Syllabus of the educational component

Program of educational discipline

ADDITIVE TECHNOLOGIES IN FOUNDRY PRODUCTION

Specialty
131 – Applied mechanics

Institute
NNI of Mechanical Engineering and Transport

Educational program
Applied mechanics, computerized foundry production, artistic and jewelry casting

Department
Foundry production (142)

Level of education
Master's degree

Course type
Special (professional).

Semester
2

Language of instruction
Ukrainian, English

Lecturers and course developers

Olga Ivanivna Ponomarenko,

Olha, Ponomarenko@khpi.edu.ua
doctor of technical sciences, professor of the department of foundry production of NTU "KhPI"

Work experience - 35 years. the author of more than 380 scientific and educational and methodological works, of which 20 are of an educational and methodological nature, 8 methodological manuals with the stamp of the Ministry of Education of Ukraine, 1 textbook, 3 monographs and 17 author's certificates and patents.
Courses:"Forming materials and mixtures", "Physico-chemical foundations of foundry production", "Theory of the formation of castings", "Working processes of modern productions", "Resource-saving technologies and melting of alloys with special properties", "Design of cast products and equipment"., " Additive technologies in foundry production"
Learn more about the teacher on the department's website

General information

Summary

The course of lectures presents information about the main concepts and tasks of the discipline.
Considered aadditive technologies or Additive Manufacturing (ADtechnologies), which involve the production of a product based on the data of a digital model (or CAD model) by the method of layer-by-layer addition (add, English – to add, hence the name) of material.
The classification of additive technologies, general information about the main types of AD technologies, manufacturers of AD machines, development trends and examples of practical use of AD technologies in industry are given.The regularities are describedcreation of new products and organization of modern industrial production using additive technologies.

Course objectives and goals

The purpose of the course is to giveto future specialists, knowledge of the main types of additive technologies, which involve the production of products according to the SAD model or the method of layer-by-layer building up of material, and the ability to develop additive technology for a specific product.

As a result of studying the course, the student should know:

- classification of additive technologies;
- to be able to correctly choose additive technology for the production of castings, fittings, molds depending on the customer's requirements;
- develop additive technology for a specific product;
- choose the manufacturing method, choose the material of the model, form;
- justify the chosen technological process from an economic point of view.

Format of classes

Lectures, laboratory and practical work, essay, independent work, consultations.
Final control - exam.

Competencies

GC1. Ability to identify, pose and solve engineering and technical and scientific and applied problems
GC 2. Ability to make informed decisions.
GC 5. Ability to develop and manage projects.
GC 8. Ability to learn and master modern knowledge
FC1. The ability to apply specialized conceptual knowledge of the latest methods and techniques of designing and researching structures, machines and/or processes in the field of mechanical engineering.
FC5. The ability to set a problem and determine ways to solve a problem by means of applied mechanics and related subject areas, knowledge of methods of finding the optimal solution under conditions of incomplete information and conflicting requirements.
FC7. Ability to describe, classify and model a wide range of technical objects and processes, based on deep knowledge and understanding of mechanical theories and practices, as well as basic knowledge of related sciences.
FC9. The ability to work independently and effectively function as a group or structural unit leader when performing production tasks, complex projects, and scientific research. Responsibility for the development of professional knowledge and practices, assessment of the team's strategic development.
FC11. The ability to plan and carry out experimental research, to process the results of the experiment based on the use of modern information technologies and microprocessor technology, to interpret the results of natural or model experiments.

Learning outcomes

LR2. Develop and put into production new types of products, in particular, perform research and design work and/or develop technological support for the process of their production.
LR 3. Apply automation systems for research, design and construction work, technological preparation and engineering analysis in mechanical engineering.
LR 7. It is clear and unambiguous to present the results of research and projects, to convey one's own conclusions, arguments and explanations in national and foreign languages orally and in writing to colleagues, students and representatives of other professional groups of various levels.
LR 9. Organize the work of the group when completing tasks, complex projects, scientific research, understand the work of others, give clear instructions.
LR 10. Search for necessary information in scientific and technical literature, electronic databases and other sources, assimilate, evaluate and analyze this information.
LR 13. Demonstrate the ability to justify and evaluate projects, knowledge of methods of promoting them on the market, ability to perform econometric and scientific evaluations.
LR14.Demonstrate knowledge of the basics of organization and personnel management.

Student workload

The total volume of the discipline is 120 hours. (4 ECTS credits): lectures – 32 hours, laboratory work – 16 hours, practical work – 16 hours, independent work – 56 hours.The course provides ppreparation of a calculation task on an individual topic.

Course prerequisites

To successfully complete the course, you must have knowledge and practical skills in the following disciplines:Graphic geometry, engineering and computer graphics", "CAD/CAM/CAE systems","Theory of the formation of castings", "Working processes of modern productions", "Resource-saving technologies and melting of alloys with special properties", "Design of cast products and equipment", "Resource-saving technologies in foundry production".

Features of the course, teaching and learning methods, and technologies

Lectures are conducted interactively using multimedia technologies. The classes use a project-based approach to learning, game methods, and focus on
application of information technologies in the field of ative technologies in foundry production. Study materials are available to students through OneNote Class Notebook..

Program of the course

Topics of lectures

Introduction.Meaning and tasks of the discipline. Literature.Historical prerequisites for the emergence of additive technologies.An overview of the achievements in the field of 3D printing in recent years. Additive technologies and their scope of application.

Topic 1. Terminology and classification of additive technologies in production. Classification: by type of building materials Classification: by key technology: laser non-laser.

Topic 2. Types of technologies
1.Bed Depositiontechnologies: SLS and SLA technologies.
Bed Deposition: SLM – Selective Laser Melting (SLM Solutions company, Germany);
DMLS – Direct Metal Laser Sintering (EOS company, Germany); EBM – Electron Beam Melting (Arcam company, Sweden); Laser Cusing (Concept Laser company, Germany); SPLS – Solid Phase Laser Sintering (Phenix Systems, France, currently acquired by 3D Systems); Ink-Jet or Binder Jetting (ExOne, 3D Systems, USA) and others.

2. Direct Depositiontechnologies.
Direct Deposition technologies: DMD - Direct Metal Deposition (POM company, USA); LENS – Laser Engineered Net Shape (Optomec company, USA); DM - Direct Manufacturing (Sciaky company, USA); MJS - Multiphase Jet Solidification (Fraunhofer IFAM, Germany; FDM, USA) and others.

Topic 3. Clasification of ASTMby categories: Material Extrusion, Material Jetting, Binder Jetting, Sheet Lamination, Vat Photopolymerization, Powder Bed Fusion, Directed energy deposition.

Topic 4.Additive technology in machine-building industries.
AD technologies: SLA, Stereolithography Apparatus – hardening of the photopolymer layer using a laser beam; SLS, Selective Laser Sintering – layer-by-layer laser sintering of powder materials, in particular polymers; DMF, Direct Metal Fabrication – a type of SLS technology, layer-by-layer laser sintering of metal powder compositions; sometimes called DMLS, Direct Metal Laser Sintering; SLM, Selective Laser Melting – a type of SLS technology, layer-by-layer laser melting of metal powder compositions; DLP, Digital Light Procession – illumination of the photopolymer layer using a digital projector; Poly-Jet – application of a layer of photopolymer through a multi-nozzle head and its hardening by means of illumination with an ultraviolet lamp; FDM, Fused Deposition Modeling – layer-by-layer application of melting filamentous

polymers; Ink-Jet – solidification of a layer of powder material by applying a binder through a multi-nozzle head (according to the type of jet 3D printer).

Topic 5. Characteristics of the AD technology market.

The market of AD technologies, in particular 3D printers. "Amateur" and "professional" 3D printers.

Topic 6. Criteria for choosing AD technologies.

Criteria: acquisition cost; productivity; surface quality of the model; the degree of detailing (the ability to build small fragments); construction accuracy; labor intensive post-processing; stability of the model material; service life of the machine (printer) before replacing the main components; cost of model (building and auxiliary) materials; reliability and terms of delivery of consumables and spare parts; development of the technical support service in the region; the cost of current machine maintenance; the cost of the service contract (in the post-warranty period); reliability and durability of the machine; life time of the main nodes before replacement or overhaul; the required qualifications and, accordingly, the cost of service personnel, as well as the required installation area and engineering infrastructure.

Topic 7.Additive technologies and rapid prototyping.

Rapid prototyping task. SLS, DLP, Poly-Jet, etc. technologies that use liquid photopolymer as a model material. Comparison of roughness of models obtained by different methods. Production of "rapid tooling" - "rapid tooling" using AD technologies.
Manufacturers of the most popular printers for prototyping.

Topic 8. Technologies and machines for the cultivation of metal products

Machines and equipment for "growing" from metal. Division of machines and equipment into groups: "Bed Deposition" and "Direct Deposition".
Machines, equipment and technologies of the "Bed Deposition" group of companies: Concept Laser Company, EOS Company, 3D Systems Company (USA). SLM Solutions Company (Germany), Realizer Company (Germany), Renishaw Company, Arcam Company, Matsuura Machinery Company.
Sheet Lamination technologies (Bed Deposition group), Main parameters of machines for layer-by-layer synthesis from metal powder compositions (Bed Deposition groupDeposition").
Machines, equipment and technologies of the "Direct Deposition" group companies: POM Group (USA), Optomec (USA), Irepa Laser (France), InssTek (South Korea), Sciaky (USA). The main parameters of machines for layer-by-layer synthesis from metal powder compositions, "Direct Deposition" group.

Topic 9. Additive technologies and foundry production

Metal casting technologies using synthesis models and synthesis forms. Synthesis models from powder polymers, SLS technology. Machines for the technology of layer-by-layer synthesis of models from polymer powder materials in foundry production. Ink-Jet technology.

Synthesis models from light-curing resins. SLA - laser stereolithography.
The use of stereolithography when growing foundry models; production of master models (for further production of silicone molds, wax models and castings from polyurethane resins); creation of design models, layouts and functional prototypes; production of full-scale and large-scale models for hydrodynamic, aerodynamic, strength and other types of research,

Quick-Cast models Advantages of Quick-Cast technology.
Nomenclature of model materials: VisiJet Flex, VisiJet Tough - ABS, VisiJet Clear, VisiJet HiTemp, VisiJet e-Stone.
The main parameters of SLA machines of the company 3D Systems.

DLP technology - Digital Light Procession for obtaining high-quality digital projection.

MJM-technology. Obtaining "waxes" - wax-like synthetic models for further casting according to the models that are melted.

Topic 10. Technologies and machines for the synthesis of sand casting molds.

General information about technologies of synthesis of sand forms.

Technologies for the production of sand casting molds: AD-technology of layer-by-layer sintering of coated sand with a laser beam (EOS company) and layer-by-layer application of a binder, or Ink-Jet technology (ExOne). The technology of EOS (Germany) is a type of SLS technology.
Machines for the synthesis of sand molds. Machines for layer-by-layer synthesis of sand forms and rods. Equipment of the foundry site for effective use of additive technologies

Topic 11. Algorithm of actions of the designer-technologist during technology design.

The sequence of operations: creating a CAD model of the product, designing a pouring system, scaling the model according to the shrinkage coefficient of the casting material, obtaining a technological CAD model, creating a CAD model of rods and external forms.

Modeling of the casting process. Modern software products such as:
Magma (Magma GmbH, Germany); ProCAST (ESI Group, France); QuikCAST (ESI Group, France); SCM LP "PolygonSoft"; LVMFlow.

Topics of laboratory and practical classes

Topic 1. The use of additive technologies at modern enterprises.
Topic 2. Construction of a 3D model of the part according to the specified overall dimensions.
Topic 3. Building a 3D model of a part in a solid-state modeling system.
Topic 4. Construction of a 3D model of a "Spring" type part in the solid-state modeling system.
Topic 5.Basic technologies of 3D printing. FDM. SLA. SLM. DMLS.
Topic 6.Materials for 3D printing. Polymer materials. Composites. Metal-containing materials.
Topic 7.Work with 3D models. Software for 3D modeling.

Self-study

The course providescalculation task on an individual topic.

Based on the issued product (castings, parts, rod, mold), choose:

1. Product manufacturing method;
2. Selection of material;
3. Develop the product manufacturing technology;
4. Provide a list of used literature.

Course materials and recommended reading

Basic literature

1. David L. Bourella, Joseph J. Beaman, Jr.a, Ming C. Leub and David W. Rosenc. A Brief History of Additive Manufacturing and the 2009 Roadmap for Additive Manufacturing: Looking Back and Looking Ahead. RapidTech 2009, www.rapidtech.itu.edu.tr.
2. Beaman JJ Solid Freeform Fabrication: An Historical Perspective. The University of Texas. Austin, Texas.
3. Techel A. et al. Laser Additive Manufacturing of Turbine Components, Precisely and Repeatably. Fraunhofer Institute for Material and Beam Technology (IWS), online publication of the Laser Institute of America.http://www.lia.org/blog/category/laser-insights-2/laser-additive-manufacturing
4. Sabina L. Campanelli et. al. Capabilities and Performances of the Selective Laser Melting Process. Polytechnic of Bari, Department of Management and Mechanical Engineering, Viale Japigia, 182 Italy [Electr. resource], Access mode:http://cdn.intechweb.org/pdfs/12285.pdf
5. 3-D Printing Manufacturing Process is Here; Independent global forum for the Unmanned Aircraft Systems community, UAS Vision [Electronic resource]. – URL: http://www.uasvision.com.
6. Khoshnevis B. et al. Metallic part fabrication using Selective Inhibition Sintering (SIS). Department of Industrial and Systems Engineering University of Southern California, Los Angeles, CA 90089, USA. [Elec. resource],https://docs.google.com/viewer?a=v&q=cache:EchCrGNayJEJ:wwwbcf.usc.
7. 5-akselinen pystykarainen työstökeskus MATSUURA MAM72-35V on uudistunut. 18.12.2012. http://www.makrum.fi/blog/matsuura-uudistanut-mam72-35v-pystykaraisentyostokeskusku/
8. Louis E. et. al. Selective laser melting of aluminum components. Journal of Materials Processing Technology. Volume 211, Issue 2, 1 February 2011, Pages 275–284. Department of Engineering, The University of Liverpool, Liverpool L69 3GH, United Kingdom.

9. Yasa E. et. al. The investigation of the influence of laser re-melting on density, surface quality and microstructure of selective laser melting parts // Rapid Prototyping Journal. - 2011. - Vol. 17. – Iss: 5. – R. 312-327.
10. Yasa E., Kruth J. Application of laser re-melting on Selective laser melting parts. Catholic University of Leuven, Dept. of Mech. Eng, Heverlee, Belgium. Advances in Production Engineering & Management 6 (2011) 4. R. 259-270, Scientific paper [Electronic resource]. URL: https://lirias.kuleuven.be.
11. Beyer E. New Industrial Systems & Concepts for Highest Laser Cladding Efficiency. Fraunhofer-Institut für Werkstoff- und Strahltechnik. MAY 6, 2011 in LASER CLADDING, LASER MANUFACTURING [Electr. resource] access mode http://www.lia.org/blog/2011/05/high-performancelaser-cladding/
12. Dutta V. et. al. Additive Manufacturing by Direct Metal Deposition ADVANCED MATERIALS & PROCESSES • MAY 2011. P. 33-36.
13. Types of 3D Printing Technology. URL: https://all3dp.com/1/types-of-3d-printers-3d-printing-technology (date accessed: 09/13/2021).

Additional literature

1. Robbie Adams, ION FUSION FORMATION, Pat. US 6,680,456 B2, Jan. 20, 2004.
2. Beyer E. New Industrial Systems & Concepts for Highest Laser Cladding Efficiency. Fraunhofer-Institut für Werkstoff- und Strahltechnik. MAY 6, 2011 in LASER CLADDING, LASER MANUFACTURING [Electr. resource access mode http://www.lia.org/blog/2011/05/high-performancelaser-cladding/
3. Hohmann M., Brooks G., Spiegelhauer C. Production methods and applications for high-quality metal powders and spray-formed products. Produktionsmethoden und Anwendungen for high-quality metal powders and spruhkompaktierte Halbzeuge. Stahl und Eisen. - 2005.
4. Boulos M. Plasma power can make better powders. Metal Powder Report. 2004. – Vol. 59. – Issue 5. – P. 16-21.
5. Donachie MJ, Donachie S. Superalloys: A Technical Guide, 2nd Ed. – ASM International, 2002. – 438
6. Fngelo HC, Subramanian R. Powder Metallurgy: Science, technology and application. - New Delhi, 2009.
7. Ahsan MN et. al. A comparison of laser additive manufacturing using gas and plasma-atomized Ti-6Al-4V powders // Innovative Developments in Virtual and Physical Prototyping. – London: Taylor & Francis Group, 2012.
8.http://foundrymag.com/feature/new-tooling-alloysmolds-and-dies-advancing-market.

Assessment and grading

Criteria for assessment of student performance, and the final score structure

100% of the final grade consists of evaluation results in the form ofexamin (40%) and current assessment (60%).

Exam: written task (2 questions from theories) and an oral report.
Current assessment: 2 modular control and abstract (20% each).

Grading scale

Total points	National	ECTS
90–100	Excellent	A
82–89	Good	B
75–81	Good	C
64–74	Satisfactory	D
60–63	Satisfactory	E
35–59	Unsatisfactory (requires additional learning)	FX
1–34	Unsatisfactory (requires repetition of the course)	F

Norms of academic integrity and course policy

The student must adhere to the Code of Ethics of Academic Relations and Integrity of NTU "KhPI": show discipline, education, benevolence, honesty, responsibility. Conflict situations should be openly discussed in study groups with the teacher, and if it is impossible to resolve the conflict, it should be brought to the attention of the employees of the institute's directorate.
Regulatory and legal support for the implementation of the principles of academic integrity of NTU "KhPI" is posted on the website:http://blogs.kpi.kharkov.ua/v2/nv/akademichna-dobrochesnist/

Approval

Approved by	22.08.2023 Date , signature	Head of the department Oleg AKIMOV
	22.08.2023 Date , signature	Guarantor of the educational program Oleksandr SHELKOVY