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Building Information Modelling recognition in ship's machinery designing and construction

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Abstract

Building Information Modelling (BIM) technology is briefly reviewed in this paper in order to demonstrate the potential application of this methodology in the shipbuilding industry. A properly-created BIM model is a valuable tool for the designers and future users of a given investment. BIM models improve the design and execution process and serve as a tool to maintain and manage any asset. The purpose of this article is to propose to use BIM technology in other construction industries, including the shipbuilding industry. A properly-constructed BIM model of a ship can be used both by the shipyard, as well as by the ship owner or target users. The information contained in the BIM model of the ship can be used to optimize the execution phase in the shipyard, as well as provide valuable assistance to the user of the unit during its operation.

Introduction

Each year, Building Information Modelling (BIM) technology sees an increase in use in the design and construction industry. Other companies that play the role of engineering, procurement, and construction (EPC) in large investments appreciate the positives that result from the use of BIM technology. Although the very process of implementing this technology may be initially disruptive and long-lasting, the benefits of its implementation fully compensate for this drawback. A properly-created BIM model is helpful not only to the investment contractor itself but can also be a valuable tool for the recipient and future user of a given investment. BIM models of a given investment facility not only improve the design and execution process but also serve as tools to maintain and manage this facility.

The purpose of this article is to demonstrate that BIM technology, although originally dedicated to the construction industry, can also be perfectly applied to other industries, including the shipbuilding industry. A properly-constructed BIM model of a ship can be used both by the manufacturer – the shipyard – as well as by the future user or ship owner. The information contained in the BIM model of the ship can be used to streamline and optimize the execution phase in the shipyard, as well as provide valuable assistance to the user of the unit during its operation.

BIM technology

The term BIM started to appear in the construction industry at the beginning of the 21st century, but its idea was developed much earlier in the 1970s at the Georgia Institute of Technology. The further development of BIM was dictated by the growing interest of construction companies and construction offices with the goal of integrating and better managing increasingly complex projects in the construction industry. A breakthrough in the scope of the relevant software for BIM was the publication of Archicad by Graphisoft in 1986. This programme was the first to enable the creation of three-dimensional objects and assignment of attributes to them (Rokooei, 2015). Using a 2D environment is so burdensome that the objects created in it are merely a collection of simple geometric elements with no dependencies between them, so that changing the geometry of one object requires manually changing the others. If this object also occurs on several projections, updating the whole project can become very cumbersome and labour-intensive (Chybowski & Gawdzińska, 2016a; 2016b). Modelling in a 3D environment using parameterized objects and creating dependencies between these objects allows for a quick and often automated revision of the project, which significantly accelerates the entire design process (Gulillen, 2016; Fernandes, Alves de Sousa & Ptak 2018a, 2018b; Karliński, Ptak & Dzialak, 2018).

A common way to define BIM is that it is a virtual model of a planned construction project. However, it should be remembered that the virtuality of this model provides more than just a spatial, three-dimensional visualization. BIM is not limited to only the 3D modelling tools of objects in a CAD environment, but it also allows a user to attach information about their properties to such objects and make them interrelated with other objects (McArtur, 2015; Gulillen, 2016). Currently, it is often said that BIM models are created in a 7-dimensional design space. In order to better understand this statement, one should consider the following dimensions of the design.

- 2D model – is a classic two-dimensional object created on a flat coordinate system. The models created in this environment have very limited possibilities of storing additional information.
- 3D model – a model created in a three-dimensional environment, in the form of solids or a set of surfaces. Such a model can be a carrier of information about geometry and basic physical features. Very often, 3D models are created using parameterization tools, which allows them to be quickly modified and adapted to variable input data.
- 4D model – is a model that includes information related to an investment flow schedule, a sequence of further actions. Such a model can be used as a source of data for planning and monitoring the course of investments.
- 5D model – a model that includes financial data. This model can be used to predict and create budgets and control the budget of a currently-implemented investment.
- 6D model – contains data necessary to ensure sustainable development. It allows you to control the impact of individual actions on the course of the investment.
- 7D model – this model contains data needed to manage an investment object. It allows planning activities to sustain the life of an investment object and facilitates strategic decision-making when managing the object. For example, reliability structures that are based on algorithms to ensure better diagnostics, maintenance, and control can be implemented (Chybowski & Żółkiewski, 2015; Gulillen, 2016; Derlukiewicz et al., 2017).

The fundamental information that the BIM model of a given object contains is of course geometric data, and any additional information can be entered manually by the person managing the model, or it can be generated automatically by the appropriate software used to create the model.

Example: After giving the appropriate geometric form and defining the material from which the element is to be made, the programme will generate information about the total surface area of this element, its volume, and report its mass (Gawdzińska, Chybowski & Przetakiewicz, 2016; Gawdzińska et al., 2017, 2018). The mere fact that material assignments can be made to the product is already a distinguishing element of BIM modelling.

As shown in Figure 1, based on the geometry, the programme provides data about the surface area and volume of a given element, and assignment of the appropriate material allows the program to calculate its mass.

An important feature of the BIM model is its open source and open data approach. This means that the model of a given facility created at the concept stage is developed not only in the design process, but also in the execution and as-built phases when used by the target user. In the implementation phase, the model can be supplemented and updated with data flowing from the production process, such as:

- manufacturing technology used;
- costs of materials;
- transport costs;
- process schedule;
- problems encountered and their solutions.

The end of the executive phase does not mean that the BIM modelling is completed. The model can still be supplemented with information provided by the user of the facility, such as:

- object maintenance costs;
- media expenditure (electricity, water);
- inconveniences encountered during use;
- emergency situations.

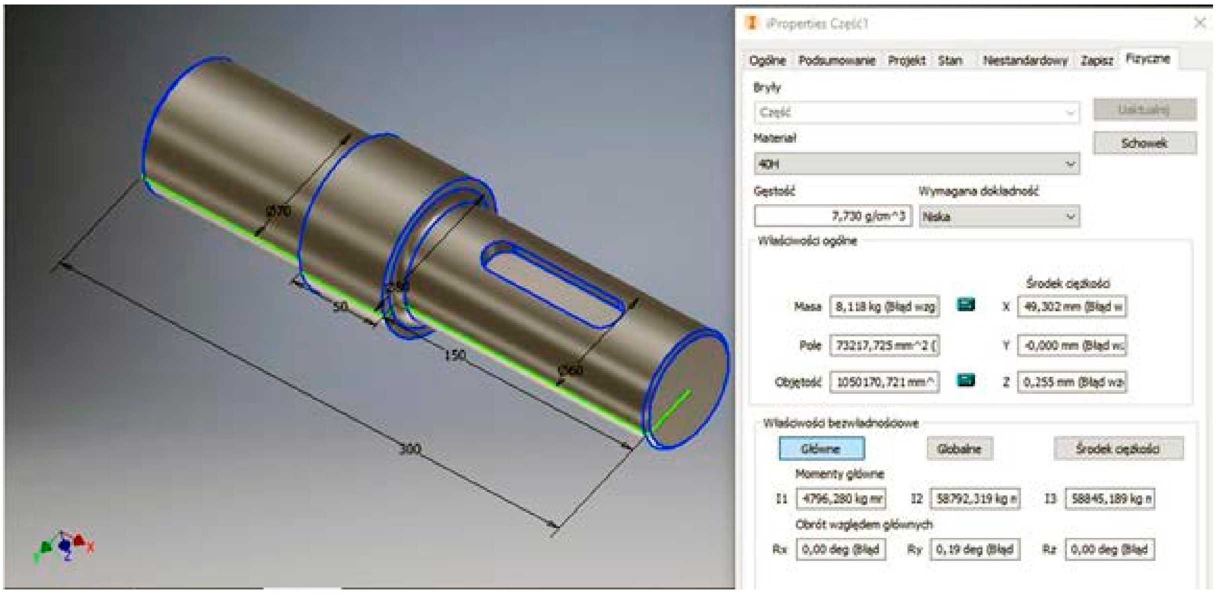

Figure 1. An example of a model created in a 3D environment for BIM purposes

The above-mentioned information that can be inserted into the model are just a few examples of data to which the BIM model can be extended. Their quantity and methods of storage in the model depend, in fact, on the person using and managing this model.

Implementation of BIM – challenges and potential difficulties

Considering how much information, often quite extensive, can be put into the BIM model, the problem of their proper formatting and ordering still exists. The issues of the format and the means of data storage seem to be relatively simple, assuming the entire project is implemented on one type of software within one company. File exchange or sharing may take place with any of the data entered into the model. However, this situation is extremely rare and usually involves small investments usually outsourced to one entity. It is much more likely to deal with multi-branch projects involving many entities.

CAD software vendors, noting how dynamically BIM ideology develops, constantly modify their flagship applications and environments so that they are compatible with commonly-accepted BIM standards. Additionally, thanks to the efforts of the building SMART organization, the IFC (Industry Foundation Classes) format has been developed, which is a universal carrier of design data. IFC files are recognized and read by leading programmes dedicated to BIM standard design (Rokooei, 2015). This format is described in detail in the ISO16739: 2013 standard "Industry Foundation Classes for data sharing in the construction and facility management industries." The second data format known within the BIM community is COBIE (Construction Operations Building Information Exchange), developed by the US Army Corps of Engineers. This format, however, is less frequently used because it is not a carrier of geometric information, but mainly gathers data such as data sheets, diagrams, lists of elements, etc. (Pajor, Marchelek & Powalka, 2002; Gulillen, 2016; Sakow et al., 2017).

The more difficult issue is the ordering and proper management of the BIM model. Of course, one can also count on appropriate supporting software, but a given programme will be effective only when the person using has the right knowledge and skills. Therefore, the people who create and manage the BIM model need to be systematic and have good organizational skills. The person creating and managing the BIM model must be aware that the model should be readable not only for the person or a small group of people connected from the beginning of the investment, but also for each person who joins this investment at its various stages. It should be remembered that the recipient or user of the BIM model will not always be a person with technical education. An example of such a situation is when financial data is included in the model, which can be used by the financial department of a given company when calculating the real costs of the investment or estimating the costs of a new, similar investment.

The structure of the BIM model must be transparent and understandable from the very beginning for each user. If this is discontinued at the initial stage of the model's development, it will be very difficult to correct it later, since the model will grow as the investment progresses. Creating a BIM model structure should anticipate a simple dependency: the more complex and extensive the investment, the more complex a virtual model of such an investment will be. Considering how much information can be contained in such a model, it can inadvertently lead to a situation in which "information noise" is created, which will only make it more difficult to use the BIM model. To avoid this situation, the person managing the BIM model must monitor what information, where, and when they are placed in the model. The appropriate procedure for submitting such data by individual investment participants should be developed prior to the creation of the BIM model. Another problem that can also occur when creating a virtual investment model is a too-detailed depiction of all elements of the model. From the point of view of the investor or the future user, a model as close as possible to the actual state is very attractive. It can then be used for marketing purposes or be used in training processes at a given facility. However, from a designer's or contractor's point of view, a too-detailed model can be a hindrance. Usually, the level of detail that is too high means that the model takes up a lot of memory and puts a heavy load on the workstation on which it is operated. For design offices that often use computer equipment dedicated to design in a 3D environment, it may not be that much of a problem (Laskowski, Chybowski & Gawdzińska, 2015). However, it should be remembered that the BIM model is also used by engineers who are directly on the construction site, where the conditions are sometimes very difficult and where there is always equipment dedicated to the use of 3D programmes. In addition, there are also problems with the bandwidth of Internet connections, which are necessary for mutual communication and sharing of the BIM model. Considering the above, it is necessary to maintain moderation and common sense when creating virtual models of individual objects. Sometimes a very complicated device with a complex shape can be graphically represented to a certain degree of simplification, while maintaining only the overall dimensions, the location of connection sockets, and other elements important from the point of view of design or assembly. It should also be remembered that for the sake of adjustment to the BIM model, sometimes information that is not visible at first glance is more important, which may turn out to be extremely valuable for design or performance.

In Figure 2, the model on the left is very realistic visually, and it shows the exact shape of the collar, its opening, and screw connections. The model on the right is a very poor graphical model since it does not contain flanges, the type of screws used, or their number. At first glance, it would seem that the model on the left is more detailed, and as such, should be more valuable for the BIM project. In fact, the model on the right is a model that better meets the requirements of BIM technology. All relevant information regarding drilling, nominal pressure, rebate type, or gaskets between flanges are given in text form as attributes assigned to each element. Extracting this information and processing it is much easier and more convenient than the model on the left. A common feature of both models is only the maintenance of basic graphical information about the dimensions of the flanges and their representation in the model. This is an important feature of every element of the model, since the overall size of a given body is an important factor influencing its location in the space often occupied by other elements of the model. In other

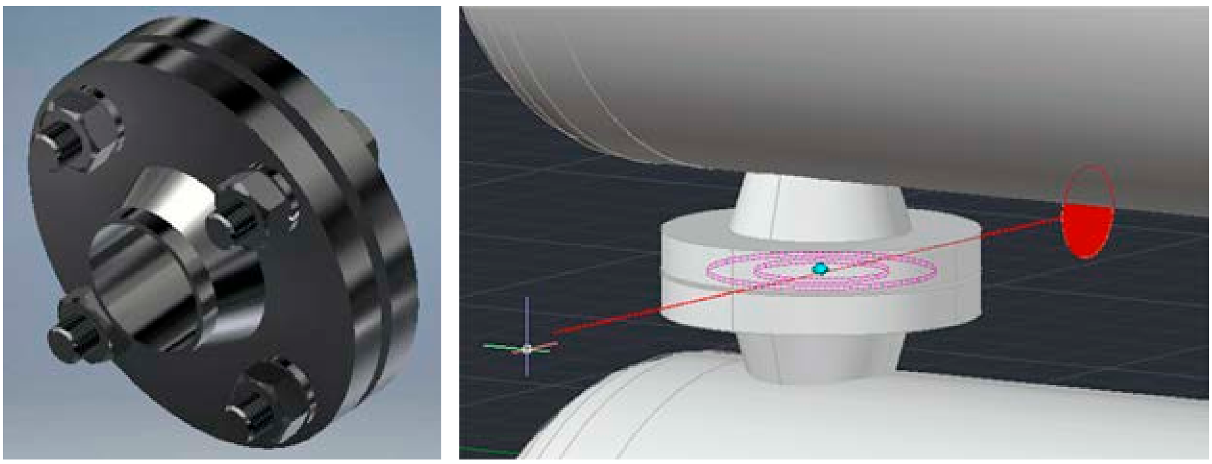

Figure 2. Examples of flange connections realized in two different CAD environments

Table 1. Levels of development (AIA E202, 2008)

Level of development (LOD)	Description
LOD 100 Schematic Design Model	Overall building massing indicative of area height, volume, location and orientation may be modelled in three dimensions or represented by other data
LOD 200 Design Development Model	Model Elements are modelled as generalized system or assemblies approximate quantities, size, shape, location and orientation. Non-geometric information may also be attached to model elements
LOD 300 Construction Documentation Model	Model Elements are modelled as specific assemblies accurate in terms of quantity, size, shape, location and orientation. Non-geometric information may be attached to model elements
LOD 400 Construction Model	Model Elements are modelled as specific assemblies accurate in terms of quantity, size, shape, location and orientation with complete information assembly, and detailing information. Non-geometric information may be attached to model elements
LOD 500 Record Model	Model Elements are modelled as constructed assemblies actual and accurate in terms of quantity, size, shape, location and orientation with complete information assembly, and detailing information. Non-geometric information may be attached to model elements

words, with the presented real dimension of a given part on the screen, the designer can assess whether a given part will fit in its designated area.

To systematize the level of detail of the model, "Level of Development" (LOD) was developed, which determines the amount and form of data (including graphic data) to be modelled at a given level. The LOD defined in the AIA E202 standard is widely accepted in the industry, and Table 1 presents the individual LOD levels and a brief description of each.

BIM in shipbuilding industry

Considering for which industry the BIM technology was developed, or even looking at the development of the shortcut (Building Information Modelling), one can have doubts as to whether something designed for the construction industry could be used in the shipbuilding industry. To understand this, the way of thinking about BIM technology should be changed and its source should not be considered. Currently, BIM is used to help in the implementation of complex, extensive investment tasks, often long-term ones. An example of such a task is the building of a ship, especially a large-size ship like a tanker, a cruise ship, or an aircraft carrier. The size of the ship itself is of course not the only determinant for the implementation of BIM technology, and it can also be used in the design of smaller vessels that are more complex in their construction. It is the degree of complexity of the project and the degree of assimilation to the building structure that should determine the possible application of solutions typical for BIM. An example of this is the design of a luxury yacht, which in terms of comfort will not be different from a luxurious apartment in the city centre or a cottage outside the city. Apart from the obvious differences between the construction of the yacht and the house, both these objects have some common features. In both there are common installations such as: lighting, ventilation, heating, or sanitary. Projects of these installations can therefore be made using BIM tools, which will ensure: a single, consistent database, correlation between individual projects, project coordination, and other essentials from the point of view of performance and maintenance elements.

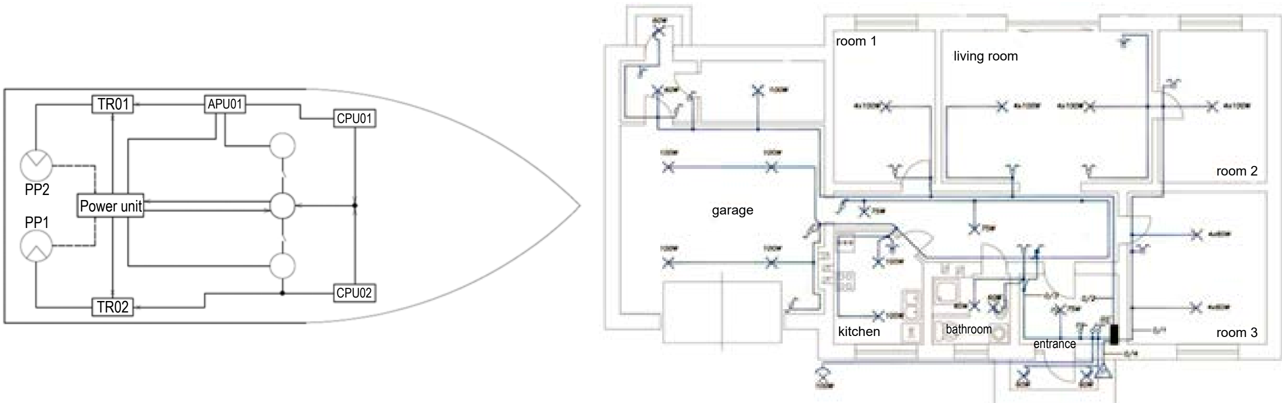

Figure 3. Wiring diagram of an exemplary boat and a residential house

The electrical installation of a boat and a dwelling may differ in many respects, but when designing them, the same tools are used, such as a schematic diagram, a list of elements, and a list of connections. All these elements of the project can be connected to each other as part of the BIM technology and additionally correlated with the projects of other installations (Figure 3).

Conclusions

The relatively new idea of using BIM methodology in the shipbuilding industry has been presented in this work. Notwithstanding of the small number of examples shown in this work, the paper's objective has been accomplished. The paper presented current tendencies of BIM implementations in ship-related projects, including implementation difficulties, challenges, advantages, and levels of development. When properly implemented, BIM methodology has great advantages when comparted to the traditional CAD modelling and designing aid. The BIM development is worth considering despite the fact it needs a higher initial workload in comparison with the limited CAD approach.

Apart from designing and constructing new ships, BIM can also be used to reverse-engineer ships currently in use. Thanks to this technology, it will be easier to convert and modernize ships, for example in terms of modern and more ecologically-friendly drives (Bejger, Chybowski & Gawdzińska, 2018; Chybowski, Grządziel & Gawdzińska, 2018). In such cases, a precise technical information base is necessary not only for the replacement of drives, but also for the replacement of ship automation systems and control systems. With BIM, it is possible to plan the modernization of, for example, passenger space, adding utility spaces (kitchens, cafes, clubs, etc.), replacement of pipelines and HVAC systems, full maintenance, or painting works to the full extent (Pajor, Marchelek & Powalka, 1999; Berczyński, Lachowicz & Pajor, 2001; Pulikowski, 2017).

In future works, exemplary realizations and use cases by means of BIM technology in applications in the ships and shipbuilding industry will be shown. The cases will allow the inclusion of preventative, volatile, and flexible conditions, extended meantime between failures periods with resources reporting, hazard inventory, and precise scheduling. The approach of the BIM model as a single source of information from the full range of information will be presented. This will facilitate using these BIM models as efficient tools for designing and managing assets.

References

1. AIA E202 (2008) Building Information Protocol Exhibit.
2. Bejger, A., Chybowski, L. & Gawdzińska, K. (2018) Utilising elastic waves of acoustic emission to assess the condition of spray nozzles in a marine diesel engine. *Journal of Marine Engineering & Technology* 17, 3, pp. 153–159, doi: 10.1080/20464177.2018.1492361.
3. Berczynski, S., Lachowicz, M. & Pajor, M. (2001) An improved method of approximating frequency characteristics in the problem of modal analysis and its applications. *Computational Methods and Experimental Measurements X. Computational Engineering* 3, pp. 575–584.
4. Chybowski, L. & Gawdzińska, K. (2016a) On the Possibilities of Applying the AHP Method to a Multi-criteria Component Importance Analysis of Complex Technical Objects. *Advances in Intelligent Systems and Computing* 445, pp. 701–710, doi: 10.1007/978-3-319-31307-8_71.
5. Chybowski, L. & Gawdzińska, K. (2016b) On the Present State-of-the-Art of a Component Importance Analysis for Complex Technical Systems. *Advances in Intelligent Systems and Computing* 445, pp. 691–700, doi: 10.1007/978-3-319-31307-8_70.
6. Chybowski, L., Grządziel, Z. & Gawdzińska, K. (2018) Simulation and Experimental Studies of a Multi-Tubular Floating Sea Wave Damper. *Energies* 11(4), pp. 1012:1–20, doi: 10.3390/en11041012.
7. Chybowski, L. & Żółkiewski, S. (2015) Basic Reliability Structures of Complex Technical Systems. In: Rocha A., Correia A., Costanzo S., Reis L. (Eds) *New Contributions in Information Systems and Technologies. Advances in Intelligent Systems and Computing* 354. Springer, Cham.
8. Derlukiewicz, D., Ptak, M., Wilhelm, J. & Jakubowski, K. (2017) The Numerical-Experimental Studies of Demolition Machine Operator Work. In: Rusiński E., Pietrusiak D. (Eds) Proceedings of the 13th International Scientific Conference. RESRB 2016. *Lecture Notes in Mechanical Engineering*, pp. 129–138, Springer, Cham.
9. Fernandes, F.A.O., Alves de Sousa, R.J. & Ptak, M. (2018a) Application of Numerical Methods for Accident Reconstruction and Forensic Analysis. In: *Head Injury Simulation in Road Traffic Accidents*. Springer Briefs in Applied Sciences and Technology, pp. 59–98, Springer, Cham.
10. Fernandes, F.A.O., Alves de Sousa, R.J. & Ptak, M. (2018b) Development of a New Finite Element Human Head Model. In: *Head Injury Simulation in Road Traffic Accidents*. Springer Briefs in Applied Sciences and Technology, pp. 25–39, Springer, Cham.
11. Gawdzińska, K., Bryll, K., Chybowski, L. & Berczyński, S. (2018) The impact of reinforcement material on selected mechanical properties of reinforced polyester composites. *Composites Theory and Practice* 2, pp. 65–70.
12. Gawdzińska, K., Chybowski, L. & Przetakiewicz, W. (2016) Proper Matrix-Reinforcement Bonding in Cast Metal Matrix Composites as a Factor of Their Good Quality. *Archives of Civil and Mechanical Engineering* 16(3), pp. 553–563, doi: 10.1016/j.acme.2015.11.004.
13. Gawdzińska, K., Chybowski, L., Przetakiewicz, W. & Laskowski, R. (2017) Application of FMEA in the Quality Estimation of Metal Matrix Composite Castings Produced by Squeeze Infiltration. *Archives of Metallurgy and Materials* 62 (4), pp. 2171–2182, doi: 10.1515/amm-2017-0320.
14. Gulillen, A.J. (2016) Building Information Modeling as Asset Management Tool. *IFAC-Papers On Line* 49, 28, pp. 191–196.

15. Karliński, J., Ptak, M. & Dzialak, P. (2018) *Improving occupant safety in heavy goods vehicles – universal energy absorbing system*. 11th International Scientific and Technical Conference on Automotive Safety, Casta Papiernicka.
16. Laskowski, R., Chybowski, L. & Gawdzińska, K. (2015) An engine room simulator as a tool for environmental education of marine engineers. New Contributions in Information Systems and Technologies. *Advances in Intelligent Systems and Computing* 354, pp. 311–322, doi: 10.1007/978-3-319-16528-8_29.
17. McArtur, J.J. (2015) A building information management (BIM) framework and supporting case study for existing building operations, maintenance and sustainability. *Procedia Engineering* 118, pp. 1104–1111.
18. Pajor, M., Marchelek, K. & Powalka, B. (1999) Experimental verification of method of machine tool – cutting process system model reduction in face milling. *Computational Methods and Experimental Measurements IX. International Series on Computational Engineering* pp. 503–512.
19. Pajor, M., Marchelek, K. & Powalka, B. (2002) Method of reducing the number of DOF in the machine tool-cutting process system from the point of view of vibrostability analysis. *Journal of Vibration and Control* 8, 4, pp. 481–492.
20. Pulikowski, D., Lackner, F., Scheuerlein, C., Meinel, D., Savary, F., Tommasini, D. & Pajor, M. (2017) Testing Mechanical Behavior of Nb3Sn Rutherford Cable During Coil Winding. *IEEE Transactions on Applied Superconductivity* 27, 4, 4802105.
21. Rokooei, S. (2015) Building Information Modelling in Project Management: Necessities, Challanges and Outcomes. *Procedia – Social and Behavioral Sciences* 210, pp. 87–95.
22. Saków, M., Parus, A., Pajor, M. & Miądlicki, K. (2017) *Nonlinear Inverse Modeling with Signal Prediction in Bilateral Teleoperation with Force-feedback*. In: Proceeding of 22nd International Conference on Methods and Models in Automation and Robotics (MMAR), pp. 141–146.