Warsaw University of Technology

COURSE OFFERED IN THE DOCTORAL SCHOOL

<table>
<tr><td rowspan="2">Code of the course</td><td rowspan="2">4606-ES-00ADFGH-0232</td><td rowspan="2">Name of the course</td><td>Polish</td><td colspan="3">Nowoczesne metody specyfikacji geometrii wyrobów</td></tr>
<tr><td>English</td><td colspan="3">Modern methods for geometrical product specifications</td></tr>
<tr><td>Type of the course</td><td colspan="6">Specialty course</td></tr>
<tr><td>Course coordinator</td><td colspan="6">Zbigniew Humienny, Ph.D., D.Sc., Eng.</td></tr>
<tr><td>Implementing unit</td><td>Faculty of Automotive and Construction Machinery Engineering</td><td>Scientific discipline / disciplines*</td><td colspan="4">Mechanical engineering; Materials engineering; Biomedical engineering; Civil engineering and transport; Automatic control, electronics and electrical engineering</td></tr>
<tr><td>Level of education</td><td>Education of PhD students</td><td>Semester</td><td colspan="4"><s>winter</s>/summer</td></tr>
<tr><td>Language of the course</td><td colspan="6">English</td></tr>
<tr><td>Type of assessment:</td><td>Credit with a grade</td><td>Number of hours in a semester</td><td>26</td><td>ECTS credits</td><td colspan="2">2</td></tr>
<tr><td>Minimum number of participants</td><td>12</td><td>Maximum number of participants</td><td>15</td><td>Available for students (BSc, MSc)</td><td colspan="2">Yes/<s>No</s></td></tr>
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<tr><td colspan="2">Type of classes</td><td>Lecture</td><td>Auditory classes</td><td>Project classes</td><td>Laboratory</td><td>Seminar</td></tr>
<tr><td rowspan="2">Number of hours</td><td>in a week</td><td>2</td><td></td><td></td><td></td><td></td></tr>
<tr><td>in a semester</td><td>26</td><td></td><td></td><td></td><td></td></tr>
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* does not apply to the Researcher's Workshop

1. Prerequisites

M. Sc. Diploma in mechanical engineering, automotive engineering, aeronautical engineering, mechatronics, materials engineering, civil engineering and transport, automation, electronic and electrical engineering or equivalent.

2. Course objectives

The aim of the course is to acquire the necessary knowledge, skills and competences necessary to:

- specification in the product design drawings the geometrical and dimensional tolerance indications used to determine the limits to which the geometry of the manufactured product may deviate from the nominal geometry in order to ensure that the product meets the designer's expectations;
- semantic analysis of typical as well as complex functional requirements specified in a technical product documentation which is necessary for the correct design, manufacture and verification of the product geometry;
- identification of the needs and directions for the development of methods for specifying product geometry, in particular the development of proposals for amendments and improvements to the international standards defining the geometrical product specification system ISO GPS;
- solid understanding that ISO GPS system standards shall be developed and used as sets of rules;
- systematic approach to assessment of the accuracy and clarity of the geometrical and dimensional tolerances given in the engineering drawings received from business partners;
- design of the functional gauges;
- develop concepts for the verification of the geometrical and dimensional requirements specified in technical product documentation.

3. Course content (separate for each type of classes)

Lecture

1. The role of the geometrical tolerances in ensuring that the functional requirements established for the product are met. Functional Requirement -> Functional Specification -> Geometric Specification. Questions that arise from using plus/minus dimensioning and tolerancing. The current concept of new standards development for the ISO GPS system of geometrical product specifications – a standard as a set of general rules, not a collection of sample drawings with tolerance indicators that the designer extrapolates/interpolates for his own drawing. International standards ISO GPS (ISO 8015, ISO 1101, ISO 1660, ISO 5458, ISO 2692, ISO 5459, . . .) and the American Standards ASME Y14. 5 and ASME Y14. 5. 1.
2. Feature of size. Default ISO interpretation of linear size: two-point size and envelope requirement E that defines two conditions, ISO 14405-1, ISO 286. Default size according to ASME Y14.5. Application of the

modifiers CT (common tolerance) and UF (united feature) for establishment of single feature of size. Specification operators for linear size for features of size according to ISO 14405 (GG, GN, GX, GC, SA, SM, LP, LS, …).

3. ISO GPS system principles. Categories of geometrical tolerances. Geometrical characteristic symbols. Tolerance indicator, adjacent indication and plane/feature indicator. Datum feature indicator. Types of geometrical features – nominal feature, actual feature, extracted feature. Indication of integral feature and derived feature as toleranced/datum feature.
4. Tolerances of form: straightness, flatness, roundness and cylindricity. Interdependencies between form tolerances. Parameters and error sources for form deviation measurement with usage of coordinate measuring technique. Filtration and toleranced feature specification elements (G, C, N, X). Form tolerances with combined tolerance zone (CZ modifier) for a few geometrical features. Form tolerances in restricted area. Straightness tolerance of an axis with MMR (maximum material requirement).
5. Datum, datum feature, datum simulator. Single datum (axis, plane), datum targets, datum systems, common datum (ISO 5459). Effects of datum precedence. Functional selection of the constraints for the secondary datum from the primary datum. Functional selection of the constraints for the tertiary datum from the primary and secondary datum. Requirements for datum feature simulators. Establishment of the datum system on coordinate measuring machine.
6. Tolerances of orientation: perpendicularity, parallelism, angularity of derived feature (axis/plane) & integral feature (plane). Orientation tolerances with modifier T – tangent plane. Combined zone CZ. Stacked tolerance indication (orientation and form). Tolerances of associated features defined by modifiers X, N, G, C. Addition constraints for an orientation tolerance zone established by the secondary datum. Angular theoretically exact dimensions.
7. Tolerances of locations for derived features (points axes, symmetry planes) and integral feature (plane). Position tolerance applied to rectangular/circular pattern of features without datum, with single datum, with two datum system and with three datum system (ISO 5458). Theoretically exact dimensions. Position tolerance with multi-level indicator. Multi-level single indicator pattern specification (sub-patterns in the pattern). Modifiers CZ (combined zone), SZ (separate zones) and >< (for orientation constraint only) for pattern of holes. Modifier SIM – simultaneous requirement. Coaxiality tolerance with respect to single datum, common datum and datum system. Symmetry tolerance with respect to single datum and datum system. Stacked tolerance indication (location controls orientation and form).
8. Tolerances of profile of a line/surface with/without datum (ISO 1660). Tolerances of profile of a line/surface as tolerances that limit deviations of size, form, orientation and location. Analogies between the tolerance of elementary geometrical primitives (surface, cylinder) and the tolerances of surfaces with complex geometry. UF – united feature. All around specification. Tolerance zone boundaries bilateral; UZ – uniform and unequally disposed. Modifier OZ – unspecified linear tolerance zone offset. Surface profile tolerance applications – tolerances for cones. Modifier ><. Tolerances of surface profile for a pattern of features. Profile of a line tolerance applied to 2D line and 3D line.
9. Maximum Material Requirement (MMR), Least Material Requirement (LMR) and Reciprocity Requirement (RPR) – ISO 2692. Perpendicularity, position, coaxiality and symmetry tolerances with MMR. Position tolerance for single hole and for rectangular/circular patterns of holes with MMR. Increase in position tolerance due to the toleranced feature not in MMC for MMR (respectively not in LMC for LMR). Displacement allowed by datum feature(-s) that is (are) not at MMC (respectively LMC). Position tolerance for two patterns of features considered individually and two groups of features considered as one pattern (SIM – simultaneous requirement). Functional aims for specifications of MMR and LMR. Zero value for MMR and LMR tolerances versus RPR. Calculation of functional gauge sizes.
10. Circular run-out radial and axial. Total run-out applied to surface around an axis (radial). Total run-out applied to surface normal to an axis (axial). Functional selection of the datums for datum system for circular run-out. Radial run-out tolerance as tolerance that limits of form deviations and location deviations.
11. Tolerance for projected tolerance feature – application: assembly with fasteners. Tolerancing intersection of axes.
12. Tolerancing of non-rigid parts where restraining of features is required during verification (ISO 10579).
13. General geometrical specifications and general size specifications (ISO 22081).
14. Challenges for new standards developers. Ambiguities and contradictions in the published ISO GPS system standards. Procedure for development of new International Standard NPWI/WD/CD/DIS/FDIS.

Laboratory

4. Learning outcomes			
	Learning outcomes description	Reference to the learning outcomes of the WUT DS	Learning outcomes verification methods*
Knowledge			
K01	Acquisition and systematization of knowledge that during manufacturing products are made with dimension, form, orientation, location and run-out deviations, as well as that a designer is responsible for determining the tolerances, i.e. the maximum permissible deviations within which the product meets the expected functional requirements. Raising awareness of the differences in requirements specified according to the system of International Standards ISO GPS and the United States Standard ASME Y14.5.	DS_K2 DS_K3	Evaluation of activity during classes. Written test
K02	PhD student shall acquire the knowledge that is necessary to identify and define the needs and directions for the development of methods for specifying product geometry, in particular the development of proposals for amendments and improvements to the International Standards establishing the geometrical product specification system ISO GPS.	DS_K2 DS_K3	Evaluation of activity during classes. Written test. Assessment of the presentation
K03	PhD student should get acquainted and understand the nature of requirements defined by geometrical tolerance symbols and selected modifiers. In-depth knowledge of the specifications for geometric tolerances in design drawings.	DS_K2 DS_K3	Evaluation of activity during classes. Written test.
Skills			
S01	Skills and competence to assesses the correctness of a product documentation regarding geometrical and dimensional tolerances as well as application (specification) in technical product documentation the geometrical tolerances with the maximum material modifier or other modifiers.	SD_S1 SD_S4	Evaluation of activity during classes. Written test.
S02	Skills to select and suggest correct method and measuring instruments for verification of geometrical and dimensional requirements.	SD_S1 SD_S4	Evaluation of activity during classes. Written test.
S03	Skills for design of functional gauges for tolerances with maximum material requirement.	SD_S1 SD_S4	Evaluation of activity during classes. Written test.
Social competences			

SC01	PhD student should be aware that the Geometrical Specification System ISO GPS is an internationally recognized language consisting of principles, rules and graphical symbols that enable communication and information exchange between designers, production engineers and quality staff working together for manufacturing final products and their suppliers at different locations around the world.	DS_SC2	Evaluation of activity during classes.

*Allowed learning outcomes verification methods: exam; oral exam; written test; oral test; project evaluation; report evaluation; presentation evaluation; active participation during classes; homework; tests

5. Assessment criteria

The PhD students' knowledge and skills are assessed in two tests during the 7th and 14th week of classes. Each test is evaluated on a scale of 2 to 5. To pass the subject, both tests must be passed, i.e. at least grade 3.0 from each shall be obtained. During the last 15th meeting, the opportunity will be provided to improve one of the test if necessary. The final evaluation is the arithmetic mean. The final grade may be upgraded by 0,5, depending on the student's activity during partially interactive lectures.

6. Literature

Fundamental Literature:

[1] Henzold G.: Geometrical dimensioning and tolerancing for design, manufacturing and inspection. A handbook for geometrical product specification using ISO and ASME standards. Butterworth-Heinemann, 2020.
[2] Tornincasa S.: Technical drawing for product design. Mastering ISO GPS and ASME GD&T. Springer, 2020.
[3] Paul J. Drake, Jr.: Dimensioning and Tolerancing Handbook. McGraw-Hill. New York 1999.
[4] Humienny Z.: State of art in standardization in the geometrical product specification area a decade later CIRP Journal of Manufacturing Science and Technology, v.33, p.42-51 (2021). DOI:10.1016/j.cirpj.2021.02.009.
[5] Humienny Z.: Can ISO GPS and ASME Tolerancing Systems Define the Same Functional Requirements? Applied Sciences-Basel, 2021, vol. 11, nr 8269, s.1-21. DOI:10.3390/app11178269
[6] Welcome to ISO/TC 213 https://committee.iso.org/home/tc213
[7] Morse E. P., Shakarji C. M., Srinivasan V.: A brief analysis of recent ISO tolerancing standards and their potential impact on digitization of manufacturing. Procedia CIRP 75 (2018) p.11–18.
[8] 16th CIRP Conference on Computer Aided Tolerancing (CIRP CAT 2020) Ed. by Edward Morse Volume 92, Pages 1-236 (2020)
[9] ISO 1101:2017 Geometrical product specifications (GPS) – Geometrical tolerancing – Tolerances of form, orientation, location and run-out.
[10] ISO 5458:2018 Geometrical product specifications (GPS) – Geometrical tolerancing – Pattern and combined geometrical specification.
[11] ISO 1660:2017 Geometrical product specifications (GPS) – Geometrical tolerancing – Profile tolerancing.
[12] ASME Y14.5-2018 Dimensioning and tolerancing. Engineering product definition and related documentation practices.

Complementary readings:

[1] Humienny Z. (ed.), Białas S., et al: Geometrical Product Specifications – Course for Technical Universities. p. 382. Warsaw University of Technology Printing House, Warsaw, 2001.

7. PhD student's workload necessary to achieve the learning outcomes**

No.	Description	Number of hours
1	Hours of scheduled instruction given by the academic teacher in the classroom	30
2	Hours of consultations with the academic teacher, exams, tests, etc.	10
3	Amount of time devoted to the preparation for classes, preparation of presentations, reports, projects, homework	10

4	Amount of time devoted to the preparation for exams, test, assessments	10
	Total number of hours	60
	ECTS credits	2

** 1 ECTS = 25-30 hours of the PhD students work (2 ECTS = 60 hours; 4 ECTS = 110 hours, etc.)