SELECTION OF MEASURING EQUIPMENT IN ASSEMBLY PROCESS - ANALYSIS OF SELECTED ELEMENTS

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Summary

The paper presents function of selection of measuring equipment - *DWP* function. Analysis of the individual elements of described the function can be used for isolation the most important measurement components of the selection of measuring equipment for selected measurement processes. The paper shows one chosen element of function of selection of measuring equipment – metrological characteristics. Those characteristics are shown on the example of chosen measuring equipment which is used in the alignment deviation measurements carried out during the assembly of elements of the ships propulsion system.

Keywords: measuring equipment, metrological characteristics, ships propulsion system.

DOBÓR WYPOSAŻENIA POMIAROWEGO W PROCESACH MONTAŻOWYCH - ANALIZA WYBRANYCH ELEMENTÓW

Streszczenie

W artykule przedstawiono funkcję doboru wyposażenia pomiarowego - funkcja *DWP*. Analiza poszczególnych elementów przedstawionej funkcji może służyć wyodrębnieniu najistotniejszych składników doboru wyposażenia pomiarowego dla wybranych zadań pomiarowych. W artykule zobrazowano jeden z elementów funkcji doboru wyposażenia pomiarowego - właściwości metrologiczne. Charakterystyki te przedstawiono na przykładzie wyposażenia pomiarowego wykorzystywanego w trakcie pomiarów odchyłki współosiowości realizowanych w trakcie montażu elementów okrętowego układu napędowego.

Słowa kluczowe: wyposażenie pomiarowe, właściwości metrologiczne, okrętowy układ napędowy.

1. INTRODUCTION

The selection of measuring equipment includes in its scope activities both associated with choosing the method of realization of measurement process and also the need to define the characteristics of the required equipment to assemble the ships propulsion system.

Appropriate analysis of criteria gives the opportunity to select the measuring equipment which may allow to provide the service of measurement and gives the results of measurement with required accuracy and reliability. Measuring equipment which is used affects the quality of the entire production process and thereby on competitiveness and customer confidence to the company.

2. CRITERIA OF THE SELECTION OF MEASURING INSTRUMENTS

In all types of measurements the proper selection of measuring instruments plays an important role. The selection is decided by the criteria for both technical and metrological, which are linked to the characteristics of measuring instruments and devices. The analysis of subsequent criteria of selection of measuring equipment allows to distinguish from many measuring equipment those which are the best for the realized measurement process.

In mechanical engineering criteria for rational selection of measuring instrument are [1]:

- kind of measured dimension,
- means of determining and fixing the measured item,
- means to receive information about the measurand,
- the possibility to develop a performance result of a measurement,
- the possibility of a direct transfer the measurement's results to the data analysis system,
- value of a measurand,
- optimal uncertainty of measurement.

When selection the measuring instruments is taken into account the required accuracy of the product, batch size, degree of mechanization and

automatization, measurement and economic characteristics of the measuring tool must be kept in mind. The following elements are required to determine [2]:

- accuracy class of the product based on the tolerances specified in the standards or technical conditions,
- precision of measuring equipment necessary to make a product within the specified tolerances,
- the type and accuracy of measuring equipment used in process of control tools as well as direct control of the product,
- mean of connection control tools with state's etalons.

Other significant factors influencing the choice of the same technical equipment proposals are general factors, such as [3], [4]:

- availability of additional equipment,
- compatibility,
- ease of service and preparation of work,
- safety,
- technical maturity,
- exploitation development.

3. SELECTION OF MEASURING EQUIPMENT

Selection of measuring equipment for the measurement process and the selection of its properties in accordance with the requirements is provided through a well-organized measurement management system. The scope of this system, which can differentiate the supervision of measuring equipment can be divided into three phases [5], [6]:

1. Planning, in which needs are defined in terms of access, the use of measurement systems, requirements, properties, time and place and quantity of the necessary equipment, and with this range of purchases and the necessary training. Information necessary for planning are derived from all areas of production.
2. The management of measuring equipment, which includes the disposition and management of data related to the equipment, evaluation and data analysis of metrological confirmation system, as well as documenting the activities of its control.
3. Control of the characteristics include an evaluation of purchased equipment and systematic monitoring of its metrological characteristics. The scope of these activities is checking equipment purchased or repaired for fulfilling the established requirements.

The issue of selection of the measuring equipment can be presented in general form as function. It illustrates how many factors affect the choice of measuring equipment.

$$DWP = f\,[(W_{1...}W_i), (U_1 \ldots U_j), (S_1 \ldots S_k), (P_1...P_l), (C_1...C_m), (K_1...K_n), (Kj_1...Kj_o), (Z_1...Z_p), (I_1...I_r)] \quad (1)$$

where:

DWP – (pol. Dobór Wyposażenia Pomiarowego) selection of measuring equipment,
W - metrological characteristics of measuring instruments such as the accuracy of the measuring range,
U - functional characteristics of measuring equipment such as ease of use, reliability, durability, maintainability,
S - characteristics of equipment and measurement systems and software for analyzing the results (uncertainty, reproducibility, repeatability),
P - structural characteristics of the propulsion system (technical specifications, dimensions, specify the test section and areas of measurement process),
C – labour consumption,
K - the cost of measurement, including direct measurement of total costs and maintenance costs of the equipment,
Kj - the cost of quality: the cost of providing and quality assessment,
Z - personnel management (training, motivation, experience, skills),
I - Infrastructure - buildings, facilities, handling equipment.

The presented function does not deplete the possibilities of the analyzed criteria in the selection process of measuring equipment. Factors which occur in formula (1) are components of both technical and economical. In this case, the determination of optimal ratios which are the best in a specific sense of the processes is very difficult. These indicators can be both described as number and descriptive, can be presented both quantitatively and qualitatively. This makes it impossible to make an exact mathematical notation of *DWP* function and thereby to achieve the value of measurand of the function (1), which is the criteria of its optimality.

4. ANALYSIS OF THE SELECTION OF MEASURING EQUIPMENT DURING THE ASSEMBLY OF SHIPS PROPULSION SYSTEM

When analyzing the selection of measuring equipment in every industry it should be aware that if there is a need to purchase equipment, particular attention should be paid to the selection of an appropriate manufacturing process of measuring equipment. The prevailing factor here is - the question of functionality and versatility of measurement tools. It is necessary to plan the use of tools on the basis of realized technological processes. Consideration should be given to the knowledge of the exploitation of ships propulsion system during normal operation, the types of couplings and examine the foundations and connections, mounting screws and other working conditions.

The next step is the cost analysis, which will determine the rationality of taking expenses. Depending on the adopted selection criteria the decision taken must be economically justified. The number of objects on which these measurements will be carried out depends on the form of business. Purchase of expensive equipment would not be profitable for the production of small series of large units, where there is a significant time-consuming process, while the cost of purchase for repairs purpose will be recovered in a short time, due to the large number of watercrafts using the services of a repair shipyard.

A selection of measuring equipment, its characteristics, range, accuracy, durability in the conditions of production, the analysis of quantity and place where the equipment is placed is essential for the well-functioning management systems. These elements support the surveillance and control mechanisms and thus to ensure the high quality of products. Particularly in small enterprises during the selection of equipment the attention should be paid to its versatility, as well as flexibility used for the periodic inspection of software, defined as the ability to customize to the specific requirements of industry standards.

Properly decisions regarding the selection of the measuring equipment must be based on appropriate supporting systems. These decisions are made under the basis of analysis of many variants of solutions which can be used thanks to constant development of measuring techniques but using them involves different consequences . To enter into this decision-making process a large number of criteria must be selected, one introduce an enormous amount of data (factors expressed by quantitatively and qualitatively), which increases the workload analysis. It is necessary to develop systematic procedures, modern techniques for making decisions on the measuring equipment used for measuring tasks in the assembly of ships propulsion systems. It should be noted to carefully select criteria. In this paper limited number of criteria was taken in consideration (*DWP* function (1)). The social or ecological criteria were omitted in undertaken analysis. Adoption of such criteria directly affects the use of chosen equipment. The rest of this article will present considerations for the metrological characteristics of measuring instruments used during the assembly of ships propulsion system.

5. COMPARISON OF THE METROLOGICAL INSTRUMENTS USED FOR MEASURING IN THE SHAFTS ASSEMBLY PROCESS

During preparation of the technological processes, it is necessary to plan the use of particular equipment in consecutive stages during the control measurements.

In accordance with standards PN-EN ISO/IEC 17025:2005 (5.5) [7], equipment and its software used for testing shall be capable of achieving the accuracy required and shall comply with specifications relevant to the tests concerned. Each item of equipment and its software used for testing significant to the result shall be uniquely identified. The equipment can be selected at the stage of planning the measurement operation but it is very important that the whole measurement process be consider when selecting measuring equipment to satisfy requirements [8]. The correctness and reliability of the measurement is determined by many factors [7]: human factors, accommodation and environmental condition, test method or metrological characteristic [8] of a measuring equipment as required for the intended use (for example accuracy, stability and range).

To illustrate the selected components of *DWP* function (1), taking in consideration mentioned metrological properties of measuring instruments that can be used while measuring the deviation of aligned elements of the shaft, were set together.

The tables presents a comparison of selected metrological characteristics for machine tools: gap gauge, dial gauge, and measuring method using piano wire (Tab. 1) and also optical and laser instruments (Tab. 2). The statements contained in the tables use the same evaluation criteria.

Tab. 1. Overview of the metrological characteristics of selected metrological instruments used during the measurement done by conventional methods in the assembly process of the propulsion system

	Conventional methods		
Characteristics	Gap gauge and Knife edge rule	Dial gauge	Piano wire
Range of indication	0,05-1 mm	10 mm	Depends on used measuring instrument
Accuracy of measurement	0,1 mm	0,02 mm	Depends on used measuring instrument, construction of element and value of a measurand
Scale interval	0,05 mm 0,1 mm	0,01 mm	Depends on used measurement instrument: e.g.: inside micrometer 0,01 mm
Measured part of shaft line	Point of measurement	Point of measurement	Depends on construction
Error of measurement	1[1]	1[1]	1[1]
Method of measurement	Point method	Radial-axial method, double radial method	Point method
Operator's experience	Long experience	Long experience	Long experience
Operator's training	Long term	Short term	Long term
Ability to safe the data files	No	No	No
Number of measuring points	4 + control position between pair of shafts	4 * number of sections depending on the construction (between the shafts, shaft and gearbox)	3 sections * 4 positions + 10 measuring points on the foundation of elements of propulsion system[2]
Results analysis	Point done by operator	Point done by operator	Point done by operator
Maintenance	Required	Required	Maintenance of used measuring instrument
Type of power supply	None	None	None
Accessories	None	Grip, fixing bridge	Stand, view fifers
Additional software	None	None	None
Problems	Surface Shape error, measurement environment	Deflection of fixing grip, grip construction, hysteresis of sensor, parallax error, measurement environment	Sag and tension, setup of stands, measurement environment

1[1] Error values can be determined for the particular case of measurement in the measurement of statistical methods.
Example: The value of permissible error for dial gauge for the entire range is 20 μm [PN 68/M53260 Warsztatowe środki pomiarowe. Czujniki zębate zegarowe]. The permissible error for the inside micrometers is (3 + V + L/50) μm, where L in mm a V-number of extensions [data sheets for Mitutoyo analog inside micrometers series 139].
[2] Depending on the design of the item being measured, the table shows the number of measurement points during the measurement of single shaft of a Con-ro vessel.

Tab. 2. Summary of selected characteristics of optical and laser instruments

Characteristics	Optical instrument	Laser instrument
Range of indication	Depends on kind and type of instrument	Unlimited with the possibility of extending depending on the kind and type of equipment; for example measuring distance for laser measurement systems company's Easy-Laser D505 is 20m., D650 Linebore is 40 m., maximum distance between sensor and laser for Rotaling Prüftechnik Ultra is 10 m.
Accuracy of measurement	Depends on used measurement equipment and kind of a measurand,	0,001 mm
Measurand	Any size	Reliable to 30 m (in view of laser beam diffusion)
Operator's experience	Long experience	Long experience is not required
Operator's training	Directly on instrument	Training is organize by the equipment manufacturers, software indicates the steps of measurement
Stability of instrument	Stability of the optical system during the measurement	Stability of laser beam is depends of environment condition
Ability to safe the data files	Only in a few models	Directly in the equipment
Method of measurement	Point method	Multipoint method or the method of measurement in continuous operation
Number of measuring points	Preset by the operator depending on the size measured	Preset by the operator within 0-99, in case Static method (Optaling, Rotaling Ultra) measured at 45 degrees in 3 to 8 points
Results analysis	Perform by operator	Perform direct by the instrument
Maintenance	Required	Required
Instrument stability	Stable, long term used glass elements	Stable, resistant to environment condition depending on the class of protection
Type of power supply	Own power supply – buttery, off-site power	Own power supply – buttery, off-site power
Accessories	E.g. measurement roller for autocollimator are performed independently	Included, opportunity to buy additional mounting arms or rods
Additional software	No	Possibility to increase the number of modules
Problems	Environment condition effect	Environment condition effect

Properties shown in the statement of chosen metrological characteristics included in Tab. 1 and Tab. 2 refer to the chosen example, measuring systems used in talk over the conditions. They can provide the database for the selection of the measurement systems used during the assembly process.

Above mentioned metrological characteristics of measuring equipment (Tab. 1, Tab. 2) when taking into account such criteria as structural characteristics of propulsion system (P), quality characteristics of equipment (S) allow to make comparative analysis and to make the selection of measuring equipment. Such analysis can be treated as initial stage of

planning. In this paper economical aspects (K, K_j) in shipyard's real production conditions (availability of resources) are not mentioned so that it is not possible to make the practical implementation of evaluation and selection of measuring equipment (*DWP* function).

That is the reason why in the paper the factor W is chosen as the factor which determines the planning of measuring supplies in measurement management system.

On the example of Con-ro Vessel type B 201-II which shaft line length is 56 meters it is necessary, when taking into account data from (Tab. 2), to exclude laser instrument when determining the theoretical shaft line and use optical instrument or piano wire instead.

There is a possibility to obtain greater grade of accuracy of measurement when using optical or laser instrument but the use of conventional methods allow to obtain ample enough range of accuracy in technical conditions while assembling the shaft line. It is recommended to use laser instruments due to the necessity to make additional elements for dial gauge, piano wire and optical instruments to measure the alignment deviation of flanges of propulsion system elements. The use of laser instruments enable to reduce the setup time. The measurement precision, the possibility of its direct recording and repeatability of the measurement results are the advantages of using laser instruments and such things cannot be achieved by using conventional methods (Tab. 1). Laser instruments enable also sighting through the elements of propulsion system and controlling horizontal and vertical correction in real time and such features are not possible when using dial gauge.

6. CONCLUSIONS

Evaluation of the usability of measuring instruments for all types of applications is a natural necessity to ensure the proper conduct of the measurement process. Based on evaluation of the measurement system, and hence the efficiency of measuring equipment, a lot of decisions is taken under the control of the next stages of the assembly process of the ships propulsion system.

A well-organized control over a measuring equipment, most of all its selection will bring a lot of benefits for company including: the ability of measurement systems to provide reliable results, minimal risk of errors during measurement and misinterpretation of results, reduction of measurement costs, standardize procedures and instructions for the selection of measuring instruments.

The analysis of the selected criteria indicates the possibility of selection of measuring equipment which can allow to execute the measurement service giving the measurement results of the measurements with the required accuracy and reliability.

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