COURSE OFFERED IN THE DOCTORAL SCHOOL

Code of the course	4606-ES-00BDFGH-0134	Name of the course	Polish	**Zaawansowane metody specyfikacji geometrii wyrobów**
			English	**Advanced methods for geometrical product specifications**
Type of the course	Specialty course			
Course coordinator	Zbigniew Humienny, Ph.D., D.Sc., Eng.			
Implementing unit	Faculty of Automotive and Construction Machinery Engineering	Scientific discipline / disciplines*	Mechanical engineering; Materials engineering; Biomedical engineering; Civil engineering and transport; Automatic control, electronics and electrical engineering	

Level of education	Education of PhD students	Semester	summer		
Language of the course	English				
Type of assessment:	Credit with a grade	Number of hours in a semester	30	ECTS credits	2
Minimum number of participants	12	Maximum number of participants	50	Available for students (BSc, MSc)	Yes/~~No~~

Type of classes		Lecture	Auditory classes	Project classes	Laboratory	Seminar
Number of hours	in a week	2				
	in a semester	30				

* 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:

- application of geometrical tolerances to engineering drawings according to the typical as well as complex functional requirements;
- solid understanding and interpretation of the geometrical and dimensional requirements specified in the received technical documentation of products;
- identification of the needs and directions for the development of methods for specifying product geometry, in particular the preparation of proposals for amendments and improvements to the international standards defining the ISO GPS system;
- assessment of the accuracy and clarity of the geometrical and-dimensional tolerances given in the engineering drawings received from business partners;
- calculation of the dimensions of the functional gauges;
- develop a concept for the verification of the geometrical and-dimensional requirements specified in the technical documentation of products.

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

Lecture

1. Questions that arise from using plus/minus dimensioning and tolerancing. Why do we need geometric dimensioning and tolerancing (GDT) – unique specification? ISO GPS system standards (ISO 8015, ISO 1101, ISO 2692, ISO 5459, ISO 1660, ISO 5458 ISO 14405-1, ...) and United States Standard ASME Y14.5.
2. Feature of size. Default ISO interpretation of linear size: two-point size and envelope requirement (ISO 14405-1, ISO 286). Dimensions GG, GN, GX, SA, LP. Modifier CT common tolerance. Rule #1 (Default Envelope). Clearance, transition and interference fits.
3. ISO GPS system principles. Categories of geometrical tolerances. Geometrical characteristic symbols. Tolerance indicator. Datum feature indicator. Indication of integral feature and derived feature as toleranced/datum feature. Actual feature, extracted feature.

4. Tolerances of form: straightness, flatness, roundness, cylindricity. Assessment of roundness deviations. Form tolerances with combined tolerance zone (CZ modifier) for a few geometrical features. Straightness tolerance of an axis with MMR (maximum material requirement)
5. Datums and datum systems. Datum, datum feature, datum simulator. Single datum (axis, plane), common datum. Datum systems – ISO 5459. Effects of datum precedence. Requirements for datum feature simulators. Datum targets. Datum system and coordinate measuring technique.
6. Tolerances of orientation: perpendicularity, parallelism, angularity of derived feature (axis) & 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.
7. Tolerances of location: position, coaxiality, symmetry. Position tolerance applied to rectangular/circular pattern of features (ISO 5458). Position tolerance applied to plane. Theoretically exact dimensions. Modifiers for orientation only ><, CZ combined zone, SZ separate zones and SIM simultaneous requirement. Composite positional tolerancing (ASME). Stacked tolerance indication (location controls orientation and form). Coaxiality tolerance with respect to single datum, common datum and datum system.
8. Tolerances of profile of a line/surface with/without datum. Tolerances of profile of a line/surface as tolerances that limit deviations of size, form, orientation and location (ISO 1660). UF – united feature. All around specification. Tolerance zone boundaries UZ – bilateral, uniform and unequally disposed. Modifier OZ – unspecified linear tolerance zone offset. Profile applications – conicity deviation. 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) for toleranced feature – ISO 2692. Perpendicularity, position and coaxiality tolerances with MMR. Increase in position tolerance allowed by toleranced feature not in MMC (respectively not in LMC). Displacement allowed by datum feature(-s) that is (are) not at MMC (respectively LMC). Position tolerance for single hole and for rectangular/circular patterns of holes. SIM (simultaneous requirement). Zero value for MMR and LMR tolerances versus RPR. Calculation of sizes of material gauges.
10. Circular runout radial and axial. Total runout applied to surface around an axis (radial). Total runout applied to surface normal to an axis (axial). Runout deviations as the product of form deviations and location deviations.
11. Tolerance for projected tolerance feature. Tolerancing intersection of axes. Tolerancing of non-rigid parts.
12. General geometrical specifications and general size specifications ISO 22081.

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.	DS_K2 DS_K3	Evaluation of activity during classes. Written test
K02	Students should get acquainted and understand the nature of requirements defined by geometrical tolerance symbols and selected modifiers. 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. Assessment of the presentation
K03	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 design drawings the tolerances of form, orientation, location, run-out and tolerances with the maximum material modifier or other modifiers.	DS_S1 DS_S4	Evaluation of activity during classes. Written test.
S02	Skills to select and suggest correctly method and measuring instruments for verification of geometrical and dimensional requirements	DS_S1 DS_S4	Evaluation of activity during classes. Written test.
S03	Skills for calculation of dimensions for hard gauges for tolerances with maximum material requirement	DS_S1 DS_S4	Evaluation of activity during classes. Written test.
Social competences			
SC01	Graduates should be aware that the Geometrical Specification System ISO GPS is an internationally recognized graphical symbol language that enables communication and information exchange between designers, production engineers and quality staff working together for manufacturing of automobiles, aircraft and other 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 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.

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.)