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Control of measurement equipment in the aspect of integrated quality management

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ABSTRACT

Purpose: of the paper has been an attainment of the confirmation that the base of improvement of production processes in the meaning
of quality of products and safety workplace are the results of measurement, monitoring and analysis realised with usage of measurement equipment.
Design/methodology/approach: Methodology used for the analysis has included design of the test and measurement system also measurement equipment required for
the correct performance of tests.
Findings: of analysis are as follows: properly designed system of management and supervision of test and measurement equipment should be capable of achieving the accurate and reliable results being the base for making subsequently relevant decisions.
Practical implications: can apply in case of any organisation, which uses clearly established procedures for obtainment, identification, usage and calibration of test and measurement equipment.
Originality/value: Value of the presented paper has been constituted by working out the plan of supervision of test and measurement equipment from the moment of selection criterion planning until the usage withdrawal.
Keywords: Improvement of process; Measurement and testing; Test and measurement equipment; Calibration

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1. Introduction

There are many factors influencing the quality of productive process and assurance of the conditions that are safe for workers' health and life and natural environment. One of those factors is properly designed test and measurement equipment management system, which should guarantee right interpretation of the results, and the proper reaction on the arisen problem - as the effect.

To make a measurement the reliable one, supervision over test and measurement equipment should be carried out from the moment of planning the criterion of the selection to the production tasks, through putting it into use, and finishing on the end-of-life stage.

Metrological equipment that has been chosen properly and has actual calibration status makes the decision concerning undertaking and application of appropriate corrective actions, in case of detection of incompatibility, easier.

If producer wants to maintain high quality of products and safety of work as well as to minimize influence on the natural environment, should carefully define conditions of handling test and measurement equipment connected with storing, calibration and periodical check-up.

Technically adjusted measurement equipment limits the possibility of supplying the market with defective product as well as of admission of breakdowns that can influence natural environment or human life.

2. Control of test and measurement equipment

ISO 9001 standard defines requirements that must be fulfil during supervision of monitoring and measurement equipment to assure correctness of results. According to 7.6 point of that standard, where it is necessary measuring equipment should be [1-3]:

- "calibrated or verified at specified intervals, or prior to use, against measurement standards traceable to international or national measurement standards; where no such standards exist, the basis used for calibration or verification shall be recorded,
- adjusted or re-adjusted as necessary,
- identified to enable the calibration status to be determined,
- safeguarded from adjustment that would invalidate the measurement result,
- protected from damage and deterioration during handling, maintenance and storage".

"In addition, the organization shall assess and record the validity of the previous measuring results when the equipment is found not to conform the requirements. The organisation shall take appropriate action on the equipment and any product affected [2]".

Control of test and calibration equipment means assessment of [11]:

- measurement needs,
- registration manner,
- calibration manner,
- identification methods,
- usage rules,
- methods of preparation and storage of records.

Accuracy of measurement is connected with permissible tolerance; measurement equipment should guarantee accuracy of measurement that is higher than tolerance of value being measured. Calibration up to too high values is of no importance, where the range of undertaken activities is not so demanding [1-4].

Before introduction of the measurement equipment to the use one should clearly define a manner of handling, conservation and storage as well as specify time limits of verification of validity of test and measurement equipment legalisation [5].

Because of the high cost of the own laboratory maintenance, the majority of organisations assigns the performance of a task connected with the requirements of 7.6 point of ISO 9001 standard to the office of measure. In such cases organisational tasks considering range of measurement equipment are limited to identification and implementation of processes that are going to guarantee that measurements conducted by properly chosen measurement equipment will demonstrate conformity of products and requirements and documents including calibration and periodic check-ups results are stored accordingly to the guidelines of records supervision [1].

3. Selection of measurement equipment

Settlement of technical and metrological criteria has fundamental meaning for reasonable choice of test and measurement equipment. Criteria should be worked out on the basis of information from particular units of the organisation, mostly from the main constructor and main technologist departments. Information are connected with [6,7]:

- values covered by measurement and verification,
- measurement accuracy,
- intervals between control and measurement activities,
- conditions of technological processes,
- reputation of potential suppliers,
- possibilities of measurement equipment testing.

3.1. Introduction of the measurement equipment to the use

Before introduction of the measurement equipment to the use one should control the delivery following the basis of requirements of Polish and international standards as well as check instructions. Positive effect of the verification causes the handover of the equipment to the magazine, granting the evidential number, opening the register and card of periodical checks-ups of measurement equipment [7,8].

Person, who takes the responsibility for realisation of test and measurement equipment management, hands over the equipment and takes it back after usage. Transfer of the equipment should be connected with verification of actual calibration status and making a note in the register [7,8].

User takes overall responsibility for the technical condition of the measurement equipment and should observe the guidelines included in the manual, and - in the case of identification of incompatibility that can influence the presented results - should report that fact and withdraw the equipment from the exploitation [7].

3.2. Equipment identification

Test and measurement instruments that organisation is equipped with should be properly marked. Identification number is granted to the measurement instrument in the moment of its introduction to the use identifying it during the time of exploitation. All information about the measurement equipment, included in the identification card, can have a character of table printouts (Table 1) or can be collected in the computer data base [9].

Table 1.
Identification card of measurement instrument [5]

IDENTIFICATION CARD OF MEASUREMENT INSTRUMENT			
Name of equipment:			
Producer:	Date of production:	Identification number:	
Place of storage:	Production number:		
Characteristics			
Measurement range:			
Measurement accuracy:			
Person who makes legalisation/ verification:		Date:	
Purpose:			
Put to use		Received	
Date: User:		Date:	Signature:
Verified features: Limits of acceptable errors:		Errors:	Date of carried out verification:
			Date of determined verification:
Decisions: • transfer to repair • scrapping		Date and signature of inspector:	
Remarks:			

Second manner is connected with costs of software obtainment personnel training, but it gives more possibilities to manage measurement equipment that needs supervision by [10]:

- overall identification and analysis of data on the basis of control plans,
- registration of place of equipment usage or storage,
- estimation of control results according to the defined plan,
- reports generation,
- access to actual data base for all users by the network work environment,
- automatic signalling the control expiration,
- overall access protection.

3.3. Verification of measurement equipment quality

Verification of measurement equipment quality can be done on the basis of [9]:

- check-up made at determined regular intervals,
- reviews realised before every usage,
- conservation carried out after every usage or periodically.

Verification of measurement equipment is realised to assure continuous reliability of the provided results and includes checks-up of metrological and functional features of measurement equipment. Independently on the possibilities of the organisation it can be subcontracted to Office of Measures, accredited laboratory or conducted inside the organisation by competent personnel [9].

The most popular incompatibilities, determined during verification, are [9-11]:

- damage,
- improper identification or lack of identification,
- exploitation of the measurement equipment in conditions that don't allow for usage,
- exploitation of the out-of-date measurement equipment.

Check-up finishes with record in the identification card, granting a status and marking as [9]:

- measurement equipment compatible, with required accuracy and precision,
- measurement equipment incompatible that can't be admitted to exploitation and undergoes a repair or scrapping.

In case of definition of improper functioning of measurement equipment one should [7,10,11]:

- immediately withdraw the measurement instrument from the exploitation,
- inform personnel responsible for the production line, where damaged measurement equipment has been applied,
- hold up the dissemination of results achieved by the usage of measurement instrument being out of order,
- protect those parts that have been controlled by measurement equipment and being out of order,
- analyse the compatibility of details that have been controlled by measurement equipment and being out of order,
- make corrective actions connected with functioning of measurement equipment,
- make incompatibility record in the identification register.

4. Metrological control

4.1. Legal meteorological control

Legal metrological control is activity aiming at demonstration that measurement equipment fulfils technical and metrological

requirements. It is usually done by [12]: type approval, authentication and legalisation.

Legal metrological control includes measurement equipment used in [13]: life and health protection, environment protection, public safety protection, consumers' rights protection and trading.

Type approval is Chairman of Main Office of Measures decision about admission of measurement instruments of the given type to the authentication or legalisation. Before admitting the measurement equipment to trade, type analysis includes the recognition of technical-metrological characteristic, on the basis of which office of measures defines methods of authentication or legalisation. Type approval interval usually amounts to ten years, or separate regulations establish different proceedings [13,14].

Legalisation is based on verification, establishment and confirmation by the legalisation certificate that the measurement instrument fulfils requirements included in regulations and it can be transferred to usage. One can differentiate [1,12]:

- primary legalisation that is analysis of construction compatibility with technical documentation as well as indication, workmanship and metrological characteristic compatibility with the approved type; it is connected with admission to trading,
- secondary legalisation that is every another legalisation of exploited equipment after time of its expiry.

Authentication means verification and establishment of fulfilling metrological requirements connected with measurement instrument as well as confirmation by the authentication certificate, that measurement equipment reading out has been referred to the national measure standards [13,14].

4.2. Calibration

Calibration is "set of activities defining, in the particular conditions, dependences among the values pointed by the measuring tool, or the system of measuring tools, or represented by the material measurement or material of reference, and proper values of amount, realised by the standard of the reference" [15].

The results obtained during calibration make possible the attribution of the measurement equipment readings to proper values of the measured value or determination of the readings correction. Calibration is made just after defining of the verification method as well as the range of the measured values suggested by the user, for which the measurement instrument is going to be calibrated [16].

Results of calibration should be recorded in detail to demonstrate all of the measures traceability with measurement standards. Another aim of detail recording is to make possible a reconstruction of every measurement in similar conditions it has been done at the first time [14-16].

Differences between analysis realised during calibration, legalisation and authentication have been shown in Table 2 [14].

Table 2.
Specification of the differences between during calibration (C), legalisation (L) and authentication (A) [14]

IS IT NECESSARY?	L	A	C
specification of the test range	no	no	yes
specification of requirements	yes	yes	no
definition of the verification method	no	no	yes
confirmation of compatibility with requirements of proper metrological documents	yes	yes	no
definition of the connection with standards of higher level	no	yes	yes
definition of the verification results	no	yes	yes
specification of the expiry date of certificate	yes	yes	no
definition of the measurement traceability	no	no	yes

4.3. Metrological confirmation according to the ISO 10012 standard

ISO 10012:2003 standard 'Measurement management systems. Requirements for measurement processes and measuring equipment' includes guidelines connected with measurement processes metrological confirmation management [17].

Metrological confirmation is used to ensure metrological properties of metrological equipment that are consistent with the requirements of the measurement process. Metrological confirmation includes measurement equipment calibration and verification. Intervals between metrological confirmations should be checked-up and adapted to the needs accordingly to the specified metrological requirements [17].

Records of the metrological confirmation process should include following information [12]:

- specification and unrepeatable identification of the producer, type, identification number, etc,
- date of the end of the metrological confirmation,
- result of metrological confirmation,
- interval between metrological confirmations,
- permissible errors,
- environmental conditions and statement about required corrections,
- details connected with service like repairs or modifications,
- all of the usage limitations,
- identification of persons conducting metrological confirmation,
- identification of persons taking responsibility for correctness of record information,
- unrepeatable identification of all calibration certificates,

- evidences of measurement traceability in calibration results,
- records of calibration results obtained after every modification and reparation.

4.4. Measurement equipment in the aspect of ISO 14001 and PN N 18001 standards

In the organisation measurements are not limited to the verification and correction of the products quality but they aim at assurance of the safety conditions for health and natural environment. That is why ISO 14001 and PN N 18001 standards introduced 'monitoring' term as activity basing on measurement and observing environmental condition, equipment and work conditions [18-21].

Organisation should work out and maintain monitoring procedures as well as record and store results according to the requirements included in ISO 10012, ISO 14001 and PN-N 18001 standards [22,23].

Measurement equipment for assurance of reliable results should be maintained in the appropriate conditions and calibrated in the determined intervals [22,23].

Properly functioning measurement equipment supports the realisation of assumptions and aims of environmental and occupational safety policy as well as effectively reacts on the raised problem [22,23].

Monitoring made by the measurement equipment can be classified as active and reactive monitoring (Fig. 1) [24].

Aim of active monitoring is to correct incompatibilities that come into being among surroundings, equipment, action and implemented safety standards. Active monitoring covers measurements and tests aiming at recognising situations that can lead to accident or threat to life. Environmental factors being measured can be [24]: composition of air, dustiness, noise, vibrations, chemical and biological factors in the air, water and soil, elements of microclimate, radiation and lighting.

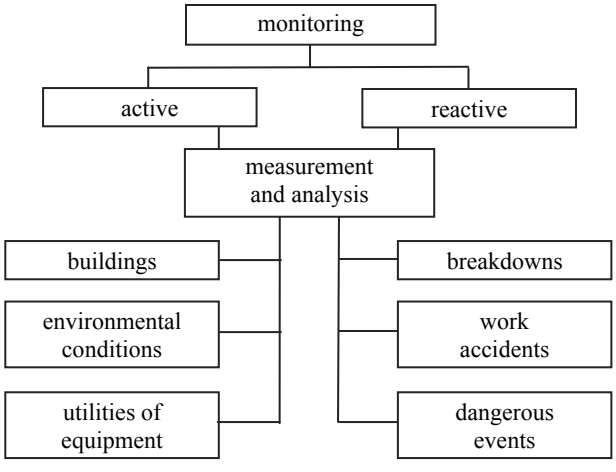

Fig. 1. Scheme of monitoring classification [24]

Reactive monitoring is based on explanation and analysing causes of dangerous accidents and occupational illnesses. Examples of reactive monitoring are [24]:

- activities undertaken after the accidents in work,
- occupational illnesses and their causes,
- decisions made by the authorities on supervision of the occupational conditions,
- actions resulted from the decisions made by the authorities on supervision of the occupational conditions.

5. Own research

The research have been conducted to attain the confirmation that only properly designed system of control of test and measurement equipment is capable of obtaining accurate and reliable results of measures.

In the planning of the supervision system one has taken into account:

- analysis of technological operations of internal ring of conical bearing taking into account all information, where properties of the product had been specified,
- interoperation verification in the aspect of monitoring and measures,
- control of test and measurement equipment,
- test of measurement capacity R&R.

Process of internal ring of conical bearing, that has been analysed, includes: forging, annealing, turning, hardening and tempering, grinding and superfinishing.

5.1. Methodology

Methodology used for the analysis has included establishment of the equipment needed for verification, measurement and test during production process of bearing elements. The plan has been done on the basis of constructional and technological documentation.

Selection of the measurement equipment has been made on the grounds of the following parameters:

- tolerance value of measured size,
- measurements frequency,
- possibility of usage of commercial equipment,
- costs and simplicity of usage,
- possibility of usage of equipment that exists as well as that had been done or bought for mostly produced types of bearing.

Control of test and measurement has been defined by 'turtle diagram' of the control process (Table 3) taking into account both record card and metric including data characteristic for individual measuring instrument.

Verification of correctness of measurement equipment exploitation has been conducted on the basis of the Table 4.

Table 3.
'Turtle diagram' of the control of test and measurement equipment [24]

WITH WHAT? (materials / equipment) With usage of what kind of materials?		WITH WHO? (competences / skills / trainings) With presence of whom?
• instruments • tools • material standards • institutions authorised to verification and repairs • data base of test and measurement equipment		• verification operators • setting and service man? • laboratory personnel • technologists • quality engineers
inputs:	PROCESS	outputs:
• instruments • tools • material standards • documentation • offer • verification decision • analysis of measurement equipment state	CONTROL OF TEST AND MEASUREMENT EQUIPMENT	• instruments • tools • material standards • documentation • offer question • complaint card • incompatibilities report
HOW? (methods / procedures / techniques) With usage of what kind of methods, procedures, techniques?		WITH WHICH CRUCIAL CRITERIONS? (measurement / assessment) What kind of process meters are used?
• quality system measurement laboratory manual • data base of measurement equipment • stand instructions • research plan of measurement systems • procedure of incompatible product supervision • standards • procedure of records supervision		• complaint level • audits results • quality cost level • measurement systems analysis

5.2. Practical analysis

Grinding processing is the last technological operation in the productive process of internal ring of conical bearing. It makes obtaining the accuracy of dimension and shape possible. Measured parameters of five following grinding treatments have been shown on Fig. 2.

Parameters undergoing measurement after grinding treatment, according to the technological card, are: height, diameter of main bearing way, ovality, lobing, run-out of main bearing way to the broad end face, high of the auxiliary bearing way, run-out of auxiliary bearing way to the broad end face, angle dimension, and diameter of hole. These are analysed in the aspect of: parameter value [mm], work tolerance [mm], verification in the time of work (unregistered and registered unit/min), type of verification card and test and measurement instrument.

Chosen measurement instrument, which had been used due to the following technological card of grinding, has been shown on Figs. 3-4.

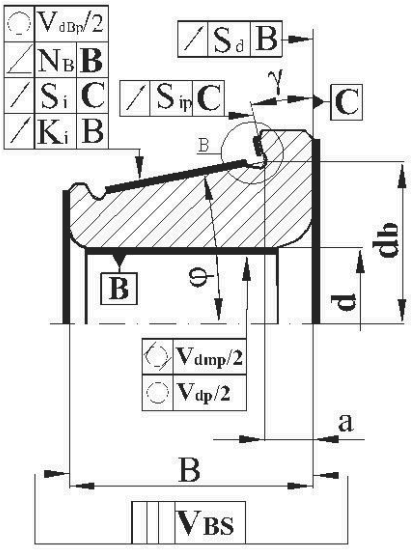

Fig. 2. Draft of internal ring with marked parameters measured after grinding treatment

Table 4.
Report of usage of test and measurement equipment [24]

REPORT OF USAGE OF TEST AND MEASUREMENT EQUIPMENT		Date:	
Stream:	Seat:	Line/machine:	
	RANGE AND RESULT OF VERIFICATION	COMPATIBLE	INCOMPATIBLE
	VISUALISATION		
1	Are measurement stands properly identified?		
2	Are measurement stands kept in cleanness?		
3	Are reference standards and measurement equipment stored in the way protecting against damage?		
	TECHNOLOGY		
4	Is there actual form of processes according to which measure is realised?		
5	Is on stands measurement equipment compatible with process?		
	STATUS		
6	Is there actual and readable validity date on the measurement equipment?		
7	Has the measurement instrument or measurement tool actual R&R test?		
8	Is the validity date on the measurement equipment equal to the one in the computer data base?		
9	Is the R&R test result on the measurement instrument card equal to the one in the computer data base?		
	SKILLS		
10	Are there accessible and actual stand instructions?		
11	Are service instructions of measurement equipment known and obeyed?		
12	Does the user operate on the measurement equipment properly?		
	OTHERS		
Remarks:			
Full Name of the person being in charge of control:	Full Name of the stream inspection:	Signature of the stream inspection:	

Fig. 3. Photography of measure of ovality and lobing parameters

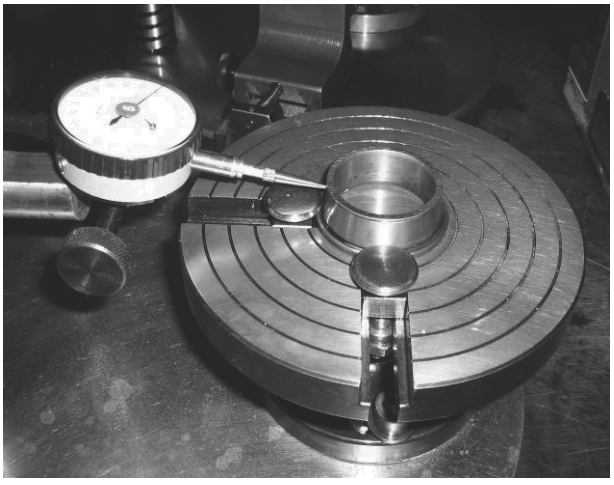

Fig. 4. Photography of measure of run-out of main bearing way to the broad end face

Control of measurement equipment used in grinding operations takes into account: dates of validity, technological condition, manner of utilisation, operator's competences and it is realised by usage of: computer data bases, machine cards, labels on measurement instruments, reports of measurement equipment usage as well as repeatability and reproducibility tests.

Undertaking decision on intervals between measurement instruments calibration one can take into consideration to main criterions: risk of the loss of measurement equipment compatibility with requirements as well as the cost of verification being minimal. Giving the definition of calibration internals one ought to consider:

- producer's recommendation,
- tendency towards consumption of the measurement surface,
- importance of the measured parameter in the technological process,
- environmental conditions.

The defined intervals are controlled at an angle of measurement equipment consumption, loss of its measurement ability and - when it is necessary - corrected.

6. Conclusions

Fundamental meaning for improvement of production processes quality as well as safety occupational and natural environment have results of measurement, monitoring and analysis made via test and measurement equipment.

System of control of test and measurement equipment, that is appropriately designed, should be able to obtain the accurate and reliable results being the base for making subsequently relevant decisions.

Being negligent in controlling test and measurement equipment can lead to tragic results of actions influencing human health, natural environment and functioning on the market.

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