology Research Journal
Volume 8, No. 22, June 2014, pp. 31–36
DOI: 10.12913/22998624.1105160

Research Article

ASSESSMENT OF THE PRODUCTIBILITY OF HYBRID NODES USING THE MULTI-CRITERIA METHOD

Tomasz Urbański[1]

[1] Department of Ship Structure, Mechanics and Fabrication, Faculty of Maritime Engineering and Transport, West Pomeranian University of Technology in Szczecin, Poland, e-mail: tomasz.urbanski@zut.edu.pl

Received: 2014.05.05
Accepted: 2014.05.20
Published: 2014.06.05

ABSTRACT
The article presents an assessment of the productibility of hybrid nodes. The hybrid node is a new structural element the implementation of which causes numerous (especially technological) problems that need to be solved. The most important element of the hybrid node is the so-called connector, the choice of which is a complex and difficult problem. It involves taking into account many aspects (constructional, strength-related, technological, economic) in order to make sure that the choice is as objective as possible. Therefore, an attempt to acquire a comprehensive view at the problem requires that a set of accurate criteria be used for assessment. In this paper, the author undertakes such an attempt. The expert method presented herein allows for choosing the right connector.

Keywords: innovative structural element, sandwich panel, hybrid node, expert method.

INTRODUCTION

In order to ensure unambiguous interpretation of the problems discussed in this paper, the following terms were introduced:

- hybrid node – a special fragment of a large-size steel structure within which two parts (distinguished from each other in structural and technological terms) of that structure are joined (in the case analyzed: an innovative structural element – a sandwich panel, and a conventional structural element – a stiffened plate). The fragments of the structure are joined with each other using an intermediate element – a connector [5],
- assembly suitability – the structure's ability to be joined with another structure, or a fragment thereof, preferably without the need for any further corrective procedures [5, 6].

The hybrid node constitutes an integral part of hybrid structures (Figure 1) and can be applied wherever sandwich panels are used [3, 4, 5].

Performing a hybrid node entails the need to:

- choose the shape of the intermediate joining element,
- choose the method for joining particular elements of the node,
- develop the technology for assembling the hybrid node at an acceptable quality level, i.e. its assembly suitability.

All of the aforementioned aspects are closely interrelated and create the broadly-defined area of the hybrid node's productibility. Since each of these aspects is so vast that it could be the topic of at least one separate article, the decision was made to narrow the scope of interest of this paper to the first of them, only.

The connector's shape has a substantial impact on the number and quality of the hybrid node's welding deformations (the effect that the welding deformation forms identified in the node have on its assembly suitability is shown in [7]).

HYBRID NODES ASSESSED

The objects (hybrid nodes) subjected to a multi-criteria assessment were developed on the basis of the author's knowledge of the phenomenon studied and his own material gathered, and

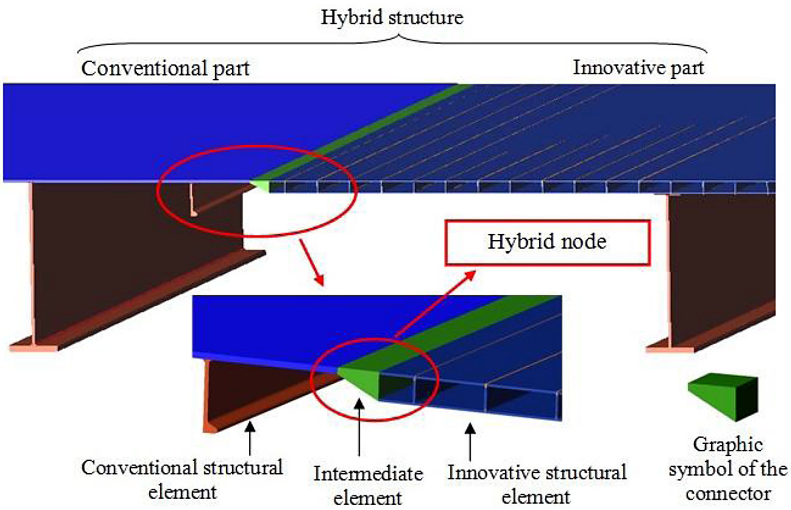
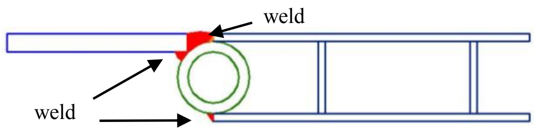
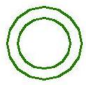
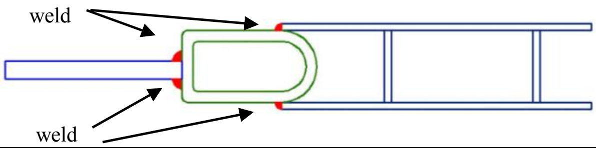
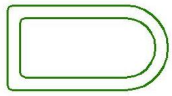
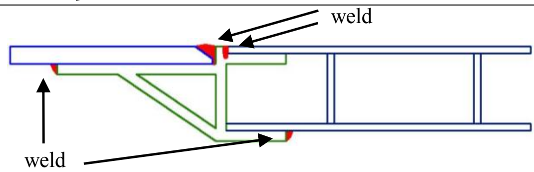
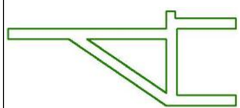
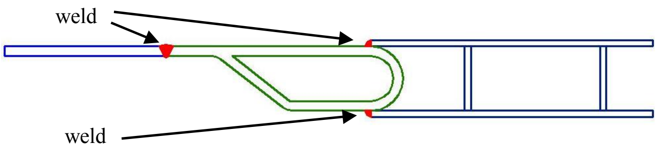
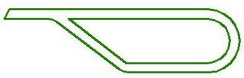
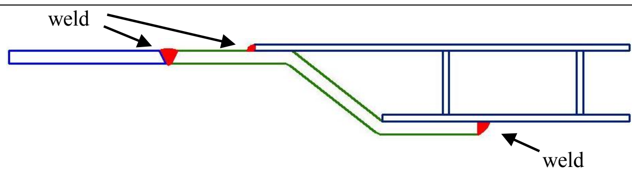
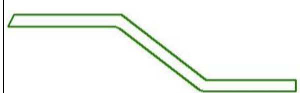
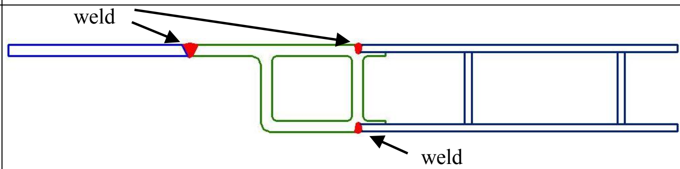
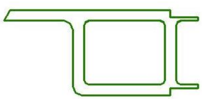
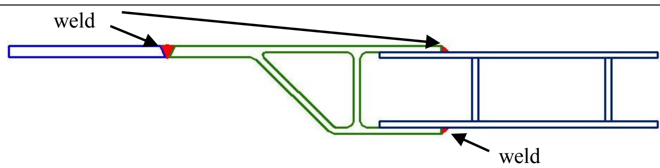
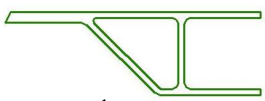


Fig. 1. Hybrid node – components [5, 6]

Table 1. Types of hybrid nodes under a multi-criteria assessment (on the basis of [5])

HN no.	Drawing of the hybrid node	Connector shape
1	 weld, weld	 simple*
2	 weld, weld	 complex*
3	 weld, weld	 complex
4	 weld, weld	 complex
5	 weld, weld	 simple
6	 weld, weld	 complex
7	 weld, weld	 complex

Denotations and notes: HN – hybrid node.
* – shape available in metallurgic products catalogues, e.g. [10].

illustrated in Table 1 (Table 1 shows the most representative node shapes, only).

PRODUCTIBILITY ASSESSMENT USING THE MULTI-CRITERIA METHOD

The purpose of the hybrid node productibility assessment is to show the direct impact that the node's geometry has on its assembly suitability, and thus to choose the connection variant that is most suitable in technological terms. The assessment was carried out using the so-called multi-criteria expert method. It follows a few basic steps:

- determination of the purpose of the analysis, and selection of the objects to be assessed.
- formulation of a set of criteria defining the group of features sought that describe the objects chosen.
- determination of assessment rules based on the criteria formulated.
- performance of the assessment for each of the objects analyzed, and selection of the best one/ones of them.

The hybrid nodes shown in Table 1 were used as the objects of the multi-criteria assessment. Eleven criteria, shown in Table 2, were used for assessing particular joint variants (node geometries). In the author's opinion, these criteria make it possible to achieve the assessment's objective in a reliable way.

The hybrid nodes selected were assessed separately according to the criteria (Table 2) on a scale of 0 to 5. The higher the assessment value the better their properties, or their assembly suitability. All criteria were brought to a dimensionless form through dividing them by the maximum number of points attributable to the given criterion, i.e. by 5.

Table 2. Criteria for assessing hybrid node joints [5]

No.	Name	Description
1	(connector) Feasibility criterion	Refers to the degree of difficulty in manufacturing the connector by the manufacturing plant.
2	Adaptability (adjustment) criterion	Refers to the degree of assembly difficulty, i.e. of a possible need to apply force in order to adjust the connector to the panel as a result of, e.g., errors in connector manufacture.
3	(connector) Accessibility criterion	Refers to the necessity of performing additional procedures preparing the element to welding, e.g. scarfing * (of one edge or more), or thickness reduction.
4	(technological) Universality criterion	Refers to the possibility of using the connector at different stages of constructing a large-size steel structure, e.g. prefabrication and/or assembly.
5	(constructional) Universality criterion	Refers to the possibility of performing the hybrid node in various joint variants, i.e. according to the location of the stiffeners of the panel's core in relation to the main structural link system, without disturbing the inner structure of the core of the panel.
6	Instrumentality criterion (concerning tools)	Refers to the necessity of developing special tools useful for assembling the given node, i.e. the number of such tools and the degree of their technological advancement.
7	Size criterion	Covers the number of welds (thus the level of consumption of welding consumables, and labor intensity required the performance of the joint), the type of welds and their concentration.
8	(joint) Feasibility criterion	Refers to the degree of difficulty of performing the joint, i.e. mainly: access to the joint, welding position, etc., and thus the welder's qualifications required.
9	Deformability criterion	Refers to the expected (quantitative and qualitative) level of welding deformations formed within the node.
10	Correctibility criterion	Refers to the possibility (and degree of difficulty) of performing repairs, mainly thermal straightening.
11	Esthetics criterion	Refers to the general visual impression with regard to the entirety of the joint, from the point of view of the engineer.

Notes:
* – it should be remembered that if it is necessary to carry out the scarfing of sheet metal, the manner of preparing the edges will depend on the element's thickness and the welding method [1, 8, 9].

Table 3. Assessment of hybrid node joints depending on the radar chart area [5]

No.	Hybrid node productibility state	Value of the radar chart area [-]
1	Very good	2.229 < a
2	Good	1.486 < a ≤ 2.229
3	Satisfactory	0.743 < a ≤ 1.486
4	Poor	a < 0.743

For each of the nodes analyzed, an 11-parameter radar chart was drawn (Figure 2). The chart area is a criterion generalized to the assessment of the hybrid node's productibility state, i.e. its impact on assembly suitability. In the ideal case, each of the 11 criteria has a dimensionless value equal to 1. The radar chart area for an ideal object is 2.972. The assessment of the hybrid node's pro-

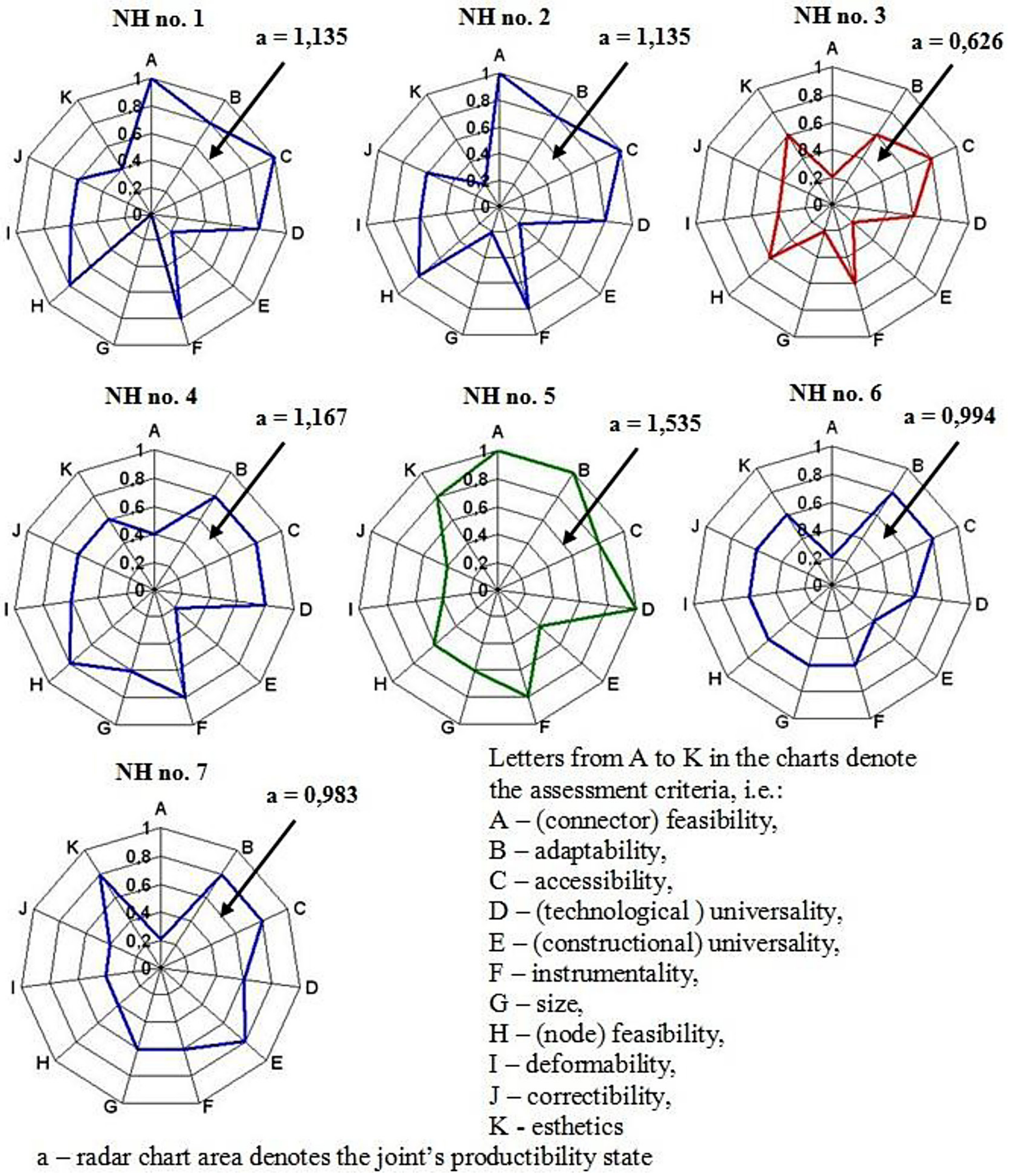


Fig. 2. A set of radar charts for the hybrid nodes assessed [5]

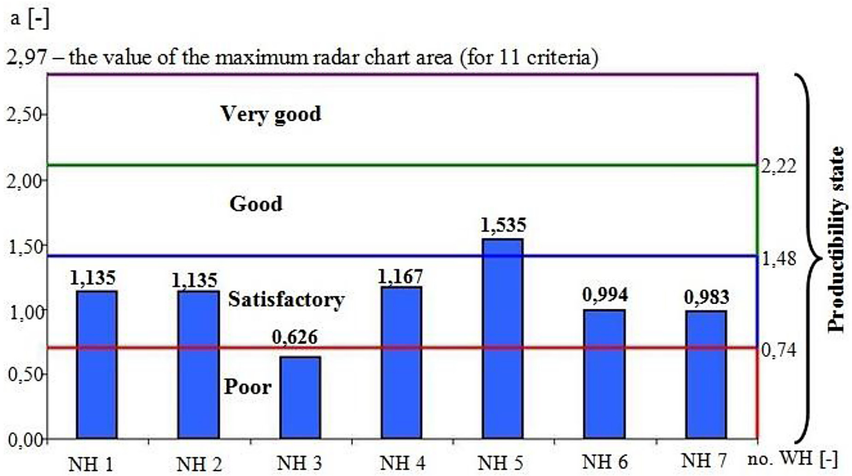


Fig. 3. A comparison of the radar chart area values describing the productibility of the hybrid nodes assessed (on the basis of [5])

ductibility depending on the radar chart area ("a") is shown in Table 3.

The resulting values of the multi-criteria assessment for this analysis are shown in Tab. 4 and illustrated in Figure 2 and Figure 3.

Fiugre 2 shows a set of radar charts for all of the objects assessed containing all the assessment states obtained (according to Table 4).

Figure 3 shows a set of radar chart areas describing the productibility state of the hybrid nodes assessed.

On the basis of the results obtained, it was found that:

- most of the nodes selected for the analysis (five out of the seven) were characterized by satisfactory productibility at comparable levels (the range of difference between the values in this area was 0.184),
- one of the nodes demonstrated poor productibility and one good productibility,
- none of the nodes reached the best, i.e. very good, productibility.

Table 4. Values of the multi-criteria assessment of the hybrid nodes analyzed (on the basis of [5])

No.	Assessment criterion	Assessment on a score scale (of 0 to 5) for particular nodes						
		HN1	HN2	HN3	HN4	HN5	HN6	HN7
1	(connector) Feasibility	5	5	1	2	5	1	1
2	Adaptability	4	4	3	4	5	4	4
3	Accessibility	5	5	4	4	4	4	4
4	(technological) Universality	4	4	3	4	5	3	3
5	(constructional) Universality	1	1	1	1	2	2	4
6	Instrumentality	4	4	3	4	4	3	3
7	Size	0	1	1	3	3	3	3
8	(node) Feasibility	4	4	3	4	3	3	2
9	Deformability	3	3	2	3	2	3	2
10	Correctibility	3	3	2	3	2	3	2
11	Esthetics	2	1	3	3	4	3	4
12	HN chart area [-]	1.135	1.135	0.626	1.167	1.535	0.994	0.983
13	Share of the HN chart area in the ideal chart area [%]	38	38	21	39	52	33	33

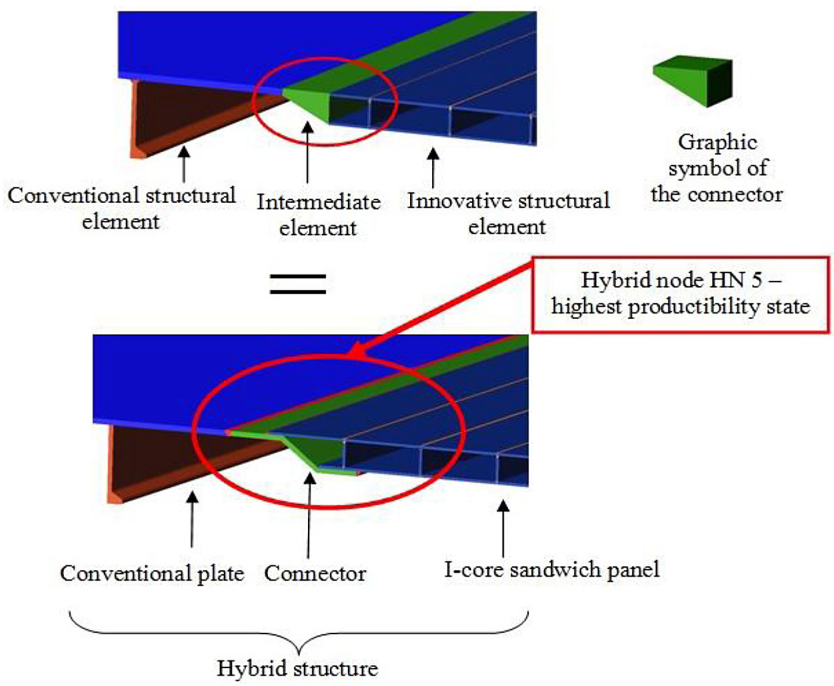


Fig. 4. The hybrid node characterized by the highest state of productibility (on the basis of [5])

The analysis performed in this paper allows for choosing the hybrid node and, at the same time, the connector shape that is characterized by the best (i.e. good) productibility. It is the node number 5 (Table 1). Therefore, the geometry of HN 5 was accepted as the most assembly suitable (Figure 4).

CONCLUSIONS

The multi-criteria expert method presented in this paper allows for determining the productibility of hybrid nodes, and thus for raising the objectivity of the choice. On the basis of this method, a hierarchy of the nodes' productibility states can be created.

Large-size steel structures are characterized by substantial structural and technological repeatability. Therefore, selecting the element that demonstrates potentially the highest assembly suitability can bring notable benefits at the stage of manufacturing the hybrid structure – namely smaller welding deformations, which in turn will help minimize the number of corrective procedures that entail considerable labor intensity and generate costs. It is estimated that the labor intensity involved in straightening large-size steel structures accounts for up to 30% of the total labor intensity required in order to perform the structure [1, 2].

That is why it is worth making the right choices at the earliest (conceptual) stages of developing the structure

REFERENCES

1. Kubera S.: Odkształcenia spawalnicze i zasady ich usuwania w okrętowych konstrukcjach cienkościennych, Doctoral Dissertation, Gdańsk University of Technology, Gdańsk 1964.
2. Metschkow B.: Współczesna technika utrzymania wysokiej jakości konstrukcji okrętowych, X Konferencja: Laboratoria technologiczne – aspekty utrzymania wysokiej jakości wyrobu, Wydawnictwo uczelniane Politechniki Szczecińskiej, Szczecin 1999.
3. Pyszko R.: Zastosowanie stalowych paneli typu sandwich w konstrukcjach okrętowych i oceanotechnicznych. Doctoral Dissertation, Department of Ship Technologies, Quality Systems and Materials Science, Faculty of Ocean Engineering and Shipbuilding of Gdańsk University of Technology, Gdańsk 2006.
4. 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.
5. Urbański T.: Metoda prognozowania odkształceń spawalniczych węzła hybrydowego na podstawie badań eksperymentalnych, Doctoral Dissertation, Chair of Ship Structure, Mechanics and Fabrication, Faculty of Maritime Technology, West Pomeranian University of Technology in Szczecin, Szczecin 2009.
6. Urbański T.: Węzeł hybrydowy – technologiczność wielkogabarytowych konstrukcji spawanych – wprowadzenie, Przegląd Spawalnictwa, 11, 2010, 21-25.
7. Urbański T.: The influence of welding deformation types of hybrid node on assembly suitability, Advances in Science and Technology Research Journal 6(16), 2012, 42-47.
8. Company standard: T081-02, Spawanie łukowe w osłonie gazów ochronnych, część II – Instrukcje technologiczne spawania WPS, Stocznia Szczecińska S.A. 2001.
9. Company standard: T081-03, Spawanie automatyczne łukiem krytym, część II – Instrukcje technologiczne spawania WPS, Stocznia Szczecińska S.A. 2001.
10. The catalogue of Stalprodukt S.A. Kształtowniki stalowe gięte na zimno. (http://www.stalprodukt.com.pl).