Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Digital Measurement Systems for Sensing and Monitoring

Teaching Note

Table of Contents

Index

Presentation 3
Objective 3
Target Group 3
Learning Aims 4
Tasks 4
Structure 4
Student Workload (Hours) 4
Evaluation 5
Additional Information 5
Essential reading: 5

DIDACTIC UNIT

UNIT TITLE: *Digital measurement systems for sensing and monitoring*

Presentation

Metrology is the field of knowledge related to measurements, encompassing all the theoretical and practical aspects of measurements, whatever their level of accuracy, the measured size, the manner and purpose of the measurement, as well as the field of science or technique in which they occur. Measurement is the set of experimental operations performed to obtain quantitative information on certain properties of an object or phenomenon. The scientific reasoning carried out in an experiment in physics is based on a series of abstract notions of different species (geometric, mechanical, caloric, etc.) called entities. Measurement process represents a certain property or characteristic of a material, phenomenon or process, which is defined and may vary quantitatively. Given that the size of the entity is its property, it can be considered under this name both the quality and quantity of the entity. The problems imposed by the continuous development of science and its practical applications have led to the need for well-established, precise units of measurement, which will ensure the creation of a system capable of expressing unitary results of measurements. The basic structure of a digital measurement system (DMS) consists of transducers, instrumentation systems and observers. The instrumentation system has the main goal to process the information gained from a measurement system without alterations of the data.

Objective

This module will enable students to understand digital measurements in terms of metrology, signals, sensors and transducers.

Target Group

The target group for the lecture for Design of Digital Manufacturing in the DIGIMAN project are mainly Master students in the fields of Mechanical/Industrial/Materials/Engineering, Informatics, and Industry 4.0.

Syllabus/Indicative content

- Metrology and measurements History of digital manufacturing
- Signals, Sensors and Transducers
- Digital measurement in sensing applications
- Basics structure of a digital measurement system
- Signal conditioning
- Signal multiplexing
- Memory circuits
- Digital measurement systems for monitoring applications
- Sensing and controlling temperature in resistance heating
- Sensing temperature in microwave heating
- Digital monitoring of temperature in silos

Learning Aims

On successful completion of this module a student should be able to:

- understand digital measurements in terms of metrology, signals, sensors and transducers;
- use digital measurements in sensing applications;
- apply digital measurement systems in monitoring applications;
- develop digital measurement systems for Industry 4.0;
- use temperature sensors and advanced temperature detectors.

Tasks

There are no specific tasks beyond visiting and participate in the lecture, read, and understand the materials.

Structure

- Synchronous and asynchronous Lectures and
- Laboratorial classes

Student Workload (Hours)

• Contact Time Total	23 Hours

• Independent Learning Time	77 Hours
Total Learning Hours	**100 Hours**

Evaluation

The students will take a test at the end of the semester, based on the Learning Note and the delivered test questions and answers.

Additional Information

Students should be encouraged to gather more information about Digital measurement systems for sensing and monitoring for their own personal interest.

Essential reading:

1. Basic Principles of non-contact temperature measurement, Optris infrared thermometers, https://www.micro-epsilon.com/download/products/dat--infrared-basics--en.pdf
2. Arora, A.; Subramaniam, S. – Wavelength Conversion Placement in WDM Mesh Optical Networks, Photonic Network Communications, Volume 4, Number 2, May 2002
3. Ishio, H. Minowa, J. Nosu, K., "Review and status of wavelength-division-multiplexing technology and its application", Journal of Lightwave Technology, Volume: 2, Issue: 4, Aug 1984, p. 448–463
4. Asif Shaik – Multiplexing, Definition, Types of Multiplexing: FDM, WDM, TDM, https://www.physics-and-radio-electronics.com/blog/multiplexing/

Additional reading:

Jumo Imago 500 Multichannel Regulator, Manual, http://www.jumo-.ro/produse/reglare/electronic/regulator-multicanal/703590/jumo-imago-500---regulator-de-proces-si-program-multicanal-703590.html

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Sisteme digitale de măsurare pentru detectare si monitorizare

Notă didactică

Cuprins

Index

Prezentare 3
Obiective 3
Grupul Țintă 3
Scopurile învățării 4
Sarcini 4
Structură 4
Timp de lucru al studentului (Ore) 4
Evaluare 5
Informații adiționale 5
Material bibliografic esențial pentru studiu: 5

Modul diactic
Denumire modul: *Sisteme digitale de măsurare pentru detectare și monitorizare*

Prezentare

Metrologia este domeniul de cunoaștere legat de măsurători, cuprinzând toate aspectele teoretice și practice ale măsurătorilor, indiferent de nivelul lor de acuratețe, dimensiunea măsurată, modul și scopul măsurării, precum și domeniul științei sau tehnicii în care acestea apar. Măsurarea este ansamblul operațiilor experimentale efectuate pentru a obține informații cantitative asupra anumitor proprietăți ale unui obiect sau fenomen. Raționamentul științific efectuat într-un experiment de fizică se bazează pe o serie de noțiuni abstracte de diferite specii (geometrice, mecanice, calorice etc.) numite entități. Procesul de măsurare reprezintă o anumită proprietate sau caracteristică a unui material, fenomen sau proces, care este definită și poate varia cantitativ. Având în vedere că mărimea entității este proprietatea acesteia, se poate considera sub această denumire atât calitatea, cât și cantitatea entității. Problemele impuse de dezvoltarea continuă a științei și a aplicațiilor sale practice au dus la necesitatea unor unități de măsură bine stabilite, precise, care să asigure crearea unui sistem capabil să exprime rezultate unitare ale măsurătorilor. Structura de bază a unui sistem digital de măsurare (DMS) constă din traductoare, sisteme de instrumentare și observatori. Sistemul de instrumentare are ca scop principal procesarea informațiilor obținute dintr-un sistem de măsurare fără modificări ale datelor.

Obiective

Acest modul permite studenților să înțeleagă măsurările digitale în ceea ce privește semnalele, senzorii și traductorii.

Grupul Țintă

Grupul țintă pentru cursul de Sisteme digitale de măsurare pentru detectare și monitorizare în proiectul DIGIMAN sunt îl reprezintă în principal studenții de la ciclul de Master în domeniul Mecanică/Materiale/Inginerie/Informatică și Industrie 4.0

Topică/Conținut

- Metrologie și măsurători Istoricul producției digitale
- Semnale, senzori și traductoare
- Măsurare digitală în aplicații de detectare
- Structura de bază a unui sistem digital de măsurare
- Condiţionarea semnalului
- Multiplexarea semnalului
- Circuite de memorie
- Sisteme digitale de măsurare pentru aplicații de monitorizare
- Sentirea și controlul temperaturii în încălzirea cu rezistență
- Sentirea temperaturii la încălzirea cu microunde
- Monitorizarea digitală a temperaturii în silozuri

Scopurile învățării

La finalizarea cu succes a acestui modul, un student ar trebui să fie capabil să:

- înțeleagă măsurătorile digitale din punct de vedere al metrologiei, semnalelor, senzorilor și traductoarelor;
- să utilizeze măsurători digitale în aplicații de detectare;
- să aplice sisteme digitale de masurare in aplicatii de monitorizare;
- dezvolte sisteme digitale de măsurare pentru Industria 4.0;
- să utilizeze senzori de temperatură și detectoare de temperatură.

Sarcini

Nu există sarcini specific decât să participle la cursuri, să citească și să înțeleagă materialele prezentate.

Structură

- Prelegeri onsite și online and
- Ore de laborator

Timp de lucru al studentului (Ore)

• Timp total in contact • Timp de studiu individual	23 Ore 77 Ore
Total ore de învățare	**100 Ore**

Evaluare

Studenții vor da un test la sfârșitul semestrului pe baza cursurilor predate și a subiectelor transmise

Informații adiționale

Studenții are trebui încurajați să strângă cât mai multe informații despre Fabricația Digitală pentru interesul lor personal.

Material bibliografic esențial pentru studiu:

1. Basic Principles of non-contact temperature measurement, Optris infrared thermometers, https://www.micro-epsilon.com/download/products/dat--infrared-basics--en.pdf
2. Arora, A.; Subramaniam, S. – Wavelength Conversion Placement in WDM Mesh Optical Networks, Photonic Network Communications, Volume 4, Number 2, May 2002
3. Ishio, H. Minowa, J. Nosu, K., "Review and status of wavelength-division-multiplexing technology and its application", Journal of Lightwave Technology, Volume: 2, Issue: 4, Aug 1984, p. 448–463
4. Asif Shaik – Multiplexing, Definition, Types of Multiplexing: FDM, WDM, TDM, https://www.physics-and-radio-electronics.com/blog/multiplexing/

Material de studiu suplimentar:

Jumo Imago 500 Multichannel Regulator, Manual, http://www.jumo-.ro/produse/reglare/electronic/regulator-multicanal/703590/jumo-imago-500---regulator-de-proces-si-program-multicanal-703590.html

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Robot Systems in Joining Processes

Teaching Note

Table of Contents

Index

Presentation 3
Objective 3
Target Group 4
Learning Aims 4
Tasks 4
Structure 5
Student Workload (Hours) 5
Evaluation 5
Additional Information 5
Essential reading: 5

DIDACTIC UNIT

UNIT TITLE: *Robot Systems in Joining Processes*

Presentation

Accordingly, with standard ISO 8373, a robot is an "actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment, to perform intended tasks." The International Federation of Robotics (IFR) also uses the same standard to approach the industrial robots, meaning as "an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications". Although the initial purpose of robots was to do tasks that would be harmful to human beings, the application fields are growing and the industry depends even more on these programmable machines. The desired products are becoming more complex and constantly demanding more precision and effectiveness. To respond to this need, the market has developed an enormous number of different types of robots. A robot system is a system composed of distinct inputs, distinct outputs and a transformation process that is based on robot service. In arc welding the weld uses an electric arc which is the main feature of an electric arc welding circuit. The power in the arc is the product of the welding current and the arc voltage. The welding power source provides the current flow across the circuit and the necessary voltage. The arc sparks between two electrodes: one is the electrode in the welding torch and the other one is the workpiece. Two welding processes are mainly used in robotic applications: one with a non-consumable electrode and one with a consumable electrode.

Objective

This module will enable students to understand the importance of the Robot Systems used in Joining Processes concepts

Target Group

The target group for the lecture for Design of Digital Manufacturing in the DIGIMAN project are mainly Master students in the fields of Mechanical/Industrial/Materials/Engineering, Informatics, and Industry 4.0.

Syllabus/Indicative content

- Structures of a robot system
- Welding processes for robot systems
- Programming of a robot system
- Explain seam tracking systems
- Health and safety in using of a robot system
- Welding simulators
- SOLDAMATIC welding basics
- Welding process

Learning Aims

On successful completion of this module a student should be able to:

- Understand different industrial robot types and their usage in industrial applications;
- Understand the main components of a robot system;
- Explain the main components in a robot system;
- Understand the structures of different robot welding systems and advantages and disadvantages in different applications;
- Understand the main safety hazards in a typical robot work cell. Safe working procedures in robot programming will be introduced;
- Achieve basic knowledge about the most common welding processes to robotize;
- Identify welding methods and their merits for a given workpiece;
- Outline possibilities to increase productivity in robot welding;
- Understand the main programming methods for industrial robots in different applications;
- Explain the difference between robot programming methods;
- Understand the meaning of seam tracking and different kind of methods of seam tracking;
- Explain seam tracking systems.

Tasks

There are no specific tasks beyond visiting and participate in the lecture, read, and understand the materials.

Structure

- Synchronous and asynchronous Lectures and
- Laboratorial classes

Student Workload (Hours)

• Contact Time Total • Independent Learning Time	23 Hours 77 Hours
Total Learning Hours	**100 Hours**

Evaluation

The students will take a test at the end of the semester, based on the Learning Note and the delivered test questions and answers.

Additional Information

Students should be encouraged to gather more information about Robot systems used in welding processes for their own personal interest.

Essential reading:

1. Susannah J. Whitney, Ashley K. W. Stephens – Use of Simulation to Improve the Effectiveness of Army Welding Training, Commonwealth of Australia, 2014.
2. DIGIWELD Erasmus + Project (2021): Project 2018-1-RO01-KA202-049218 (https://ec.europa.eu/programmes/erasmus-plus/projects/eplus-project-details/#project/2018-1-RO01-KA202-049218).
3. Seabery (2019): SOLDAMATIC Welding Curricula (online course on-demand).

Additional reading:

CESOL Spanish Association of Welding (2015): Manual of International Welder

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Sisteme Robotizate în Procesele de Îmbinare

Notă Didactică

Cuprins

Index

Prezentare 3
Obiective 3
Grup Țintă 3
Conținut curs 4
Scopurile învățării 4
Sarcini 4
Structură 4
Timp de lucru al studentului (Ore) 5
Evaluare 5
Informații adiționale 5
Material bibliografic esențial pentru studiu: 5

Modul diactic

Denumire modul: *Sisteme robotizate în Procesele de îmbinare*

Prezentare

În concordanță cu standardul ISO 8373, un sistem robotizat este un „mecanism acționat programabil în două sau mai multe axe, cu un grad de autonomie, care se deplasează în mediul său, pentru a îndeplini sarcinile propuse". Federația Internațională de Robotică (IFR) folosește, de asemenea, același standard pentru a aborda roboții industriali, adică „un manipulator multifuncțional controlat automat, reprogramabil, programabil în trei sau mai multe axe, care poate fi fie fix pe loc, fie mobil pentru utilizare în industrie. aplicații de automatizare". Deși scopul inițial al roboților era acela de a face sarcini care ar fi dăunătoare ființelor umane, domeniile de aplicare sunt în creștere, iar industria depinde și mai mult de aceste mașini programabile. Produsele dorite devin din ce în ce mai complexe și cer în mod constant mai multă precizie și eficacitate. Pentru a răspunde acestei nevoi, piața a dezvoltat un număr enorm de tipuri diferite de roboți. Un sistem robotizat este un sistem compus din intrări distincte, ieșiri distincte și un proces de transformare care se bazează pe serviciul robotizat. În sudarea cu arc, sudarea utilizează un arc electric, care este caracteristica principală a unui circuit de sudare cu arc electric. Puterea în arc este produsul dintre curentul de sudare și tensiunea arcului. Sursa de putere de sudare asigură fluxul de curent prin circuit și tensiunea necesară. Arcul produce scântei între doi electrozi: unul este electrodul din pistolul de sudură și celălalt este piesa de prelucrat. Două procese de sudare sunt utilizate în principal în aplicațiile robotizate: unul cu un electrod neconsumabil și unul cu un electrod consumabil.

Obiective

Acest modul va permite studenților să înțeleagă importanța conceptului de Sistemelor Robotizate în procese de îmbinare.

Grup Țintă

Grupul țintă pentru cursul de Sisteme Robotizate în procese de îmbinare în proiectul DIGIMAN îl reprezintă în principal studenții de la ciclul de Master în domeniul Mecanică/Materiale/Inginerie/Informatică și Industrie 4.0

Conținut curs

- Structura unui system robotizat
- Procese de sudare pentru sisteme robotizate
- Programarea unui system robotizat
- Explicarea sistemelor de urmărire a cordoanelor de sudură
- Norme de protecția muncii la utilizarea unui system robotizat
- Simulatoare de sudură
- Bazele sudării cu simulatorul SOLDAMATIC
- Procese de sudare

Scopurile învățării

La finalizarea cu succes a acestui modul, un student ar trebui să fie capabil să:
- Înțeleagă diferitelor tipuri de roboți industriali și utilizarea acestora în aplicații industriale;
- Înțeleagă principalelor componente ale unui sistem robot;
- Înțeleagă principalele componente dintr-un sistem robot;
- Înțeleagă structurilor diferitelor sisteme de sudare cu robot și a avantajelor și dezavantajelor în diferite aplicații;
- Înțeleagă principalelor pericole de siguranță dintr-o celulă tipică de lucru cu robot. Vor fi introduse proceduri de lucru sigure în programarea roboților;
- Obțină cunoștințe de bază despre cele mai comune procese de sudare de robotizat;
- Identifice metodele de sudare și a meritelor acestora pentru o anumită piesă de prelucrat;
- Înțeleagă posibilități de creștere a productivității în sudarea robot;
- Înțeleagă principalele metode de programare pentru roboții industriali în diferite aplicații;
- Înțeleagă diferența dintre metodele de programare a roboților;
- Înțeleagă semnificația urmăririi cusăturilor și diferitelor tipuri de metode de urmărire a cusăturilor;
- Înțeleagă sistemele de urmărire.

Sarcini

Nu există sarcini specific decât să participle la cursuri, să citească și să înțeleagă materialele prezentate.

Structură

- Prelegeri onsite și online

- Ore de laborator

Timp de lucru al studentului (Ore)

• Timp total in contact • Timp de studiu individual	23 ore 77 ore
Total ore de învățare	**100 ore**

Evaluare

Studenții vor da un test la sfârșitul semestrului pe baza cursurilor predate și a subiectelor transmise.

Informații adiționale

Studenții are trebui încurajați să strângă cât mai multe informații despre Fabricația Digitală pentru interesul lor personal.

Material bibliografic esențial pentru studiu:

1. Susannah J. Whitney, Ashley K. W. Stephens – Use of Simulation to Improve the Effectiveness of Army Welding Training, Commonwealth of Australia, 2014.
2. DIGIWELD Erasmus + Project (2021): Project 2018-1-RO01-KA202-049218 (https://ec.europa.eu/programmes/erasmus-plus/projects/eplus-project-details/#project/2018-1-RO01-KA202-049218).
3. Seabery (2019): SOLDAMATIC Welding Curricula (online course on-demand).

Material de studiu suplimentar:

CESOL Spanish Association of Welding (2015): Manual of International Welder

Digital Manufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Quality Assurance and Quality Control in AM

Teaching Notes

Table of Contents

Presentation 3
Objective 3
Target Group 4
Learning Aims 4
Tasks 5
Structure 5
Student Workload (Hours) 5
Evaluation 5
Additional Information 5
Essential reading: 6

DIDACTIC UNIT 3

UNIT TITLE: *Quality Assurance and Quality Control in AM*

Presentation

Technology is changing the way people live, work, and do business. Digitalization and automation are framing our future. This creates new and exciting opportunities, but at the same time challenges.

Interest in additive manufacturing (AM) is continuing to increase year-upon-year across many different industrial sectors as it can provide significant design flexibility for generating highly complex components. However, present barriers prevent the potential of additive processes from performing optimally. Some of the barriers/challenges are recognized as: i) development of standard procedures for powder recyclability to potentially reduce direct manufacturing cost and provide a positive impact on the sustainability of additive processes; ii) finishing features such as internal pathways or lattices which still present a huge barrier as good surface quality may be a critical variable for certain applications within medical and aerospace industries; and iii) geometric limitations, particularly for Directed Energy Deposition (DED) AM methods. Therefore, eliminating any additional post processes for finishing operations could be beneficial for the efficiency of these additive processes. These challenges are still under investigation, particularly for manufacturing small and medium size components.

Objective

This module will enable students to understand the Importance of Quality Management, Standards, Quality Control and Measurement in metal Additive Manufacturing

Target Group

The target group for the lecture for Quality Assurance and Quality Control in AM in the DIGIMAN project are mainly Master students in the fields of Mechanical, material, chemical engineering, informatics, and industry 4.0.

Syllabus/Indicative content

- General introduction to part quality
- Measurement of MA parts quality
- Factors affecting the Quality of MA manufactured parts
- Importance of Quality Management, Standards, Quality Control and Measurement Sciences in Additive Manufacturing
- General Introduction to ND techniques.
- Typical defects of MA manufactured parts.
- Characteristics and application range of the different ND techniques.
- Construction codes and standards
- Mechanical properties of metals
- Different destructive testing methods (e.g. Compression test and tensile test)
- Mechanical testing standards
- Mechanical characterization of MA manufactured parts

Learning Aims

On successful completion of this module a student should be able to:

- Identify Understand the concept of part quality.
- Understand how part quality is measured.
- Identify all the factors which can affect part quality.
- Understand the relationship between standards and use standards to achieve required part quality.
- Identify the basic principles of the different NDT techniques.
- Understand the probability of occurrence of the different defect types for a selection of materials and AM techniques.
- Assess the potential of each technique for practical applications.

- Identify appropriate ND techniques for AM parts,
- Select the appropriate NDT techniques for analysing the quality of MAM parts.
- Understand and interpret ND examinations.
- Define the materials mechanical properties.
- Outline the most common destructive tests.
- Select the appropriate standard for each DT
- Determine the metals mechanical properties regarding each destructive test results.
- Select the appropriate destructive test to evaluate the MAM part properties.
- Interpret the test results and take decisions.

Tasks

There are no specific tasks beyond visiting and participate in the lecture, read, and understand the materials.

Structure

- Face-to-face and online lectures
- Laboratorial classes

Student Workload (Hours)

• Contact Time Total • Independent Learning Time	23 Hours 77 Hours
Total Learning Hours	**100 Hours**

Evaluation

The students will take a test at the end of the semester, based on the Learning Note and the delivered test questions and answers.

Additional Information

Students should be encouraged to gather more information about Quality in AM for their own personal interest.

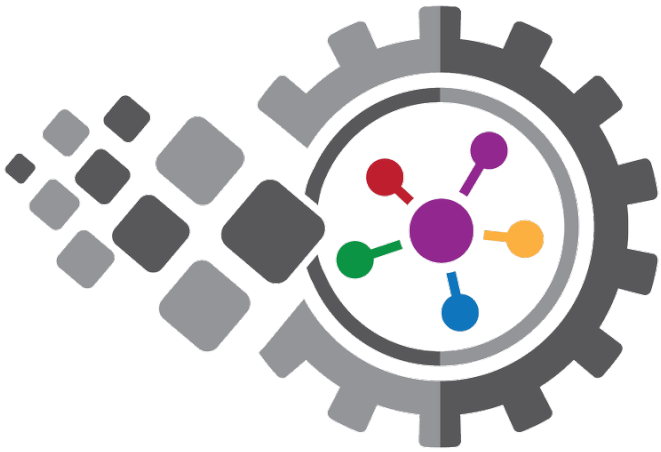
Essential reading:

1. Chee Kai Chua, Chee How Wong and Wai Yee Yeong; "Standards, Quality Control, and Measurement Sciences in 3D Printing and Additive Manufacturing" 2017, Academic Pres
2. R Halmshaw, "Introduction to the Non-Destructive Testing of Welded Joints, 2nd Edition ,1997, Woodhead Publishing.
3. Howard Kuhn, Howard Kuhn, Dana Medlin - ASM Handbook_ Volume 8_ Mechanical Testing and Evaluation, 2000, ASM International

Additional reading:

W.E. Gardner; "Improving the Effectiveness and Reliability of Non-Destructive Testing" ;1992, Pergamon Press.

Digital **Man**ufacturing Master para definir especialistas para o início da indústria 4.0



DIGIMAN

master programme for digital manufacturing

Número do projeto:
2019-1-RO01-KA203-063486

Garantia e Controlo de Qualidade em AM

Notas pedagógicas

Tabela de Conteúdos

Apresentação 3
Objetivo 3
Grupo-Alvo 3
Objetivos de Aprendizagem 4
Tarefas 5
Estrutura 5
Carga de Trabalho dos Estudantes (Horas) 5
Avaliação 5
Informação Adicional 5
Leitura essencial: 5

UNIDADE DIDÁTICA 3
TÍTULO DA Unidade: *Garantia e controlo da qualidade em AM*

Apresentação

A tecnologia está a mudar a forma como as pessoas vivem, trabalham e fazem negócios. A digitalização e a automação estão a moldar o nosso futuro, criando novas e desafiantes oportunidades, mas ao mesmo tempo lançando novos desafios.

O interesse pelo fabrico aditivo (AM) continua a aumentar ano após ano em muitos sectores industriais diferentes, por proporcionar uma flexibilidade significativa no design para gerar componentes altamente complexos. No entanto, as barreiras atuais impedem que os potenciais dos processos aditivos se realizem da melhor forma. Algumas das barreiras/desafios são reconhecidas como: i) desenvolvimento de procedimentos padrão para a reciclagem do pó para reduzir os custos de fabrico diretos e proporcionar um impacto positivo na sustentabilidade dos processos aditivos; ii) características de acabamento, tais como vias internas ou reticulados que ainda apresentam uma enorme barreira, uma vez que a boa qualidade da superfície pode ser uma variável crítica para determinadas aplicações no âmbito das indústrias médica e aeroespacial; e iii) limitações geométricas, particularmente para métodos de deposição de energia dirigida (DED). Por conseguinte, a eliminação de quaisquer processos adicionais de acabamento poderia ser benéfica para a eficiência destes processos aditivos. Estes desafios ainda estão a ser investigados, nomeadamente para o fabrico de componentes de pequena e média dimensão.

Objetivo

Este módulo permitirá aos alunos compreender a importância da gestão da qualidade, normas, controlo de qualidade e avaliação de componentes obtidos por fabrico aditivo

Grupo-Alvo

O grupo-alvo do módulo referente à Garantia e Controlo de Qualidade em AM no projeto DIGIMAN são principalmente estudantes de engenharia nas áreas da engenharia Mecânica, engenharia de materiais, engenharia Química, Informática e Indústria 4.0.

Conteúdo indicativo

- Introdução genérica à qualidade das peças
- Medição da qualidade das peças produzidas por AM
- Fatores que afetam a qualidade das peças fabricadas em AM
- Importância da Gestão da Qualidade, Normas, Controlo de Qualidade e Ciências da Medição no Fabrico de Aditivo
- Introdução geral às técnicas de Ensaios Não Destrutivos.
- Defeitos típicos de peças fabricadas por AM.
- Características e gama de aplicações das diferentes técnicas de NDT
- Códigos e normas de construção
- Propriedades mecânicas dos metais
- Diferentes métodos de ensaio destrutivos (por exemplo, ensaio de compressão e ensaio de tração)
- Normas de ensaios mecânicos
- Caracterização mecânica das peças fabricadas por AM

Objetivos de Aprendizagem

Após a conclusão com sucesso deste módulo, um aluno deve ser capaz de:

- Identificar e compreender o conceito de qualidade de peças produzidas por AM.
- Entender os métodos para medição da qualidade
- Identificar os fatores que podem afetar a qualidade parcial.
- Compreender a relação entre normas e saber usá-las para alcançar a qualidade parcial necessária.
- Identificar os princípios básicos das diferentes técnicas NDT.
- Compreender a causa de ocorrência dos diferentes tipos de defeito para uma seleção de materiais e técnicas de AM.
- Avaliar o potencial de cada técnica para aplicações práticas.
- Identificar técnicas de END adequadas para peças AM,
- Selecione as técnicas NDT adequadas para analisar a qualidade das peças produzidas por AM.
- Compreender e interpretar os resultados dos END.
- Definir as propriedades mecânicas dos materiais.
- Delinear os testes destrutivos mais comuns.
- Selecione as normas mais apropriadas para cada DT
- Determinar as propriedades mecânicas dos metais relativamente a cada resultado de teste destrutivo.
- Selecione o ensaio destrutivo apropriado para avaliar as propriedades de peças obtidas por AM.
- Interprete os resultados dos testes e tome decisões.

Tarefas

Não há tarefas específicas para além de visitas de estudo e da participar em seminários. A leitura e compreensão dos materiais fornecidos é fundamental.

Estrutura

- Aulas presencias e à distância
- Aulas laboratoriais

Carga de Trabalho dos Estudantes (Horas)

• Total de tempo de contato • Tempo de aprendizagem independente	23 Horas 77 Horas
Horas totais de aprendizagem	**100 Horas**

Avaliação

Os alunos farão um teste no final do semestre, com base no material dado durante o Módulo.

Informação Adicional

Os alunos devem ser encorajados a pesquisar mais informações sobre o tema de Qualidade em AM para seu próprio desenvolvimento e interesse pessoal.

Leitura essencial:

1. Chee Kai Chua, Chee How Wong e Wai Yee Yeong; "Normas, Controlo de Qualidade e Ciências da Medição em Impressão 3D e Fabrico aditivo" 2017, Pres Académico
2. R Halmshaw, "Introdução ao Teste Não Destrutivo de Articulações Soldadas, 2ª Edição ,1997, Woodhead Publishing.
3. Howard Kuhn, Howard Kuhn, Dana Medlin - ASM Handbook_ Volume 8_ Testes e Avaliação Mecânica, 2000, ASM International

Leitura adicional:

W.E. Gardner; "Melhorar a eficácia e a fiabilidade dos testes não destrutivos";1992, Pergamon Press.

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Post-Processing in AM

Teaching Notes

Table of Contents

Presentation 3
Objective 4
Target Group 4
Learning Aims 4
Tasks 5
Structure 5
Student Workload (Hours) 5
Evaluation 5
Additional Information 5
Essential reading 6

DIDACTIC UNIT 4

UNIT TITLE: *Post-Processing in AM*

Presentation

Post processing is a critical part of AM. It is the final step of the manufacturing process, where parts receive adjustments, such as smoothing and strengthening. Despite all the advantages AM has over traditional manufacturing methods, it is still imperfect. AM parts can still have poor surface finishes, and the production method can affect the mechanical properties of the component. The main objective of post-processing is to eliminate these potentially dangerous defects, and there are a few ways this can be achieved. These processes can include heat treatment, which is needed to reduce the stress on components before their removal from the building plate, separating the components from support structure, as well as surface finishing and processes such as CNC machining, blasting and polishing. The post processing of AM parts can be just as vital as the fabrication itself .

Industrials have spent the last twenty years singing the praises of additive manufacturing, but reality shows that if there is one thing that truly enables to appreciate the benefits and the results of this technology, it is post-processing. Post-processing is an umbrella term that covers a variety of stages that 3D printed parts have to undergo before being used for the final purpose. No matter what post-processing stage the AM part needs to go through, the goal remains the same: removing the undesired properties that have been built-in the final product during the additive manufacturing process. Furthermore, as the name suggests, it takes place at the end of the manufacturing process, and the type of post-processing actions leveraged as well as the amount of work at this stage of the manufacturing depends on many variables including applications.

Objective

This module aims to document post-processing technologies and their applications concerning different AM processes.

Various types of post-process treatments are reviewed and their integrations with AM process are discussed. During this course, the following objective:

1. Describe the different post processing techniques
2. Explain the benefits and limitations of each post processing technique with respect to each AM process
3. Identify the most suitable post processing technique for a specific AM process and application

Target Group

The target group for the lecture for Post-Processing in AM, in the DIGIMAN project are mainly Master students in the fields of Mechanical, material, chemical engineering, informatics, and industry 4.0.

Syllabus/Indicative content

- Post-processing techniques.
- Shot-peening, heat treatments, HIPping
- Materials science

Learning Aims

On successful completion of this module a student should be able to:

1. Obtain advanced knowledge and critical understanding of the theory, principles and applicability of: Post processing methods
2. Explain how post process fits in the AM chain
3. Describe the different post-processing technologies and their applications in AM process as built parts

4. Discuss the different methods that can be used to reduce residual stresses and distortion, for a variety of part geometries and AM processes
5. Describe the effect of different heat treatments on microstructure, mechanical properties, residual stresses and defects

Explain the steps and respective cost associated to the different post process, according to each AM process

Tasks

There are no specific tasks beyond visiting and participate in the lecture, read, and understand the materials.

Structure

- face-to-face and online Lectures
- Laboratorial classes

Student Workload (Hours)

• Contact Time Total • Independent Learning Time	23 Hours 77 Hours
Total Learning Hours	**100 Hours**

Evaluation

The students will take a test at the end of the semester, based on the Learning Note and the delivered test questions and answers.

Additional Information

Students should be encouraged to gather more information about for their own personal interest.

Essential reading:

1. Gibson, I., Rosen, D., Stucker, B., Material jetting, in Additive manufacturing technologies: 3D printing, rapid prototyping, and direct digital manufacturing, 2010, Springer
2. Yang, Li & Hsu, Keng & Baughman, Brian & Godfrey, Donald & Medina, Francisco & Menon, Mamballykalathil & Wiener, Soeren. Additive Manufacturing of Metals: The Technology, Materials, Design and Production. pp. 21-22. (2017). https://doi.org/10.1007/978-3-319-55128-9
3. Davim, J. Additive Manufacturing: Applications and Innovations. CRC Press: Taylor & Fran. pp. 45-47 (2019).
4. Yang, Li & Hsu, Keng & Baughman, Brian & Godfrey, Donald & Medina, Francisco & Menon, Mamballykalathil & Wiener, Soeren. Additive Manufacturing of Metals: The Technology, Materials, Design and Production. pp. 42-43. (2017). https://doi.org/10.1007/978-3-319-55128-9.

Additional reading:

Davim, J. Additive Manufacturing: Applications and Innovations. CRC Press: Taylor & Fran. pp. 45-47. (2019).

Digital **Man**ufacturing Master para definir especialistas para o início da indústria 4.0



Número do projeto:
2019-1-RO01-KA203-063486

Pós-Processamento em AM

Notas pedagógicas

Tabela de Conteúdos

APRESENTAÇÃO 3
Objetivo 3
Grupo Alvo 4
Conteúdo indicativo 4
Objetivos de Aprendizagem 4
Tarefas 4
Estrutura 5
Carga de Trabalho dos Estudantes (Horas) 5
Avaliação 5
Informação Adicional 5
Leitura essencial 5
Leitura adicional 5

UNIDADE DIDÁTICA 4
TÍTULO DA UNIDADE: *Pós-Processamento em AM*

APRESENTAÇÃO

O pós-processamento é uma etapa crítica em AM. É a fase final do processo de fabrico, onde as peças recebem ajustes, tais como acabamento e alteração das propriedades mecânicas. Apesar de todas as vantagens que o fabrico aditivo apresenta sobre os métodos tradicionais de fabrico, ainda é imperfeito. As peças produzidas por AM ainda têm em alguns casos mau acabamento superficial, e o método de produção pode afetar as propriedades mecânicas do componente. O principal objetivo do pós-processamento é eliminar estes defeitos potencialmente prejudiciais, havendo algumas formas de o conseguir. Estes processos podem incluir o tratamento térmico, que é necessário para reduzir as tensões dos componentes antes da sua remoção da placa de construção, separação dos componentes da estrutura de suporte, bem como o acabamento superficial e processos como a maquinação CNC, a explosão e o polimento. O processamento pós-processamento de peças em AM pode ser tão vital como o próprio fabrico.

Os industriais passaram os últimos vinte anos enaltecer a produção por fabrico aditivo, mas a realidade mostra que se há uma coisa que realmente permite apreciar os benefícios e os resultados desta tecnologia, é o pós-processamento. O termo pós-processamento é uma espécie de guarda-chuva que abrange uma variedade de etapas que as peças obtidas por impressão 3D têm de ser submetidas antes de serem usadas como componente final. Independentemente da fase de pós-processamento que a peça obtida por AM tenha de passar, o objetivo mantém-se o mesmo: remover as propriedades não desejadas que foram incorporadas no produto final durante o processo de fabrico aditivo. Além disso, como o nome sugere, ocorre no final do processo de fabrico, sendo que o tipo de tratamento a realizar depende de muitas variáveis, incluindo a aplicação

Objetivo

Este módulo tem como objetivo documentar tecnologias de pós-processamento e suas aplicações relativas a diferentes processos de AM.

Neste módulo é feita uma revisão dos tipos de tratamentos pós-fabrico aditivo mais utilizados e as suas integrações com o processo AM são discutidas. Pretendendo-se com este módulo atingir os seguintes objetivos:

1. Descrever as diferentes técnicas de pós-processamento
2. Explicar os benefícios e limitações de cada técnica de processamento pós-processamento em relação a cada processo AM
3. Identificar a técnica de pós-processamento mais adequada para um processo e aplicação am específicos

Grupo Alvo

O grupo-alvo para o módulo de Pós-Processamento em AM, no projeto DIGIMAN são principalmente estudantes nas áreas da engenharia Mecânica, engenharia de Materiais, Engenharia Química, Informática e Indústria 4.0.

Conteúdo indicativo

- Técnicas de pós-processamento.
- Tratamentos, tratamentos térmicos, HIPping
- Ciência dos materiais

Objetivos de Aprendizagem

Após a conclusão com sucesso deste módulo, um aluno deve ser capaz de:

1. Obter conhecimentos avançados e compreensão crítica da teoria, princípios e aplicabilidade de diferentes métodos de pós-processamento
2. Explicar como é que a etapa de Pós-processo se encaixa na cadeia de fabrico Aditivo
3. Descrever as diferentes tecnologias de pós-processamento função do processo de Fabrico Aditivo e da aplicação final
4. Discutir os diferentes métodos que podem ser usados para reduzir as tensões residuais e a distorção, para uma variedade de geometrias e processos de fabrico aditivo
5. Descrever o efeito de diferentes tratamentos térmicos na microestrutura, propriedades mecânicas, tensões residuais e defeitos
6. Explicar os passos associados às diferentes técnicas de pós-processamento aplicadas consoante o processo e a aplicação.

Tarefas

Não há tarefas específicas para além de visitas de estudo e da participação em seminários. A leitura e compreensão dos materiais fornecidos é fundamental.

Estrutura

- Aulas presencias e à distância
- Aulas laboratoriais

Carga de Trabalho dos Estudantes (Horas)

• Total de tempo de contato • Tempo de aprendizagem independente	23 Horas 77 Horas
Horas totais de aprendizagem	**100 Horas**

Avaliação

Os alunos farão um teste no final do semestre, com base no material dado durante o Módulo.

Informação Adicional

Os alunos devem ser encorajados a pesquisar mais informações sobre o tema pós-processamento em AM para seu próprio desenvolvimento e interesse pessoal.

Leitura essencial

1. Gibson, I., Rosen, D., Stucker, B., Material jetting, em tecnologias de fabrico aditivo: impressão 3D, prototipagem rápida e fabrico digital direto, 2010, Springer
2. Yang, Li & Hsu, Keng & Baughman, Brian & Godfrey, Donald & Medina, Francisco & Menon, Mamballykalathil & Wiener, Soeren. Fabrico aditivo de metais: A Tecnologia, Materiais, Design e Produção. pp. 21-22. (2017 https://doi.org/10.1007/978-3-319-55128-9).
3. Davim, J. Fabricação Aditiva: Aplicações e Inovações. CRC Press: Taylor & Fran. pp. 45-47 (2019).
4. Yang, Li & Hsu, Keng & Baughman, Brian & Godfrey, Donald & Medina, Francisco & Menon, Mamballykalathil & Wiener, Soeren. Fabrico aditivo de metais: A Tecnologia, Materiais, Design e Produção. pp. 42-43. (2017 https://doi.org/10.1007/978-3-319-55128-9).

Leitura adicional

Davim, J. Fabricação Aditiva: Aplicações e Inovações. CRC Press: Taylor & Fran. pp. 45-47. (2019).

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Rapid Tooling for Competitive AM

Teaching Note

Table of Content

Presentation 3
Objective 3
Target Group 4
Learning Aims 4
Structure 5
Student Workload (Hours) 5
Evaluation 5
Additional Information 5
Selected references 5

DIDACTIC UNIT

UNIT TITLE: *Rapid Tooling for Competitive AM*

Presentation

The purpose of the course is to ensure the accumulation of technical competences on how to make AM more competitive for industrial production. The course deals with aspects related to Rapid Tooling (RT), which are innovative technologies working with master models made by AM, which are further used for low and medium volume production of complex parts, made from different materials (plastics, metals, composite materials, etc.). On successful completion of this module a student should be able to:

- Obtain advanced knowledge and good understanding of the theory, principles and applicability of: different RT techniques: Silicone rubber moulding, Metal spray tooling for injection moulding, Investment casting, Selective Laser Sintering, Selective Laser Melting, etc.;
- Discuss and select the appropriate RT methods, which should take advantage of the master models made by 3D printing;
- Explain the competitive industrial applications of AM;
- Describe the main factors which have significant influence of the AM competitiveness and what are the main criteria to select he appropriate tooling route (volume production, type of material, complexity of the part, etc.).

Objectives

- Understand the principles of when and how AM could be a competitive technology for industrial production, not only an interesting method within the research laboratories
- Learn the basic Rapid Tooling methods and industrial applications of the patterns made by 3D printing
- Understand the principles of direct and indirect RT methods
- Select the appropriate RT techniques for specific industrial or medical applications of AM

Target Group

The target group for the *Rapid Tooling for competitive AM* lecture, within the DIGIMAN project, are mainly Master students in the fields of Mechanical/Industrial/Materials/ Engineering, Informatics, and Industry 4.0.

Syllabus/Indicative content

- Moving AM from research laboratories to industrial production
  - Design for AM and virtual prototyping
  - Transferring the CAD model to the AM machines
  - The need and importance of AM for RPD
  - How to select the adequate AM method, for specific applications
- Vacuum Casting by SRM (Silicone Rubber Molding)
  - How does SRM works?
  - How to cast parts into SRM?
- Investment casting of metal parts and applications
- Rapid tooling by SLM
  - Steps and procedure in the SLM process
  - Simulation of SLM process
  - Technological parameters
  - Heat treatment for stress releasing
  - Supports removal and finishing the SLM parts

Learning Aims

On successful completion of this module a student should be able to:

- Evaluate the specific productions requirements (e.g. volume production, type of material, complexity of the part), in order to select the suitable AM process to print the master model;
- Investigate, which are the available RT techniques, suitable to use the master model (printed from a simulant material), in order to get a low volume production of the parts, made from final material;
- Evaluate the possibilities of using AM in Rapid Product Development, where functional tests of the new product are required and the complex parts have to be made from final materials;
- Design the appropriate RT technology, select the splitting line, gating, venting for vacuum casting, investment casting, metal spray tooling, etc.;
- Coordinate the tasks distribution between the operators according to the work plan as well as manage the links between them;

Tasks

- Multiple choice questions and exercises;
- Practical setting up of the splitting line, gating, venting for vacuum casting, investment casting, metal spray tooling, for a group case study based on specific requirements for a particular industrial application.

Structure

- Interactive Lectures
- Laboratorial classes on 3D Printing, Vacuum Casting, Investment Casting and Selective Laser Melting

Student Workload (Hours)

• Contact Time Total • Independent Learning Time	23 Hours 77 Hours
Total Learning Hours	**100 Hours**

Evaluation

The students will undertake a written test at the end of the semester, based on the teaching materials. The students should be able to select the correct answers/solutions, to different questions /tasks.

Additional Information

Students should be encouraged to gather more information on Rapid Tooling and competitive AM technologies, for their own personal interest.

Selected references

1. A. Gebhardt, J. Kessler, L. Thurn, 3D Printing: Understanding Additive Manufacturing / Edition 2, Hanser, 2018
2. N. Balc (Ed.): "Modern Technologies in Manufacturing", - MTeM 2015, Trans Tech Publications (Switzerland), Volume 808, SBN-13: 978-3-03835-653-0
    a. Book available online (open access): https://www.scientific.net/AMM.808/book
3. N. Balc (Ed.): "Advanced Manufacturing Technologies", MTeM 2017, MATEC Web Conf. (France), Volume 137 (2017), ISBN: 978-2-7598-9027-9
    a. Book available online (open access): https://www.matec-conferences.org/articles/matecconf/abs/2017/51/contents/contents.html
4. N. Balc, D. Leordean (Eds.): "Research and Applications in Manufacturing Engineering", MTeM 2019, MATEC Web Conf. (France), Volume 299, ISBN: 978-2-7598-9083-5
    a. Book available online (open access): https://www.matec-conferences.org/articles/matecconf/abs/2019/48/contents/contents.html

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Pregătirea Rapidă a Fabricației Competitive

Sinteza cursului

Cuprins

Prezentare 3
Obiective 3
Grupul țintă 4
Structura cursului 4
Rezultatele învățării 4
Activități 5
Structura 5
Timp alocat 5
Evaluare 5
Informații suplimentare 5
Bibliografie 5

MODUL DIDACTIC

TITLU MODUL: *Pregătirea Rapidă a Fabricației Competitive*

Prezentare

Scopul cursului este de a asigura acumularea de competențe tehnice în domeniul AM și aplicarea lor direct în industrie. Cursul tratează aspecte legate de procesele Rapid Tooling (RT), care sunt tehnologii inovative, ce utilizează modele master realizate prin AM, pentru producția de piese complexe în serii mici și mijlocii, realizate din diferite materiale (plastice, metale, materiale compozite, etc.). La finalizarea cu succes a acestui modul, un student trebuie să fie capabil să:

- Obțină cunoștințe avansate și să înțeleagă partea teoretică, principiul de lucru și aplicabilitatea tehnologiilor RT: turnarea sub vid în matrițe din cauciuc siliconic, fabricarea matrițelor metalice prin pulverizare de metal topit, turnarea sub vid cu modele ușor fuzibile, sinterizarea selectivă cu laser, topirea selectivă cu laser, etc.;
- Analizeze și să selecteze procedeul RT adecvat și de asemenea, să utilizeze tehnologiile de printare 3D, pentru fabricația modelelor master.
- Explice aplicațiile industriale competitive ale AM;
- Descrie principalii factori care au o influență semnificativă asupra competitivității AM și care sunt principalele criterii de selectare a tehnologiei potrivite (seria de fabricație, tipul de material, complexitatea piesei, etc.).

Obiective

- Înțelegerea principiilor și capacitatatea de a stii când și cum AM ar putea fi o tehnologie competitivă pentru industrie și nu doar o metodă interesantă în laboratoarele de cercetare
- Învățarea principiilor de bază a metodelor Rapid Tooling și aplicațiile industriale care utilizează modele master fabricate prin imprimare 3D
- Înțelegerea metodelor RT directe și indirecte
- Selectarea metodei RT corespunzătoare, pentru aplicații industriale sau medicale

Grupul țintă

Grupul țintă căruia i se adresează modulul de curs *Pregătirea Rapidă a Fabricației Competitive*, dezvoltat în cadrul proiectului DIGIMAN, sunt studenți masteranzi în domeniile Inginerie Mecanică/ Industrială, Materiale, Informatică și Industria 4.0.

Structura cursului

- Transferul tehnologiilor AM din laboratoarele de cercetare, direct în industrie
  - Proiectarea pentru AM si dezvoltarea de prototipuri virtuale
  - Transferul modelului CAD la echipamentele AM
  - Necesitatea și importanța AM pentru dezvoltarea rapidă de produse
  - Cum se selectează metoda AM adecvată, pentru aplicații specifice
- Turnarea sub vid în matrițe din cauciuc siliconic (CS)
  - Metoda de fabricație a matrițelor din CS
  - Cum se toarnă piese în matrițele din CS
- Turnarea sub vid a pieselor metalice și aplicații
- Fabricația prin SLM
  - Etapele și metodele utilizate la procesul SLM
  - Simularea procesului SLM
  - Parametri tehnologici
  - Tratament termic de detensionare
  - Îndepărtarea suporților și finisarea pieselor fabricate prin SLM

Rezultatele învățării

La finalizarea cu succes a acestui modul, un student ar trebui să poată să:

- Evalueze cerințele specifice de producție (de exemplu, seria de fabricație, tipul de material, complexitatea piesei) și să selecteze procesul AM adecvat, pentru fabricația modelului master;
- Să studieze, care sunt tehnologiile RT disponibile, adecvate pentru a utiliza modelul master (fabricat printr-o tehnologie AM), în vederea fabricării unor piese în serie mică de fabricație, din materialul final;
- Evalueze posibilitățile de utilizare a tehnologiilor AM în dezvoltarea rapidă a produsului, în cazul în care sunt necesare teste privind funcționalitatea noului produs și piesele complexe trebuie să fie realizate din materialul final;
- Proiecteze tehnologia RT corespunzătoare, selecteze planul de separație, rețeaua de alimentare cu material, canalele de aerisire pentru turnare sub vid, turnarea pieselor metalice, turnarea în matrițe realizate prin pulverizare de metal topit, etc.;
- Coordoneze repartizarea activităților între operatori, conform planului de lucru, precum și gestionarea legăturilor dintre aceștia;

Activități

- Întrebări și exerciții cu variante multiple de răspuns;
- Activități practice, pe echipe (privind alegerea planului de separație, stabilirea rețelei de alimentare cu material, a canalelor de aerisire pentru turnare sub vid, turnarea pieselor metalice, fabricația matrițelor metalice prin pulverizare de metal topit) pentru un studiu de caz, bazat pe cerințe specifice pentru o anumită aplicație industrială.

Structura

- Cursuri interactive
- Aplicații în domeniul printării 3D, turnarea sub vid, turnarea metalelor și topirea selectivă cu laser

Timp alocat

• Cursuri și aplicații • Studiu individual	23 Ore 77 Ore
Total ore	**100 Ore**

Evaluare

Studenții vor susține o probă scrisă la finalul semestrului, pe baza materialelor didactice. Studenții trebuie să selecteze răspunsurile/soluțiile corecte, la diferite întrebări/activități.

Informații suplimentare

Studenții trebuie încurajați să colecteze mai multe informații despre fabricația rapidă și tehnologiile de fabricație competitivă, pentru propriul lor interes personal.

Bibliografie

1. A. Gebhardt, J. Kessler, L. Thurn, 3D Printing: Understanding Additive Manufacturing / Edition 2, Hanser, 2018
2. N. Balc (Ed.): "Modern Technologies in Manufacturing", - MTeM 2015, Trans Tech Publications (Switzerland), Volume 808, SBN-13: 978-3-03835-653-0
   a. Book available online (open access): https://www.scientific.net/AMM.808/book
3. N. Balc (Ed.): "Advanced Manufacturing Technologies", MTeM 2017, MATEC Web Conf. (France), Volume 137 (2017), ISBN: 978-2-7598-9027-9
   a. Book available online (open access): https://www.matec-conferences.org/articles/matecconf/abs/2017/51/contents/contents.html
4. N. Balc, D. Leordean (Eds.): "Research and Applications in Manufacturing Engineering", MTeM 2019, MATEC Web Conf. (France), Volume 299, ISBN: 978-2-7598-9083-5
   a. Book available online (open access): https://www.matec-conferences.org/articles/matecconf/abs/2019/48/contents/contents.html

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Innovative Manufacturing and Quality Engineering

Teaching Note

Table of Content

Presentation 3
Objective 3
Target Group 4
Learning Aims 4
Structure 5
Student Workload (Hours) 5
Evaluation 5
Additional Information 5
Selected references 5

DIDACTIC UNIT

UNIT TITLE: *Innovative Manufacturing and Quality Engineering*

Presentation

The purpose of the course is to ensure the accumulation of technical competences on how the composite material parts are made in low volume production, when the innovative water jet machining is efficient and how important the quality engineering is, in Digital Manufacturing! The course deals with aspects related to 3D printing of the master models, vacuum bag technology and direct 3D printing of the complex parts made from composite materials. The working principle for the AWJ technology is presented, together with applications and case studies. Both tactile and optical measurements methods are presented, followed by a reverse engineering case study. On successful completion of this module a student should be able to:

- Obtain advanced knowledge and good understanding of the theory, principles and applicability of how to produce parts made from composite materials, using either classical methods or direct 3D printing of the complex parts made from composite materials;
- Discuss the efficiency and practical applications of the water jet machining process;
- Explain the competitive industrial applications of innovative manufacturing;
- Describe the main factors which have significant influence on the quality of the engineering products and how the quality engineering could be assured in Digital Manufacturing.

Objectives

- Understand the principles of the innovative manufacturing to produce parts from composite materials
- Learn the basic of the Water Jet Machining process and applications
- Understand the principles of Quality Engineering in Digital Manufacturing
- Select the appropriate measurement method for specific industrial applications.

Target Group

The target group for the *Innovative Manufacturing and Quality Engineering* lecture, within the DIGIMAN project, are mainly Master students in the fields of Mechanical/Industrial/Materials/ Engineering, Informatics, and Industry 4.0.

Syllabus/Indicative content

- Innovative manufacturing to produce parts from composite materials
  - Classical melding technology
  - 3D printing of the master models
  - Mould building using metal spray technology
  - Vacuum bag technology
  - Direct 3D printing of the complex parts made from composite materials
  - Software for 3D printing
- Water Jet Machining
  - Working principle for the AWJ technology
  - Types of equipment and manufactures
  - Technological parameters
  - Case study
- Quality Engineering in Digital Manufacturing
  - Inspection in quality control
  - Tactile measurement
  - Optical measurement
  - Reverse engineering a part using an optical scanner

Learning Aims

On successful completion of this module a student should be able to:

- Evaluate the specific methods to produce parts made of composite materials, in low volume production;
- Investigate, when it's appropriate to use the classical moulding technology (compression moulding), or the direct 3D printing of the complex parts made from composite materials;
- Evaluate the possibilities of using the Water Jet Machining technology;
- Contribute with ideas, solutions, and efforts in a group work or project
- Design the appropriate method to assure quality engineering in Digital Manufacturing
- Working in multidisciplinary team of people with variety of skills, knowledge, and backgrounds. Actively participating and collaborating with team members in order to get better ideas and solutions;

Tasks

- Multiple choice questions and exercises;
- Practical setting up of the master model for classical moulding technology, versus direct 3D printing of the complex parts made from composite materials.

Structure

- Interactive Lectures
- Laboratorial classes on 3D Printing, Water Jet Machining and Quality Engineering

Student Workload (Hours)

• Contact Time Total • Independent Learning Time	23 Hours 77 Hours
Total Learning Hours	**100 Hours**

Evaluation

The students will undertake a written test at the end of the semester, based on the teaching materials. The students should be able to select the correct answers/solutions, to different questions /tasks.

Additional Information

Students should be encouraged to gather more information on Innovative Manufacturing and Quality Engineering, for their own personal interest.

Selected references

1. Sina Ebnesajjad, APPLIED PLASTICS ENGINEERING HANDBOOK, Chadds Ford, PA, USA,
2. Y. Natarajan, P. K. Murugesan, M. Mohan, and S. A. Liyakath Ali Khan, 'Abrasive Water Jet Machining process: A state of art of review', Journal of Manufacturing Processes, vol. 49, pp. 271–322, Jan. 2020, doi: 10.1016/j.jmapro.2019.11.030.
3. I. A. Popan, N. Balc, and A. I. Popan, 'Avoiding carbon fibre reinforced polymer delamination during abrasive water jet piercing: a new piercing method', Int J Adv Manuf Technol, Nov. 2021, doi: 10.1007/s00170-021-08294-7
4. Keyence. (2021). Coordinate Measuring Machines | Measurement System Types and Characteristics | Measurement Fundamentals | KEYENCE America. https://www.keyence.com/ss/products/measure-sys/measurement-selection/type/3d.jsp

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Fabricație Inovativă și Ingineria Calității

Sinteza cursului

Cuprins

Prezentare 3
Obiective 3
Grupul țintă 4
Structura cursului 4
Rezultatele învățării 4
Activități 5
Structura 5
Timp alocat 5
Evaluare 5
Informații suplimentare 5
Bibliografie 5

MODUL DIDACTIC
TITLU MODUL: *Fabricație Inovativă și Ingineria Calității*

Prezentare

Scopul cursului este de a asigura acumularea de competențe tehnice despre cum se fabrică piesele din materiale compozite, în serii mici, despre eficiența prelucrărilor cu jet de apă și cât de importantă este ingineria calității, în producția digitală. Cursul cuprinde aspect legate de fabricația pieselor din materiale compozite prin 2 metode: prin tipărire 3D a modelelor master și prin formare în vid. De asemenea este prezentat principiul procesului de tăiere cu jet de apă, aplicații și studii de caz. Sunt descrise metode de măsurare prin palpare, cât și metode de măsurare optică, urmate de un studiu de caz de inginerie inversă. La finalul modulului studenții trebuie să fie capabili să:

- Obțină cunoștințe avansate și o bună înțelegere a teoriei, principiilor și aplicabilității modului de fabricație a pieselor realizate din materiale compozite, utilizând fie metode clasice, fie imprimarea 3D a pieselor complexe realizate din materiale compozite;
- Analizeze eficiența și aplicațiile practice ale procesului de prelucrare cu jet de apă;
- Explice aplicațiile industriale competitive ale fabricației inovative;
- Descrie factorii principali care au o influență semnificativă asupra calității pieselor și modul în care ingineria calității ar putea fi asigurată în fabricația digitală.

Obiective

- Înțelegerea principiului de fabricație a pieselor din materiale compozite prin tehnologii inovative
- Studiul elementelor principale ale procesului de prelucrare cu jet de apă și aplicațiile sale
- Înțelegerea principiilor ingineriei calității în fabricația digitală
- Selectarea metodei adecvate de măsurare, pentru aplicații industriale specifice.

Grupul țintă

Grupul țintă pentru cursul de *Fabricație Inovativă și Ingineria Calității*, dezvoltat în cadrul proiectului DIGIMAN, sunt în general studenți masteranzi în domeniile Inginerie Mecanică/ Industrială, Materiale, Informatică și Industria 4.0.

Structura cursului

- Tehnologii innovative de fabricație a pieselor din materiale compozite
  - Procesul convențional de formare în matriță
  - Printarea 3D a modelelor master
  - Fabricația matriței prin pulverizare de metal topit
  - Procesul de formare în vid
  - Printarea 3D a pieselor complexe din materiale compozite
  - Software pentru printarea 3D
- Fabricația prin tăiere cu jet de apă
  - Principiul de lucru al procesului de tăiere cu jet de apă
  - Tipuri de echipamente și producători
  - Parametri tehnologici
  - Studiu de caz
- Ingineria calității în fabricația digitală
  - Inspecția în controlul calității
  - Măsurarea prin palpare
  - Măsurarea optică
  - Ingineria inversă a unei piese, utilizând un scaner optic.

Rezultatele învățării

La finalizarea cu succes a acestui modul, un student ar trebui să poată:

- Evalueze metodele specifice de fabricație a pieselor din materiale compozite în serii mici de fabricație;
- Analizeze și sa aleagă tehnologia potrivită pentru fiecare aplicație (tehnologia convențională sau fabricația prin printare 3D a pieselor din materiale compozite)
- Să evalueze posibilitățile de utilizare a tehnologiei de prelucrare cu jet de apă;
- Contribuie cu idei și soluții la lucrările sau proiectele de grup;
- Proiecteze metoda adecvată pentru asigurarea calității în fabricația digitală;
- Lucreze în echipe multidisciplinare, cu persoane cu abilități diverse, cunoștințe și expertiză. Participarea activă și colaborarea cu membri echipei pentru a obține idei și soluții mai bune;

Activități

- Întrebări și exerciții cu variante multiple de răspuns;
- Activități practice privind tehnologia convențională de fabricație în matriță, comparativ cu fabricația prin printare 3D a pieselor complexe din materiale compozite.

Structura

- Cursuri interactive
- Aplicații în domeniul printării 3D, tăiere cu jet de apă și ingineria calității

Timp alocat

• Cursuri și aplicații • Studiu individual	23 Ore 77 Ore
Total ore	**100 Ore**

Evaluare

Studenții vor susține o probă scrisă la finalul semestrului, pe baza materialelor didactice. Studenții trebuie să selecteze răspunsurile/soluțiile corecte, la diferite întrebări/activități.

Informații suplimentare

Studenții trebuie încurajați să colecteze mai multe informații despre fabricația inovativă și ingineria calității, pentru propriul lor interes personal.

Bibliografie

1. Sina Ebnesajjad, APPLIED PLASTICS ENGINEERING HANDBOOK, Chadds Ford, PA, USA,
2. Y. Natarajan, P. K. Murugesan, M. Mohan, and S. A. Liyakath Ali Khan, 'Abrasive Water Jet Machining process: A state of art of review', Journal of Manufacturing Processes, vol. 49, pp. 271–322, Jan. 2020, doi: 10.1016/j.jmapro.2019.11.030.
3. I. A. Popan, N. Balc, and A. I. Popan, 'Avoiding carbon fibre reinforced polymer delamination during abrasive water jet piercing: a new piercing method', Int J Adv Manuf Technol, Nov. 2021, doi: 10.1007/s00170-021-08294-7
4. Keyence. (2021). Coordinate Measuring Machines | Measurement System Types and Characteristics | Measurement Fundamentals | KEYENCE America. https://www.keyence.com/ss/products/measure-sys/measurement-selection/type/3d.jsp

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:

2019-1-RO01-KA203-063486

Virtual Reality

Teaching Notes

Table of Contents

Presentation 3

Objective 3

Target Group 3

Learning Aims 4

Tasks 4

Structure 5

Student Workload (Hours) 5

Evaluation 5

Additional Information 5

Essential reading: 5

COURSE 7
COURSE TITLE: *Virtual Reality*

Presentation

Technology is changing the way people live, work, and do business. Digitalization and automation are framing our future. This creates new and exciting opportunities, but at the same time challenges.

With Virtual Reality (VR) it is possible to experience scenarios very immersive and thus to get a "deeper impression". For a long time, however, this deeper impression was hindered by various problems. For example, the quality of VR products was often not good, and the price was very expensive. Due to these problems and the therefore lack of interest of people in VR, the number and quality of software for VR was also low. Thanks to technical innovations in terms of hardware and software, many of these problems are now a thing of the past and VR can realize its full potential.

Objective

This module will enable students to understand what VR is and what it can be used for. Students will understand what the problems and advantages in VR are and what to expect in the future as well as a basic understanding of implementing VR applications.

Target Group

The target group for the lecture for Virtual Reality in the DIGIMAN project are mainly Master students in the fields of software engineering, informatics, and industry 4.0.

Syllabus/Indicative content

- Definition of VR
- History of VR
- Important VR related terms and definitions
- Technical needed systems for VR
- Showcase and explanation of VR Hardware
- How does VR software work?
- Problems of VR
- Possible use cases for VR
- Outlook

Learning Aims

Aim of this course is it that the students collect a broad and solid understanding of VR.

This includes:

- Solid understanding of what Virtual Reality is and how it is defined
- What are potential risks and threads of VR
- An understanding of how VR applications can be implemented

After the course students will

- know how VR works and what things are important while handling VR
- be aware of potential threads when using VR
- be able to implement basic VR applications

Tasks

There are no specific tasks beyond visiting and participate in the lecture, read, and understand the materials.

Structure

The course is structured like a usual lecture with frontal teaching.

Student Workload (Hours)

• Contact Time Total • Independent Learning Time	22,5 Hours 67,5 Hours
Total Learning Hours	**90 Hours**

Evaluation

The students will take a test at the end of the semester, based on the Learning Note and the delivered test questions and answers.

Additional Information

Students should be encouraged to gather more information about VR for their own personal interest.

Essential reading:

Xymatic. (2021). XR Glossary: The Perfect Resource for Virtual and Augmented Reality Terminology. Retrieved from https://delight-vr.com/xr-glossary/

Additional reading:

Find the essential readings at the end of each chapter in the student handbook.

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:

2019-1-RO01-KA203-063486

Virtual Reality

Lehrvermerke

Inhalt

Präsentation 3

Zielsetzung 3

Zielgruppe 4

Lehrplan/Inhaltsangabe 4

Lernziele 4

Aufgaben 5

Struktur 5

Studentische Arbeitsbelastung (Stunden) 5

Auswertung 5

Zusätzliche Informationen 5

Essenzielle Lektüre 6

KURS 7

KURSTITEL: Virtuelle Realität

Präsentation

Die Technologie verändert die Art und Weise, wie Menschen leben, arbeiten und Geschäfte machen. Digitalisierung und Automatisierung prägen unsere Zukunft. Dies schafft neue und spannende Möglichkeiten, aber auch Herausforderungen.
Mit Virtual Reality (VR) ist es möglich, Szenarien sehr immersiv zu erleben und so einen "tieferen Eindruck" zu bekommen. Lange Zeit wurde dieser tiefere Eindruck jedoch durch verschiedene Probleme behindert. Zum Beispiel war die Qualität der VR-Produkte oft nicht gut und der Preis sehr teuer. Aufgrund dieser Probleme und des dadurch bedingten mangelnden Interesses der Menschen an VR war auch die Anzahl und Qualität der Software für VR gering. Dank der technischen Innovationen im Bereich der Hard- und Software gehören viele dieser Probleme der Vergangenheit an und VR kann sein volles Potenzial entfalten.

Zielsetzung

Dieses Modul ermöglicht es den Studierenden zu verstehen, was VR ist und wofür sie eingesetzt werden kann. Die Studierenden werden verstehen, was die Probleme und Vorteile von VR sind und was in der Zukunft zu erwarten ist, sowie ein grundlegendes Verständnis der Implementierung von VR-Anwendungen.

Zielgruppe

Die Zielgruppe für die Vorlesung zur Virtuellen Realität im DIGIMAN-Projekt sind vor allem Masterstudenten aus den Bereichen Software Engineering, Informatik und Industrie 4.0.

Lehrplan/Inhaltsangabe

- Definition der VR
- Geschichte der VR
- Wichtige Begriffe im Umgang mit VR
- Technische Systeme für den Umgang mit VR
- Erklärung von VR Hardware
- Erklärung von VR Software
- Probleme mit VR
- Potenziell interessante Bereiche für VR
- Ausblick

Lernziele

Ziele dieses Kurses ist es, dass die Studenten einen breiten Überblick über das Thema VR bekommen

Das beinhaltet:

- Ein solides Verständnis von VR und dessen Definition
- Was sind die potenziellen Risiken von VR
- Verstehen wie VR Applikationen implementiert werden können

Nach diesem Kurs werden die Studenten verstanden haben:

- Wie VR funktioniert und welche Dinge zu beachten sind
- Wie man mit möglichen Gefahren und Risiken bei VR umgeht
- Wie man grundlegende VR Anwendungen implementiert

Aufgaben

Es gibt keine spezifischen Aufgaben, die über den Besuch und die Teilnahme an der Vorlesung, das Lesen und das Verstehen der Materialien hinausgehen.

Struktur

Der Kurs ist wie eine normale Vorlesung mit Frontalunterricht aufgebaut.

Studentische Arbeitsbelastung (Stunden)

• Kontaktzeit Insgesamt • Unabhängige Lernzeit	22,5 Stunden 67,5 Stunden
Lernstunden insgesamt	**90 Stunden**

Auswertung

Am Ende des Semesters absolvieren die Studierenden einen Test, der auf der Grundlage der Lernnotiz und der mitgelieferten Testfragen und -antworten durchgeführt wird.

Zusätzliche Informationen

Die Schüler sollten ermutigt werden, mehr Informationen über VR für ihr eigenes persönliches Interesse zu sammeln.

Essenzielle Lektüre

Xymatic. (2021). XR Glossary: The Perfect Resource for Virtual and Augmented Reality Terminology. Retrieved from https://delight-vr.com/xr-glossary/

Weitere Lektüre:

Die wichtigsten Lektüren finden Sie am Ende eines jeden Kapitels im Studentenhandbuch.

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0

DIGIMAN

master programme for digital manufacturing

Project number:

2019-1-RO01-KA203-063486

Augmented Reality

Teaching Notes

Table of Contents

Presentation.....3

Objective.....3

Target Group.....4

Learning Aims.....4

Tasks.....5

Structure.....5

Student Workload (Hours).....5

Evaluation.....5

Additional Information.....5

Essential reading:.....5

COURSE 8

COURSE TITLE: *Augmented Reality*

Presentation

Technology is changing the way people live, work, and do business. Digitalization and automation are framing our future. This creates new and exciting opportunities, but at the same time challenges.

With Augmented Reality (AR) it is possible to experience scenarios very immersive and thus to get a "deeper impression". For a long time, however, this deeper impression was hindered by various problems. For example, the quality of AR products was often not good, and the price was very expensive. Due to these problems and the therefore lack of interest of people in AR, the number and quality of software for AR was also low. Thanks to technical innovations in terms of hardware and software, many of these problems are now a thing of the past and AR can realize its full potential.

Objective

This module will enable students to understand what AR is and what it can be used for. Students will understand what the problems and advantages in AR are and what to expect in the future as well as a basic understanding of implementing AR applications.

Target Group

The target group for the lecture for Virtual Reality in the DIGIMAN project are mainly Master students in the fields of software engineering, informatics, and industry 4.0.

Syllabus/Indicative content

- Definition of AR
- History of AR
- Important AR related terms and definitions
- Technical needed systems for AR
- Showcase and explanation of AR Hardware
- How does AR software work?
- Problems of AR
- Possible use cases for AR
- Outlook

Learning Aims

Aim of this course is it that the students collect a broad and solid understanding of AR.

This includes:

- Solid understanding of what the Reality-Virtuality Continuum is and how it is defined
- Solid understanding of what Augmented Reality is and how it is defined
- What are potential risks and threads of AR
- An understanding of how AR applications can be implemented

After the course students will

- understand the Reality-Virtuality Continuum and why it is important
- know how AR works and what things are important while handling AR
- be aware of potential threads when using AR
- be able to implement basic AR applications

Tasks

There are no specific tasks beyond visiting and participate in the lecture, read, and understand the materials.

Structure

The course is structured like a usual lecture with frontal teaching.

Student Workload (Hours)

• Contact Time Total • Independent Learning Time	22,5 Hours 67,5 Hours
Total Learning Hours	**90 Hours**

Evaluation

The students will take a test at the end of the semester, based on the Learning Note and the delivered test questions and answers.

Additional Information

Students should be encouraged to gather more information about AR for their own personal interest.

Essential reading:

Ronald T. Azuma; A Survey of Augmented Reality. Presence: Teleoperators and Virtual Environments 1997; 6 (4): 355–385. doi: https://doi.org/10.1162/pres.1997.6.4.355

Additional reading:

Find the essential readings at the end of each chapter in the student handbook.

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:

2019-1-RO01-KA203-063486

Erweiterte Realität

Anmerkungen für den Unterricht

Inhaltsübersicht

Präsentation 3

Zielsetzung 3

Zielgruppe 4

Lehrplan/Inhaltsangabe 4

Lernziele 4

Aufgaben 5

Struktur 5

Studentische Arbeitsbelastung (Stunden) 5

Auswertung 5

Zusätzliche Informationen 5

Essenzielle Lektüre 6

KURS 8

KURSTITEL: Erweiterte Realität (Augmented Reality)

Präsentation

Die Technologie verändert die Art und Weise, wie Menschen leben, arbeiten und Geschäfte machen. Digitalisierung und Automatisierung prägen unsere Zukunft. Dies schafft neue und spannende Möglichkeiten, aber auch Herausforderungen.
Mit Augmented Reality (AR) ist es möglich, Szenarien sehr immersiv zu erleben und so einen "tieferen Eindruck" zu bekommen. Lange Zeit wurde dieser tiefere Eindruck jedoch durch verschiedene Probleme behindert. Zum Beispiel war die Qualität der AR-Produkte oft nicht gut und der Preis sehr teuer. Aufgrund dieser Probleme und des dadurch bedingten mangelnden Interesses der Menschen an AR war auch die Anzahl und Qualität der Software für AR gering. Dank der technischen Innovationen im Bereich der Hard- und Software gehören viele dieser Probleme der Vergangenheit an und VR kann sein volles Potenzial entfalten.

Zielsetzung

In diesem Modul lernen die Studierenden zu verstehen, was AR ist und wofür sie eingesetzt werden kann. Die Studenten werden verstehen, was die Probleme und Vorteile von AR sind und was in der Zukunft zu erwarten ist, sowie ein grundlegendes Verständnis für die Implementierung von AR-Anwendungen.

Zielgruppe

Die Zielgruppe für die Vorlesung Augmented Reality im DIGIMAN-Projekt sind vor allem Masterstudenten aus den Bereichen Software Engineering, Informatik und Industrie 4.0.

Lehrplan/Inhaltsangabe

- Definition der AR
- Geschichte der AR
- Wichtige Begriffe im Umgang mit AR
- Technische Systeme für den Umgang mit AR
- Erklärung von AR Hardware
- Erklärung von AR Software
- Probleme mit AR
- Potenziell interessante Bereiche für AR
- Ausblick

Lernziele

Ziele dieses Kurses ist es, dass die Studenten einen breiten Überblick über das Thema AR bekommen

Das beinhaltet:

- Ein solides Verständnis dessen, was das Reality-Virtuality Continuum ist und wie dieses definiert wird
- Solide Kenntnisse darüber, was Augmented Reality ist und wie sie definiert wird
- Was die Vor- und Nachteile von AR sind
- Ein Verständnis dafür, wie AR-Anwendungen implementiert werden können

Nach dem Kurs werden die Studenten

- das Kontinuum Realität-Virtualität zu verstehen und zu verstehen, warum es wichtig ist
- wissen, wie AR funktioniert und worauf es beim Umgang mit AR ankommt
- bei der Verwendung von AR auf mögliche Fäden achten
- in der Lage sein, grundlegende AR-Anwendungen zu implementieren

Aufgaben

Es gibt keine spezifischen Aufgaben, die über den Besuch und die Teilnahme an der Vorlesung, das Lesen und das Verstehen der Materialien hinausgehen.

Struktur

Der Kurs ist wie eine normale Vorlesung mit Frontalunterricht aufgebaut.

Studentische Arbeitsbelastung (Stunden)

• Kontaktzeit Insgesamt	22,5 Stunden
• Unabhängige Lernzeit	67,5 Stunden
Lernstunden insgesamt	**90 Stunden**

Auswertung

Am Ende des Semesters absolvieren die Studierenden einen Test, der auf der Grundlage der Lernnotiz und der mitgelieferten Testfragen und -antworten durchgeführt wird.

Zusätzliche Informationen

Die Schüler sollten ermutigt werden, mehr Informationen über AR für ihr eigenes persönliches Interesse zu sammeln.

Essenzielle Lektüre

Ronald T. Azuma; A Survey of Augmented Reality. Presence: Teleoperators and Virtual Environments 1997; 6 (4): 355–385. doi: https://doi.org/10.1162/pres.1997.6.4.355

Weitere Lektüre:

Die wichtigsten Lektüren finden Sie am Ende eines jeden Kapitels im Studentenhandbuch.

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Design of Digital Manufacturing

Teaching Note

Table of Contents

Index

Presentation 3
Objective 3
Target Group 4
Learning Aims 4
Tasks 4
Structure 5
Student Workload (Hours) 5
Evaluation 5
Additional Information 5
Essential reading: 5

DIDACTIC UNIT

UNIT TITLE: *Design of Digital Manufacturing*

Presentation

Manufacturing is a constantly evolving industry, and data show that the industry contributes a significant amount of revenue to any country. That being said, industry leaders have begun to shift their focus from traditional to smart production using Industry 4.0 solutions, as it offers a multitude of benefits to operators, managers and executives in companies in this sector. The integration of information technology (IT) and operations technology (OT) to form a stronger production organization is a state that is commonly referred to as Industry 4.0. Also known as SMART manufacturing or Manufacturing 4.0, Industry 4.0 is marked by a transition from physical to digital and vice versa connection. A design is created by drawing, CAD software or scanning a physical file object and in this way creating data. This data is then communicated to the executing machine's design, bringing it from the digital environment to the physical one. When design engineers and manufacturing engineers work together to design and rationalize both the product and production and support processes, it is known as integrated product and process design Another concept that Industry 4.0 introduces is the one called the "smart factory". This concept refers to cyber-physical systems monitoring the physical processes of the factory and making reasoned decisions. Physical systems become in this way the Internet of Things, communicating and cooperating both with each other and with a human operator in real-time.

Objective

This module will enable students to understand the importance of the Design of Digital Manufacturing concepts

Target Group

The target group for the lecture for Design of Digital Manufacturing in the DIGIMAN project are mainly Master students in the fields of Mechanical/Industrial/Materials/Engineering, Informatics, and Industry 4.0.

Syllabus/Indicative content

- Introduction in digital manufacturing
- History of digital manufacturing
- Introduction to Industry 4.0
- New trends for Industry 5.0
- Digital manufacturing vs traditional manufacturing
- Design for Manufacturing
- Design for X
- DFM in Conceptual design
- DFM and Concurrent Engineering
- Design automation requirements for supporting integrated product development

Learning Aims

On successful completion of this module a student should be able to:

- Understand what Digital Manufacturing is, what is possible and what tools and technologies are available;
- Know the techniques of synchronizing real (physical) and digitally simulated (cyber) production;
- Be able to develop and implement real-time digital representations of physical engineering systems;
- Be able to analyze the operation of production systems digitally utilizing simulation, having knowledge of IT;
- Understand the transformation process of digital manufacturing from the position of traditional manufacturing methodologies;
- Understand the workflow of digital manufacturing: from scanning to modelling to printing;
- Initiate, plan and execute, document and present digital manufacturing process projects;
- Identify the factors to consider when selecting technologies and implementing Digital Manufacturing;
- Identify the barriers to implementation of digital manufacturing and how to mitigate them;

Tasks

There are no specific tasks beyond visiting and participate in the lecture, read, and understand the materials.

Structure

- Synchronous and asynchronous Lectures and
- Laboratorial classes

Student Workload (Hours)

• Contact Time Total • Independent Learning Time	23 Hours 77 Hours
Total Learning Hours	**100 Hours**

Evaluation

The students will take a test at the end of the semester, based on the Learning Note and the delivered test questions and answers.

Additional Information

Students should be encouraged to gather more information about Design of digital manufacturing for their own personal interest.

Essential reading:

1. Zhong RY, Xu X, Klotz E, Newman ST (2017) Intelligent Manufacturing in the Context of Industry 4.0: A Review. Engineering 3:616–630. https://doi.org/10.1016/J.ENG.2017.05.015
2. Kutin A, Dolgov V, Sedykh M, Ivashin S (2018) Integration of Different Computer-aided Systems in Product Designing and Process Planning on Digital Manufacturing. Procedia CIRP 67:476–481. https://doi.org/10.1016/j.procir.2017.12.247
3. Holdowsky, Mahto, Raynor, and Cotteleer, Inside the Internet of Things (IoT), Deloitte University Press, August 21, 2015
4. Ghobakhloo M (2018) The future of manufacturing industry: a strategic roadmap toward Industry 4.0. J Manuf Technol Manag 29:910–936. https://doi.org/10.1108/JMTM-02-2018-0057

Additional reading:

Anand Kannan Smart vs. Traditional Manufacturing: A "Never-Before-Seen" Comparison, 2020, Smart Manufacturing vs. Traditional Manufacturing | IIoT (hakunamatatatech.com)

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Proiectarea fabricației digitale

Notă didactică

Cuprins

Index

Prezentare 3
Obiective 3
Grup Țintă 4
Topică/Conținut 4
Scopurile învățării 4
Sarcini 4
Structură 5
Timp de lucru al studentului (Ore) 5
Evaluare 5
Informații adiționale 5
Material bibliografic esențial pentru studiu: 5

Modul diactic

Denumire modul: *Proiectarea fabricației digitale*

Prezentare

Prelucrarile mecanice reprezintă o industrie în continuă evoluție, iar datele arată că industria contribuie cu o sumă semnificativă la produsul intern brut al oricărei țări. Acestea fiind spuse, liderii din industrie au început să-și schimbe atenția de la producția tradițională la cea inteligentă folosind soluțiile Industry 4.0, deoarece oferă o multitudine de beneficii operatorilor, managerilor și directorilor din companiile din acest sector. Integrarea tehnologiei informației (IT) și a tehnologiei operațiunilor (OT) pentru a forma o organizație de producție mai puternică este o stare care este denumită în mod obișnuit Industria 4.0. Cunoscută și sub denumirea de SMART manufacturing sau Manufacturing 4.0. Industria 4.0 este marcată de o tranziție de la o conexiune fizică la cea digitală și invers. Un design este creat prin desen, software CAD sau scanarea unui obiect de fișier fizic și în acest fel creând date. Aceste date sunt apoi comunicate proiectării mașinii unelte, aducându-l din mediul digital în cel fizic. Atunci când inginerii proiectanți și inginerii de producție lucrează împreună pentru a proiecta și raționaliza atât produsul, cât și procesele de producție și suport, este cunoscut sub numele de proiectare integrată a produsului și procesului. Un alt concept pe care Industria 4.0 îl introduce este cel numit „fabrica inteligentă”. Acest concept se referă la sistemele cyber-fizice care monitorizează procesele fizice ale fabricii și iau decizii motivate. Sistemele fizice devin astfel Internetul Lucrurilor - Internet of Things, comunicând și cooperând atât între ele, cât și cu un operator uman în timp real.

Obiective

Acest modul le permite studenților să înțeleagă importanța conceptului de Proiectare a Fabricației Digitale.

Grup Țintă

Grupul țintă pentru cursul de Proiectare a Fabricației Digitaledin cadrul proiectului DIGIMAN îl reprezintă în principal studenții de la ciclul de Master în domeniul Mecanică/Materiale/Inginerie/Informatică și Industrie 4.0

Topică/Conținut

- Introducere in fabricația digitală
- Istoria fabricației digitale
- Introducere în Industry 4.0
- Noi tendințe pentru Industry 5.0
- Fabricația digitală vs fabricația tradițională
- Proiectarea fabricației
- Design for X
- Proiectarea fabricației in proiectarea conceptuală
- Proiectarea fabricației și Ingineria Concurenta
- Cerințe ale automatizării proiectării pentru a sprijini dezvoltarea integrate a produsului

Scopurile învățării

La finalizarea cu succes a acestui modul, un student ar trebui să fie capabil să:

- Înțeleagă ce este Fabricația Digitală, ce este posibil, care sunt instrumentele și tehnologiile disponibile;
- Să cunoască tehnicile de sincronizare a producției fizice și virtuale;
- Să fie capabil să dezvolte și să implementezereprezentări digitale în timp real ale sistemelor inginerești fizice;
- Să fie capabil să analizeze operarea sistemelor de producție digitale utilizând simularea și având cunoștințe de IT;
- Să înțeleagă transformarea proceselor digitale de fabricație plecând de la metodologiile fabricației tradiționale;
- Să înțeleagă parcursul fabricației digitale de la scanare la modelare și printare 3D;
- Să inițieze, planifice, execute și să prezinte proiecte de fabricație digitală ;
- Să identifice factorii ce trebuie considerați la alegerea și implementarea fabricației digitale;
- Să identifice barierele în implementareafabricației digitale și cum să atenueze aceste bariere ;

Sarcini

Nu există sarcini specific decât să participle la cursuri, să citească și să înțeleagă materialele prezentate.

Structură

- Prelegeri onsite și online
- Ore de laborator

Timp de lucru al studentului (Ore)

• Timp total in contact • Timp de studiu individual	23 Ore 77 Ore
Total ore de învățare	**100 ore**

Evaluare

Studenții vor da un test la sfârșitul semestrului pe baza cursurilor predate și a subiectelor transmise

Informații adiționale

Studenții are trebui încurajați să strângă cât mai multe informații despre Fabricația Digitală pentru interesul lor personal.

Material bibliografic esențial pentru studiu:

1. Zhong RY, Xu X, Klotz E, Newman ST (2017) Intelligent Manufacturing in the Context of Industry 4.0: A Review. Engineering 3:616–630. https://doi.org/10.1016/J.ENG.2017.05.015
2. Kutin A, Dolgov V, Sedykh M, Ivashin S (2018) Integration of Different Computer-aided Systems in Product Designing and Process Planning on Digital Manufacturing. Procedia CIRP 67:476–481. https://doi.org/10.1016/j.procir.2017.12.247
3. Holdowsky, Mahto, Raynor, and Cotteleer, Inside the Internet of Things (IoT), Deloitte University Press, August 21, 2015
4. Ghobakhloo M (2018) The future of manufacturing industry: a strategic roadmap toward Industry 4.0. J Manuf Technol Manag 29:910–936. https://doi.org/10.1108/JMTM-02-2018-0057

Material de studiu suplimentar:

Anand Kannan Smart vs. Traditional Manufacturing: A "Never-Before-Seen" Comparison, 2020, Smart Manufacturing vs. Traditional Manufacturing | IIoT (hakunamatatatech.com)

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Digitális gyártás tervezése

Oktatói jegyzet

Tartalomjegyzék

Bemutatás 3
Célkitűzés 3
Célcsoport 4
Tanulási célok 4
Feladatok 5
Oktatási forma 5
Hallgatói munkaterhelés (órák) 5
Teljesítményértékelési módszerek 5
Kiegészítő információk 5
Kötelező irodalom: 5

A TANTÁRGY CÍME: *Digitális gyártás tervezése*

Bemutatás

A gyártástudomány folyamatosan fejlődő iparág, és a pénzügyi adatok azt mutatják, hogy az iparág jelentős bevételekkel járul hozzá bármely ország gazdaságához. Emiatt az iparági vezetők elkezdték áthelyezni a hangsúlyt a hagyományosról az intelligens termelésre az Ipar 4.0 megoldások használatával, mivel ez számos előnyt kínál az ágazatban működő vállalatok üzemeltetőinek, vezetőinek és ügyvezetőinek. Az információs technológia (IT) és az üzemeltetési technológia (OT) integrálása egy erősebb termelési szervezet kialakítása érdekében egy olyan stratégia, amelyet általában Ipar 4.0-nak neveznek. A SMART Manufacturing vagy Manufacturing 4.0 néven is ismert Ipar 4.0-t a fizikai környezetből a digitális környezetbe való átmenet jellemzi, és fordítva. A tervezés tervrajz elkészítésével, CAD-szoftverrel vagy egy fizikai tárgy szkennelésével és így adatok létrehozásával jöhet létre. Ezeket az adatokat azután továbbítják a végrehajtó gyártógép szoftveréhez, és így a digitális környezetből a fizikai környezetbe helyezik. Amikor a tervezőmérnökök és a gyártómérnökök együtt dolgoznak a termék- és a gyártási és támogatási folyamatok tervezésén és racionalizálásán, ezt integrált termék- és folyamattervezésnek nevezik. Egy másik koncepció, amelyet az Ipar 4.0 bevezet, az úgynevezett „okos gyár”. Ez a fogalom a gyár fizikai folyamatait figyelő és megalapozott döntéseket hozó kiberfizikai rendszereire vonatkozik. A fizikai rendszerek ily módon egy felhő alapú online adatcsomaggá fordíthatók, amely valós időben kommunikál és együttműködik egymással és egy emberi kezelővel.

Célkitűzés

Ez a modul lehetővé teszi a hallgatóknak, hogy megértsék a digitális gyártási koncepciók tervezésének fontosságát.

Célcsoport

A DIGIMAN projekt Digitális Gyártás Tervezése című moduljának célcsoportja elsősorban a Gépész/Gyártástudomány/Anyag/Műszaki, Informatika és Ipar 4.0 szakos mesterszakos hallgatók.

Tanterv/Indikatív tananyag

- Bevezetés a digitalis gyártásba
- A digitalis gyártás története
- Bevezetés az Ipar 4.0-ba
- Új trendek az Ipar 5.0-ban
- Digitális vs. hagyományos gyártás
- Gyártástervezés
- Kiválóságtervezés
- Koceptuális gyártástervezés
- Párhuzamos gyártástervezés
- Tervezési automatizálási követelmények az integrált termékfejlesztés támogatásához

Tanulási célok

A modul sikeres elvégzése után a hallgatónak képesnek kell lennie:
- Megérteni, mi az a digitális gyártás, mire van lehetőség, és milyen eszközök és technológiák állnak rendelkezésre;
- Ismerni a valós (fizikai) és a digitálisan szimulált (kiber) termelés szinkronizálásának technikáit;
- Legyen képes fizikai mérnöki rendszerek valós idejű digitális reprezentációinak fejlesztésére és megvalósítására;
- Szimulációt alkalmazva digitálisan elemezni a termelőrendszerek működését, az informatikai ismeretek birtokában;
- Megérteni a digitális gyártás bevezetésének folyamatait a hagyományos gyártási módszerekkel összehasonlítva;
- Megérteni a digitális gyártás munkafolyamatait a szkenneléstől a modellezésen át az additív gyártásig;
- Képesnek kell Lennie a digitális gyártási projektek kezdeményezésére, tervezésére és végrehajtására, dokumentálására és bevezetésére;
- Azonosítani azokat a tényezőket, amelyeket figyelembe kell venni a technológiák kiválasztása és a digitális gyártás megvalósítása során;
- Azonosítani a digitális gyártás megvalósítása előtt álló akadályokat és ismerni azok mérséklésének lehetőségeit;

Feladatok

Az előadások látogatásán és a kiegészítő tananyagok ismeretén kívül nincs egyéb feladat.

Oktatási forma

- Szinkron és aszinkron előadások
- Laboratóriumi gyakorlatok

Hallgatói munkaterhelés (órák)

• Kontakt óraszám • További, a teljesítéshez szükséges munkaidő ráfordítás	23 óra 77 óra
Összesen	**100 óra**

Teljesítményértékelési módszerek

A hallgatók a félév végén összegző telejsítményértékelési tesztet írnak az oktatási jegyzet alapján.

Kiegészítő információk

A diákokat arra kell ösztönözni, hogy saját személyes érdekeik érdekében gyűjtsenek több információt a digitális gyártás tervezéséről.

Kötelező irodalom:

1. Zhong RY, Xu X, Klotz E, Newman ST (2017) Intelligent Manufacturing in the Context of Industry 4.0: A Review. Engineering 3:616–630. https://doi.org/10.1016/J.ENG.2017.05.015
2. Kutin A, Dolgov V, Sedykh M, Ivashin S (2018) Integration of Different Computer-aided Systems in Product Designing and Process Planning on Digital Manufacturing. Procedia CIRP 67:476–481. https://doi.org/10.1016/j.procir.2017.12.247
3. Holdowsky, Mahto, Raynor, and Cotteleer, Inside the Internet of Things (IoT), Deloitte University Press, August 21, 2015
4. Ghobakhloo M (2018) The future of manufacturing industry: a strategic roadmap toward Industry 4.0. J Manuf Technol Manag 29:910–936. https://doi.org/10.1108/JMTM-02-2018-0057

Javasolt irodalom:

Anand Kannan Smart vs. Traditional Manufacturing: A "Never-Before-Seen" Comparison, 2020, Smart Manufacturing vs. Traditional Manufacturing | IIoT (hakunamatatatech.com)

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Computer modelling and simulation

Teaching Note

Table of Contents

Index

Presentation 3
Objective 3
Target Group 3
Learning Aims 4
Tasks 4
Structure 4
Student Workload (Hours) 4
Evaluation 5
Additional Information 5
Essential reading: 5

DIDACTIC UNIT
UNIT TITLE: *Computer modelling and simulation*

Presentation

Computer modelling and simulation playing a significant role in digital manufacturing. Computer-aided design (CAD) systems are traditionally used in industrial design in order to define the product geometry in a digital environment. Nowadays, CAD systems are much more integrated with the manufacturing and engineering stages of a product development. Comprehensive computer-aided systems are developed, which helps to reduce design and manufacturing time, while optimizing CNC program, tool paths, etc. at the earliest stage of the conceptual design. Virtual reality (VR) and augmented reality (AR) tools are more and more involved into CAD systems. VR and AR techniques made available to inspect the designed geometry in 'real' three dimension, using 1:1 scale and comparison to other parts of a product. This helps shortening the design process, as a virtual prototype can be displayed for inspection and evaluation before any physical object is being manufactured. Computer simulation is also playing a significant role in industrial design and manufacturing. With the help of finite element analysis engineering calculations can be performed in an extent where no physical experiments would be available or cost efficient. This reduces design time, prototype product evaluation stage.

Objective

This module will enable students to understand the importance of computer modelling and simulation, focusing on the digital manufacturing aspects of these areas. The aim of the course is to presents the process and technologies of construction design, the concept and areas of CAD, product and process modelling, computer drawing / editing, finally methods and systems of computer geometric modelling.

Target Group

The target group for the lecture for Computer modelling and simulation in the DIGIMAN project are mainly Master students in the fields of Mechanical / Industrial / Materials / Engineering / Informatics, and Industry 4.0.

Syllabus/Indicative content

- Introduction to CAD systems
- Graphic geometric modelling techniques
- CAD systems in digital manufacturing
- Reverse engineering in product design and modelling
- Introduction to finite element analysis
- How to build up a simulation
- Examples for simulation problems

Learning Aims

On successful completion of this module a student should be able to:

- Gain knowledge of the basics of computer-aided parallel engineering.
- Gain knowledge of computer design resources, resource sharing, system design, and management.
- Gain knowledge of current areas of virtual reality (VR) development
- Create the product or process model using CAD systems.
- Choose a right element for a simulation
- Build a FEM simulation in a software

Tasks

There are no specific tasks beyond visiting and participate in the lecture, read, and understand the materials.

Structure

- synchronous and asynchronous lectures and
- full semester team project work

Student Workload (Hours)

• Contact Time Total	28 Hours
• Independent Learning Time	72 Hours

Total Learning Hours	100 Hours

Evaluation

The students will take a test at the end of the semester, based on the Learning Note and the delivered test questions and answers.

Additional Information

Students should be encouraged to gather more information about computer modelling and simulation for their own personal interest.

Essential reading:

1. P. Hervay, R.Horváth, L. Kátai, I. Madarász, B. Mikó, L. Molnár, I. Nagy, I. Oldal, O. Papp, A. Piros, L. Rabb, I. Szabó, G. Nóra Tóth, K. Váradi . CAD book, Budapest, 2012, Typotex publisher

Additional reading:

1. I. Moharos I. Oldal A. Szekrényes. Finite Element Method, Budapest, 2012, Typotex publisher
2. A. Öchsner, M. Öchsner. The finite element analysis program Marc/Mentat, Singapore, 2016, Springer publisher

Digital Manufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Számítógépes modellezés és szimuláció

Oktatói jegyzet

Tartalomjegyzék

Bemutatás 3
Célkitűzés 3
Célcsoport 3
Tanulási célok 4
Feladatok 4
Oktatási forma 4
Hallgatói munkaterhelés (órák) 4
Teljesítményértékelési módszerek 5
Kiegészítő információk 5
Kötelező irodalom: 5

A TANTÁRGY CÍME: *Számítógépes modellezés és szimuláció*

Bemutatás

A számítógépes modellezés és szimuláció jelentős szerepet játszik a digitális gyártásban. A számítógéppel támogatott tervezési (CAD) rendszereket hagyományosan az ipari tervezésben használják a termék geometriájának digitális környezetben történő meghatározására. Manapság a CAD-rendszerek sokkal jobban integrálódnak a termékfejlesztés gyártási és tervezési szakaszaiba. Átfogó számítógépes rendszereket fejlesztenek ki, amelyek segítenek csökkenteni a tervezési és gyártási időt, miközben a koncepcionális tervezés legkorábbi szakaszában optimalizálják a CNC programokat, szerszámpályákat stb. A virtuális valóság (VR) és a kiterjesztett valóság (AR) eszközöket egyre inkább bevonják a CAD-rendszerekbe. A VR és AR technikák elérhetővé tették a tervezett geometria „valódi" háromdimenziós vizsgálatát, 1:1 méretarányban és a termék más részeivel való összehasonlításban. Ez segít lerövidíteni a tervezési folyamatot, mivel egy virtuális prototípus megjeleníthető ellenőrzésre és értékelésre, mielőtt bármilyen fizikai tárgyat gyártanának. A számítógépes szimuláció az ipari tervezésben és gyártásban is jelentős szerepet játszik. A végeselemes analízis segítségével mérnöki számítások végezhetők olyan mértékben, ahol fizikai kísérletek nem állnak rendelkezésre, illetve nem költséghatékonyak. Ez csökkenti a tervezési időt, a prototípus termékértékelési szakaszát.

Célkitűzés

Ez a modul lehetővé teszi a hallgatók számára, hogy megértsék a számítógépes modellezés és szimuláció fontosságát, összpontosítva e területek digitális gyártási vonatkozásaira. A tantárgy célja bemutatni a kontruktív tervezés folyamatokat és technológiákat, a CAD és területeit, a termék- és folyamatmodellezést, a számítógépes rajzolást/szerkesztést, végül a számítógépes geometriai modellezés módszereit és rendszereit.

Célcsoport

A DIGIMAN projekt Számítógépes modellezés és szimuláció című moduljának célcsoportja elsősorban a Gépész/Gyártástudomány/Anyag/Műszaki, Informatika és Ipar 4.0 szakos mesterszakos hallgatók.

Tanterv/Indikatív tananyag

- Bevezetés a CAD rendszerekbe
- Grafikus modellezési rendszerek
- CAD rendszerek a digitalis gyártásban
- Visszamodellezés
- Bevezetés a végeselemes szimuláció alapjaiba
- Szimuláció felépítése
- Szimulációs példák

Tanulási célok

A modul sikeres elvégzése után a hallgatónak képesnek kell lennie:

- Megismerni a számítógéppel segített párhuzamos tervezés alapjait.
- Megismerni a számítógépes tervezési erőforrásokat, az erőforrások megosztását, a rendszertervezést és a menedzsmentet.
- Megismerni a virtuális valóság (VR) fejlesztésének jelenlegi területeivel
- Elkészíti a termék- vagy folyamatmodellt CAD-rendszerekkel.
- Kiválasztja a megfelelő elemtípust a szimulációhoz
- Felépít egy végeselemes szimulációt egy szoftverben

Feladatok

Az előadások látogatásán és a kiegészítő tananyagok ismeretén kívül nincs egyéb feladat.

Oktatási forma

- Szinkron és aszinkron előadások
- Laboratóriumi gyakorlatok

Hallgatói munkaterhelés (órák)

• Kontakt óraszám • További, a teljesítéshez szükséges munkaidő ráfordítás	23 óra 77 óra
Összesen	**100 óra**

Teljesítményértékelési módszerek

A hallgatók a félév végén összegző telejsítményértékelési tesztet írnak az oktatási jegyzet alapján.

Kiegészítő információk

A diákokat arra kell ösztönözni, hogy saját személyes érdekeik érdekében gyűjtsenek több információt a digitális gyártás tervezéséről.

Kötelező irodalom:

1. P. Hervay, R.Horváth, L. Kátai, I. Madarász, B. Mikó, L. Molnár, I. Nagy, I. Oldal, O. Papp, A. Piros, L. Rabb, I. Szabó, G. Nóra Tóth, K. Váradi . CAD book, Budapest, 2012, Typotex publisher

Javasolt irodalom:

1. l.Moharos I. Oldal A. Szekrényes. Finite Element Method, Budapest, 2012, Typotex publisher
2. A. Öchsner, M. Öchsner. The finite element analysis program Marc/Mentat, Singapore, 2016, Springer publisher

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Energy systems

Teaching Notes

Table of Contents

Presentation 3
Objective 3
Target Group 4
Learning Aims 4
Tasks 5
Structure 5
Student Workload (Hours) 5
Evaluation 5
Additional Information 5
Essential reading: 5

DIDACTIC UNIT 9

UNIT TITLE: *Energy Systems*

Presentation

Renewable energy systems are modern power plant to generate power instead of increasing the green effect with traditional technologies. Although, traditional way is still really important, but in some cases it can replaceable with alternative results. It includes sources such as sunlight, wind, rain, tides, waves, and geothermal heat.

Even if the use of fossil fuels can be reduced significantly, and accepting that nuclear power

is no long-term alternative, the question remains as to how the future supply of energy can

be secured. The first step is to significantly increase the efficiency of energy usage, i.e. useful

energy must be produced from a much smaller amount of primary energy, thus reducing

carbon dioxide emissions. The increasing global population and the unsatisfied demand of

the developing countries will more than cancel out possible reductions due to higher energy

efficiency. Renewable energies will be the key to this development, because they are the

only option that can cover the energy demand of Earth in a climatically sustainable way.

Objective

This module aims to present energy systems. Various types of renewable energy systems

are reviewed and discussed. During this course, the following objective:

1. Describe the different renewable energy system

2. Explain the operation and the application

Target Group

The target group for the lecture for Energy Systems in the DIGIMAN project are mainly Master students in the fields of Mechanical, material, chemical engineering, informatics, and industry 4.0, but it is not an obligatory module, so every students can reach in the target university.

Syllabus/Indicative content

- General introduction to renewable energy
- Hydropower and their applications
- Solar energy, solar panels and applications
- Geothermal energy and their applications
- Biomass energy and their applications
- Wind energy and their applications
- Heat pump systems.
- Introduction to the life cycle assessment

Learning Aims

On successful completion of this module a student should be able to:

- Recognize different renewable energy systems
- Distinguishes between individual energy storage technologies, constraints and solution options
- Knows the ways of utilizing hydropower
- Knows the ways of utilizing wind energy,
- Provides an overview of the technologies used to generate electricity from solar energy

- Knows the ways of utilizing geothermal and bioenergy
- Recognize a life cycle assessment model

Tasks

There are no specific tasks beyond visiting and participate in the lecture, read, and understand the materials.

Structure

- Synchronous and asynchronous Lectures and
- Laboratorial classes

Student Workload (Hours)

• Contact Time Total • Independent Learning Time	23 Hours 77 Hours
Total Learning Hours	**100 Hours**

Evaluation

The students will take a test at the end of the semester, based on the Learning Note and the delivered test questions and answers.

Additional Information

Students should be encouraged to gather more information about Quality in AM for their own personal interest.

Essential reading:

W. C. Turkenburg. Renewable Energy Technologies", World energy Assessment : Energy and Challenges of Sustainability Chapter 7, 2000 UNDP Report.

Additional reading:

Michael Z. Hauschild Ralph K. Rosenbaum Stig Irving Olsen. Life Cycle Assessment, - Theory and Practice, Montpellier, 2018, Springer

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Energetikai rendszerek

Oktatói jegyzet

Tartalomjegyzék

Bemutatás 3
Célkitűzés 3
Célcsoport 3
Tanulási célok 4
Feladatok 4
Oktatási forma 4
Hallgatói munkaterhelés (órák) 4
Teljesítményértékelési módszerek 5
Kiegészítő információk 5
Kötelező irodalom: 5

A TANTÁRGY CÍME: *Energetikai rendszerek*

Bemutatás

A megújuló energetiaki rendszerek olyan modern erőművek, amelyek energiát termelnek, ahelyett, hogy a hagyományos technológiákkal növelnék a zöld hatást. Bár a hagyományos módszerek továbbra is nagyon fontosak, de bizonyos esetekben helyettesíthetők alternatív megoldásokkal. Ezek forrásokat foglalnak magukban, mint a nap, a szél, az eső, az árapály, a hullámok és a geotermikus hő.
Még akkor is, ha a fosszilis tüzelőanyagok felhasználása jelentősen csökkenthető, és elfogadott, hogy az atomenergia már nem hosszútávú megoldás, továbbra is fennáll a kérdés, hogyan biztosítható a jövőbeni energiaellátás. Első lépésként jelentősen növelni kell az energiafelhasználás hatékonyságát, azaz jóval kisebb mennyiségű primer energiából kell hasznos energiát előállítani, ezzel is csökkentve a szén-dioxid kibocsátást. A világ népességének növekedése és a fejlődő országok kielégítetlen kereslete bőven kizárja a magasabb energiahatékonyság miatti esetleges csökkentéseket. Ennek a kulcsa a megújuló erőforrások lesznek, mert ez az egyetlen lehetőség, amely éghajlatilag fenntartható módon fedezheti a Föld energiaigényét.

Célkitűzés

Ez a modul lehetővé teszi a hallgatók számára, hogy megértsék az energetiaki rendszereket és azok csoportosításait. A tantárgy célja bemutatni és megismertetni egyesével a megújuló erőforrásokat és azok kihasználhatóságát.

Célcsoport

A DIGIMAN projekt Energetiaki rendszerek című moduljának célcsoportja elsősorban a Gépész/Gyártástudomány/Anyag/Műszaki, Informatika és Ipar 4.0 szakos mesterszakos hallgatók.

Tanterv/Indikatív tananyag

- Bevezetés a megújuló erőforrásokba
- Vízerőművek és azok alkalmazásai
- Napenergia, napenegria tároló berendezések és alkalmazásai

- Geotermikus energia és alkalmazásai
- Biomassza és alkalmazásai
- Szélenergia és alkalmazásai
- Hőszivattyú rendszerek
- Életciklus elemezés bemutatása

Tanulási célok

A modul sikeres elvégzése után a hallgatónak képesnek kell lennie:

- Felismerni a különböző megújuló erőforrásokat.
- Megkülönböztetni az egyes energiatárolási technológiákat, a korlátokat és megoldási lehetőségeket
- Ismernni a vízenergia hasznosítási módjait,
- Ismeri a szélenergia hasznosítás módjait,
- Átlátni a napenergiából villamos energia előállításához használt technológiákat,
- Tisztában lenni a bioenergia hasznosításának módjaival,
- Tudni értelmezni az életciklus modellt.

Feladatok

Az előadások látogatásán és a kiegészítő tananyagok ismeretén kívül nincs egyéb feladat.

Oktatási forma

- Szinkron és aszinkron előadások
- Laboratóriumi gyakorlatok

Hallgatói munkaterhelés (órák)

• Kontakt óraszám	23 óra
• További, a teljesítéshez szükséges munkaidő ráfordítás	77 óra
Összesen	**100 óra**

Teljesítményértékelési módszerek

A hallgatók a félév végén összegző telejsítményértékelési tesztet írnak az oktatási jegyzet alapján.

Kiegészítő információk

A diákokat arra kell ösztönözni, hogy saját személyes érdekeik érdekében gyűjtsenek több információt a digitális gyártás tervezéséről.

Kötelező irodalom:

W. C. Turkenburg. Renewable Energy Technologies", World energy Assessment : Energy and Challenges of Sustainability Chapter 7, 2000 UNDP Report

Javasolt irodalom:

Michael Z. Hauschild Ralph K. Rosenbaum Stig Irving Olsen. Life Cycle Assessment, - Theory and Practice, Montpellier, 2018, Springer

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Directed Energy Deposition – Arc (DED-Arc) Manual

Teaching Notes

Table of Contents

Presentation 3
Objective 3
Target Group 3
Learning Aims 4
Tasks 4
Structure 4
Student Workload (Hours) 4
Evaluation 5
Additional Information 5
Essential reading 5

DIDACTIC UNIT 10

UNIT TITLE: *Directed Energy Deposition – Arc (DED-Arc) Manual*

Presentation

Additive processes are a way to manufacture objects obtained from Computer Aided Design (CAD) models. Additive manufacturing (AM) includes many different technologies for the creation of a part, such as binder jetting, powder bed fusion, sheet lamination, VAT photopolymerisation, material extrusion, material jetting, or directed energy deposition (DED), which are processes addressed in this manual.

Objective

This module will enable students to understand the principles of DED-Arc processes, process feedstock and process limitations.

Target Group

The target group for the lecture for DED-Arc manual in the DIGIMAN project are mainly Master students in the fields of Mechanical, material, chemical engineering, informatics, and industry 4.0.

Syllabus/Indicative content

-Introduction to the Process DED-Arc

-DED-Arc Manufacturing Strategy (DED-Arc variants, Fixturing, Positioning and Nesting, Layer Thickness, Interaction of Layers, Gas System, Wire Feeding System, Deposition rate/Production Rate, Hybrid Build Strategies, Parameters adjustments along the layer)

-DED-Arc associated problems (Distortion and Residual Stress – Heat related problems, Weld Bead Defects – Porosity, cracks and Delamination)

-Post-processing (Thermal Post-Processing (Post-Heating, Annealing, Hardening, Hot Isostatic Pressure (HIP)), Surface Finishing, Interpass cold rolling, Peening and ultrasonic impact treatment (UIT), Support and substrate removal)

-DED-Arc build substrate, feedstock and other consumables (Substrate, Feedstock)

-DED-arc advantages and disadvantages (Advantages of DED-Arc, Disadvantages of DED-Arc, Speed of the DED-Arc process, Economics of DED-Arc, Wire vs. Powder, DED-Arc vs. other AM processes, DED-Arc vs. traditional processes, Typical DED applications)

Learning Aims

On successful completion of this module a student should have knowledge of:

-DED–Arc systems

-Arc physics

-Processable materials with DED–Arc

-Processing atmosphere requirements with DED–Arc

-Sensors and process controls with DED–Arc

-DED–Arc equipment, accessories, including build platform, feedstock and other consumables

-DED–Arc process parameters and variables, including post-processing operations

Tasks

There are no specific tasks beyond attending and participate in the lecture, read, and understand the materials.

Structure

- Synchronous and asynchronous lectures
- Laboratorial classes

Student Workload (Hours)

Each discipline duration: 2h/week x 14 weeks 1h/week x 14 weeks	 28 hours theory 14 hours practice
Total learning hours	42 hours

Evaluation

The students will take a test at the end of the semester, based on the Learning Note and the delivered test questions and answers.

Additional Information

Students should be encouraged to gather more information about DED-Arc for their own personal interest.

Essential reading

1. Sames, W. J., List, F. A., Pannala, S., Dehoff, R. R., & Babu, S. S. (2016). The metallurgy and processing science of metal additive manufacturing. International Materials Reviews. Taylor and Francis Ltd
2. Wu, B., Pan, Z., Ding, D., Cuiuri, D., Li, H., Xu, J. and Norrish, J., 2018. A review of the wire arc additive manufacturing of metals: properties, defects and quality improvement. Journal of Manufacturing Processes.
3. Cunningham, C., Flynn, J., Shokrani, A., Dhokia, V. and Newman, S., 2018. Invited review article: Strategies and processes for high quality wire arc additive manufacturing.
4. Jiao, Z., Luan, J., Guo, W., Poplawsky, J. and Liu, C., 2016. Effects of welding and post-weld heat treatments on nanoscale precipitation and mechanical properties of an ultra-high strength steel hardened by NiAl and Cu nanoparticles. Acta Materialia.

Additional reading

1. Sames, W. J., List, F. A., Pannala, S., Dehoff, R. R., & Babu, S. S. (2016). The metallurgy and processing science of metal additive manufacturing. International Materials Reviews. Taylor and Francis Ltd.
2. Quan, Z., Wu, A., Keefe, M., Qin, X., Yu, J., Suhr, J., Byun, J., Kim, B. and Chou, T., 2015. Additive manufacturing of multi-directional preforms for composites: opportunities and challenges. Materials Today.

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Manual de Deposição de Energia Direta – Arc

(Directed Energy Deposition – Arc (DED-Arc) Manual

Notas de ensino

Índice

Apresentação 3
Objetivo 3
Público-alvo 3
Objetivos da aprendizagem 4
Tarefas 4
Estrutura 5
Carga horária 5
Avaliação 5
Informação adicional 5
Leitura obrigatória 5

UNIDADE DIDÁTICA 10

TÍTULO DA UNIDADE: Manual de Deposição de Energia Direta – Arc (*Directed Energy Deposition – Arc (DED-Arc) Manual)*

Apresentação

Os processos aditivos são uma forma de fabricar objetos obtidos a partir de modelos Desenho Assistido por Computador (CAD). A manufatura aditiva inclui muitas tecnologias diferentes para a criação de uma peça, tais como projeção de adesivo, fusão em cama de pós, laminação de folhas, fotopolimerização, extrusão de material, projeção de material, deposição de energia direta, que são processos abordados neste manual.

Objetivo

Este módulo permitirá aos estudantes compreenderem os princípios dos processos de Deposição de Energia Direta – Arc, a matéria-prima do processo e as limitações do processo.

Público-alvo

O público-alvo da palestra para o manual de Deposição de Energia Direta – Arc no projeto DIGIMAN são principalmente estudantes de mestrado nas áreas de mecânica, material, engenharia química, informática, e indústria 4.0.

Conteúdo

-Introdução ao processo de Deposição de Energia Direta – Arc

-Estratégia de manufatura em Deposição de Energia Direta – Arc (Variantes de DED-Arc, Fixação, Posicionamento e Preparação para corte, Espessura de camadas, Interação entre camadas, Sistema de gás, Sistema de alimentação de fio, Taxa de deposição/Taxa de produção, Estratégias de fabrico híbridas, Ajustes de parâmetros ao longo da camada)

-Problemas associados à Deposição de Energia Direta – Arc (Distorção e Tensões Residuais – Problemas de Calor, Defeitos nos Cordões de Soldadura – Porosidade, Fissuras e Delaminação)

-Pós-processamento (Pós-processamento térmico (Pós-aquecimento, recozimento, endurecimento, pressão isostática quente (HIP)), Acabamento Superficial, Laminagem a frio e tratamento de impacto ultrassónico (UIT), remoção de suporte e substrato)

- Substratos para Deposição de Energia Direta – Arc, matérias-primas e outros consumíveis

-Vantagens e desvantagens de Deposição de Energia Direta – Arc (Vantagens de Deposição de Energia Direta – Arc, Desvantagens de Deposição de Energia Direta – Arc, Velocidade do processo de Deposição de Energia Direta – Arc, Custos de Deposição de Energia Direta – Arc, Fio vs. Pó, Deposição de Energia Direta – Arc vs. outros processos de manufatura aditiva, Deposição de Energia Direta – Arc vs. processos tradicionais, Aplicações usuais de Deposição de Energia Direta – Arc)

Objetivos da aprendizagem

Ao concluir com sucesso este módulo, o/a estudante deve ter conhecimentos sobre:

-Sistemas de Deposição de Energia Direta – Arc

-Física do Arco elétrico

-Materiais processáveis através de Deposição de Energia Direta – Arc

-Requisitos de atmosfera de processamento com Deposição de Energia Direta – Arc

-Sensores e controlos de processo com Deposição de Energia Direta – Arc

-Equipamento, acessórios, incluindo plataforma de construção, material de alimentação e outros consumíveis de Deposição de Energia Direta – Arc

-Parâmetros e variáveis do processo Deposição de Energia Direta – Arc, incluindo operações de pós-processamento

Tarefas

Não há tarefas específicas para além de assistir e participar na palestra, ler, e compreender os materiais.

Estrutura

- Palestras síncronas e assíncronas
- Aulas laboratoriais

Carga horária

Duração de cada disciplina: 2h/semana x 14 semanas 1h/semana x 14 semanas	 28 horas teóricas 14 horas práticas
Total de horas de aprendizagem	42 horas

Avaliação

Os/as estudantes serão avaliados/as no final do semestre, através de um teste com perguntas de escolha múltipla baseado.

Informação adicional

Os/as estudantes/as devem ser encorajados/as a recolher informação adicional sobre Deposição de Energia Direta – Arc para o seu próprio interesse pessoal.

Leitura obrigatória

1. Sames, W. J., List, F. A., Pannala, S., Dehoff, R. R., & Babu, S. S. (2016). The metallurgy and processing science of metal additive manufacturing. International Materials Reviews. Taylor and Francis Ltd
2. Wu, B., Pan, Z., Ding, D., Cuiuri, D., Li, H., Xu, J. and Norrish, J., 2018. A review of the wire arc additive manufacturing of metals: properties, defects and quality improvement. Journal of Manufacturing Processes.
3. Cunningham, C., Flynn, J., Shokrani, A., Dhokia, V. and Newman, S., 2018. Invited review article: Strategies and processes for high quality wire arc additive manufacturing.
4. Jiao, Z., Luan, J., Guo, W., Poplawsky, J. and Liu, C., 2016. Effects of welding and post-weld heat treatments on nanoscale precipitation and mechanical

properties of an ultra-high strength steel hardened by NiAl and Cu nanoparticles. Acta Materialia.

Leitura Adicional

1. Sames, W. J., List, F. A., Pannala, S., Dehoff, R. R., & Babu, S. S. (2016). The metallurgy and processing science of metal additive manufacturing. International Materials Reviews. Taylor and Francis Ltd.
2. Quan, Z., Wu, A., Keefe, M., Qin, X., Yu, J., Suhr, J., Byun, J., Kim, B. and Chou, T., 2015. Additive manufacturing of multi-directional preforms for composites: opportunities and challenges. Materials Today.

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Directed Energy Deposition – Laser Beam (DED-LB) Manual

Teaching Notes

Table of Contents

Presentation 3
Objective 3
Target Group 3
Learning Aims 4
Tasks 4
Structure 4
Student Workload (Hours) 5
Evaluation 5
Additional Information 5
Essential reading 5

DIDACTIC UNIT 11

UNIT TITLE: *Directed Energy Deposition – Laser Beam (DED-LB) Manual*

Presentation

Additive Manufacturing (AM) was born as a rapid prototyping technology with the process of joining materials in successive layer by layer to make objects. It allows designers to produce accurate physical prototypes directly from 3-Dimensional Computer-Aided Design (3D-CAD) model in few hours. AM has many advantages over the traditional process used to develop a product such as allowing early customer involvement in product development, complex shape generation and it also saves time as well as money. The main objective of this manual is to explore Laser Directed Energy Deposition which is used in AM. DED-LB is a technology that works by melting material that is fed to a local site on the build layer, usually occurring within an inert gas atmosphere. While this can be used for nonmetal materials, it is predominately used with metals and metal alloys. Feedstock usually comes in the form of powder or wire and is melted with a focused energy source which in the case of DED-LB is a laser beam. The mechanical properties of an AM part produced by wire-fed laser and powder laser deposition processes rely heavily on process parameters, load direction, and post build up heat treatment.

Objective

This module will enable students to understand the principles of DED-LB processes, process feedstock and process limitations.

Target Group

The target group for the lecture for DED-LB manual in the DIGIMAN project are mainly Master students in the fields of Mechanical, material, chemical engineering, informatics, and industry 4.0.

Syllabus/Indicative content

-Introduction to the Process DED-LB

-DED-LB Manufacturing Strategy (Fixturing, Positioning and Nesting, Layer Thickness, Dosing Factor (Powder Capture Efficiency, Powder Optimization), Interaction of Layers, Distortion avoidance, Deposition rate/Production Rate (Deposition Rate, Production Rate), Hybrid Build Strategies, Parameters adjustments along the layer)

-Equipment and accessories (Optical System, Powder/wire Feeding System, Gas System, Powder Feeding System (Powder feeding and Conveyance Systems), Deposition Direction (Types of Nozzles), Sieves and Filters (Sieves, Filters)

-DED-LB Build substrate (Common defects, Influence of Inclined Substrate in DED)

-Post-processing

-Consumables (Feedstock)

-Advantages and Limitations

Learning Aims

On successful completion of this module a student should have knowledge of:

-DED–LB systems

-Laser characteristics

-Build platform

-Powder/wire

-Gases

-DED-LB equipment, accessories, including build platform, feedstock and other consumables

-DED-LB process parameters and variables, including post-processing operation

Tasks

There are no specific tasks beyond attending and participate in the lecture, read, and understand the materials.

Structure

- Synchronous and asynchronous lectures

- Laboratorial classes

Student Workload (Hours)

Each discipline duration: 2h/week x 14 weeks 1h/week x 14 weeks	 28 hours theory 14 hours practice
Total learning hours	42 hours

Evaluation

The students will take a test at the end of the semester, based on the Learning Note and the delivered test questions and answers.

Additional Information

Students should be encouraged to gather more information about DED-LB for their own personal interest.

Essential reading

1. Singh, A., Kapil, S. and Das, M. (2020) “A comprehensive review of the methods and mechanisms for powder feedstock handling in directed energy deposition,” Additive Manufacturing.
2. Yang, L., Hsu, K., Baughman, B., Godfrey, D., Medina, F., Menon, M. and Wiener, S., 2017. Additive Manufacturing of Metals: The Technology, Materials, Design and Production. 1st ed. Birmingham: Springer.
3. Gibson, I., Rosen, D., Stucker, B. and Khorasani, M., 2015. Additive manufacturing technologies. 2nd ed. Springer.
4. El-Sari, Bassel & Biegler, Max & Rethmeier, Michael. (2020) “Distortion-based validation of the heat treatment simulation of Directed Energy Deposition additive manufactured parts”

Additional reading

1. Corbin, D. J. et al. (2018) “Effect of substrate thickness and preheating on the distortion of laser deposited Ti–6Al–4V,” Journal of manufacturing science and Engineering.
2. Rosas Coutinho, F., 2016. Study and Development of a Metal Additive Manufacturing System. Master. Faculdade de Engenharia da Universidade do Porto.

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Manual de Deposição de Energia Direta – Feixe Laser

(Directed Energy Deposition – LB (DED-LB) Manual

Notas de ensino

Índice

Apresentação 3
Objetivo 3
Público-alvo 4
Objetivos da aprendizagem 4
Tarefas 5
Estrutura 5
Carga horária 5
Avaliação 5
Informação adicional 5
Leitura obrigatória 6

UNIDADE DIDÁTICA 11

TÍTULO DA UNIDADE: Manual de Deposição de Energia Direta – Feixe Laser (*Directed Energy Deposition – Laser Beam (DED-LB) Manual)*

Apresentação

A manufatura aditiva nasceu como uma tecnologia de prototipagem rápida através do processo de unir materiais em camadas sucessivas de forma a criar objetos. Permite aos/às criadores/as produzir protótipos físicos e precisos diretamente a partir do modelo 3D-CAD (Desenho Assistido por Computador) em poucas horas. A manufatura aditiva tem muitas vantagens sobre o processo tradicional utilizado para desenvolver um produto, tal como permitir o envolvimento precoce do/a cliente no desenvolvimento do produto, a geração de formas complexas e também poupa tempo, bem como dinheiro. O principal objetivo deste manual é explorar a deposição de energia dirigida a laser que é utilizada em manufatura aditiva. Deposição de Energia Direta – Feixe Laser é uma tecnologia que funciona através da fusão do material que é alimentado a um local na camada de construção, ocorrendo normalmente dentro de uma atmosfera de gás inerte. Embora isto possa ser utilizado para materiais não metálicos, é predominantemente utilizado com metais e ligas metálicas. O material de alimentação, normalmente, apresenta a forma de pó ou fio e é fundido com uma fonte de energia concentrada que, no caso de Deposição de Energia Direta – Feixe Laser, é um feixe laser. As propriedades mecânicas de uma peça de manufatura aditiva produzida por processos de deposição por laser com fio ou pó dependem fortemente dos parâmetros do processo, da direção das cargas aplicadas (anisotropia) e do tratamento térmico pós-fabrico.

Objetivo

Este módulo permitirá aos estudantes compreenderem os princípios dos processos Deposição de Energia Direta – Feixe Laser, a matéria-prima do processo e as limitações do processo.

Público-alvo

O público-alvo da palestra para o manual Deposição de Energia Direta – Feixe Laser no projeto DIGIMAN são principalmente estudantes de mestrado nas áreas de mecânica, material, engenharia química, informática, e indústria 4.0.

Conteúdo

-Introdução ao processo de Deposição de Energia Direta – Feixe Laser
-Estratégia de manufatura em Deposição de Energia Direta – Feixe Laser (Fixação, Posicionamento e Nidificação, Espessura de camadas, Fator de dosagem (Eficiência de Captura de Pó, Otimização de Pó), Interação de Camadas, Evitar Distorção, Taxa de Depósito/Taxa de Produção, Estratégias de Construção Híbrida, Ajustes de Parâmetros ao longo da camada))
-Equipamento e acessórios (Sistemas óticos, Sistema de alimentação de pó/fios, Sistema de gás, Sistema de alimentação de pó (Sistemas de alimentação e transporte de pó), Direção da deposição (Tipos de bocal), Peneiras e Filtros)
-Substratos para Deposição de Energia Direta – Feixe Laser (Defeitos comuns, Influência da inclinação do substrato)
-Pós-processamento
-Consumíveis
-Vantagens e Limitações

Objetivos da aprendizagem

Ao concluir com sucesso este módulo, o/a estudante deve ter conhecimentos sobre:

-Sistemas de Deposição de Energia Direta – Feixe Laser
-Características do Laser
-Construção da plataforma
-Pó/fio
-Gases

-Equipamento, acessórios, incluindo substrato, material base e material de adição e outros consumíveis de Deposição de Energia Direta – Feixe Laser
-Parâmetros e variáveis do processo de Deposição de Energia Direta – Feixe Laser, incluindo operações de pós-processamento

Tarefas

Não há tarefas específicas para além de assistir e participar na palestra, ler, e compreender os materiais.

Estrutura

- Palestras síncronas e assíncronas
- Aulas laboratoriais

Carga horária

Duração de cada disciplina: 2h/semana x 14 semanas 1h/semana x 14 semanas	 28 horas teóricas 14 horas práticas
Total de horas de aprendizagem	42 horas

Avaliação

Os/as estudantes serão avaliados/as no final do semestre, através de um teste com perguntas de escolha múltipla baseado.

Informação adicional

Os/as estudantes/as devem ser encorajados/as a recolher informação adicional sobre Deposição de Energia Direta – Feixe Laser para o seu próprio interesse pessoal.

Leitura obrigatória

1. Singh, A., Kapil, S. and Das, M. (2020) “A comprehensive review of the methods and mechanisms for powder feedstock handling in directed energy deposition,” Additive Manufacturing.
2. Yang, L., Hsu, K., Baughman, B., Godfrey, D., Medina, F., Menon, M. and Wiener, S., 2017. Additive Manufacturing of Metals: The Technology, Materials, Design and Production. 1st ed. Birmingham: Springer.
3. Gibson, I., Rosen, D., Stucker, B. and Khorasani, M., 2015. Additive manufacturing technologies. 2nd ed. Springer.
4. El-Sari, Bassel & Biegler, Max & Rethmeier, Michael. (2020) “Distortion-based validation of the heat treatment simulation of Directed Energy Deposition additive manufactured parts”

Leitura Adicional

1. Corbin, D. J. et al. (2018) “Effect of substrate thickness and preheating on the distortion of laser deposited Ti–6Al–4V,” Journal of manufacturing science and Engineering.
2. Rosas Coutinho, F., 2016. Study and Development of a Metal Additive Manufacturing System. Master. Faculdade de Engenharia da Universidade do Porto.

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Power Bed Fusion – Laser Beam (PBF-LB) Manual

Teaching Notes

Table of Contents

Presentation 3
Objective 3
Target Group 3
Learning Aims 4
Tasks 4
Structure 4
Student Workload (Hours) 5
Evaluation 5
Additional Information 5
Essential reading 5

DIDACTIC UNIT 12

UNIT TITLE: *Power Bed Fusion – Laser Beam (PBF-LB) Manual*

Presentation

Powder Bed Fusion is a manufacturing process steadily improving to directly produce net-shape or net-shape metal tools or functional products. PBF presents an unlimited drawing freedom: complex shapes with a rapid, flexible and economical way, where the traditional techniques show their limits. Stability and small weight turn this technology suitable for the medical sector, but also automotive and aerospace fields. However, this technology also presents challenges: high material costs, slow setup, laborious post-processing and restrictions on material compatibility. Due to the modern techniques PBF workpieces near full density can be fabricated with mechanical properties at the same level of conventional parts, sometimes higher. This technology is strongly suitable for metals because it offers a nearly unlimited flexibility of geometry and complexity, together with the possibility to have fully dense parts generated without any further infiltrations. Powder Bed Fusion – Laser Beam (PBF-LB) is one of the possible PBF processes that utilises a laser beam to melt and fuse metal powders together to form a part.

Objective

This module will enable students to understand the principles of PBF-LB processes, process feedstock and process limitations.

Target Group

The target group for the lecture for PBF-LB manual in the DIGIMAN project are mainly Master students in the fields of Mechanical, material, chemical engineering, informatics, and industry 4.0.

Syllabus/Indicative content

-Introduction to the Process PBF-LB (General Introduction to PBF, and PBF-LB Specifically, Classification, Advantages and Disadvantages, Process Mechanics)

-PBF-LB Manufacturing Strategy (Fixturing, Positioning and Nesting, Layer Thickness, Dosing Factor, Interaction of Layers (Effect of spatter on powder layer height, Effect of denudation on powder layer height), Distortion avoidance (Evolution along the building process, Thermal Conductivity of Metal Powder and Surrounding Gas Effect, Cooling Rate, Thermal Stresses, Solutions), Deposition rate/Production Rate, Hybrid Build Strategies, Parameters adjustments along the layer, Scanning Strategy)
-Equipment and accessories (Optical System, Powder Feeding System, Powder Handling System, Gas System, Deposition Direction, Sieves and Filters)
- Defects (Sources of Defects, Defect Control)
-Post-processing
-Consumables (Feedstock, Process Gas and Gas System)

Learning Aims

On successful completion of this module a student should have knowledge of:
-PBF–LB systems
-Laser characteristics
-Build platform
-Powder
-Gases
-Processable materials with PBF
-PBF-LB process parameters and variables, including post-processing operation

Tasks

There are no specific tasks beyond attending and participate in the lecture, read, and understand the materials.

Structure

- Synchronous and asynchronous lectures
- Laboratorial classes

Student Workload (Hours)

Each discipline duration: 2h/week x 14 weeks 1h/week x 14 weeks	 28 hours theory 14 hours practice
Total learning hours	42 hours

Evaluation

The students will take a test at the end of the semester, based on the Learning Note and the delivered test questions and answers.

Additional Information

Students should be encouraged to gather more information about PBF-LB for their own personal interest.

Essential reading

1. Oliveira, J. P., LaLonde, A. D., & Ma, J. (2020). Processing parameters in laser powder bed fusion metal additive manufacturing. Materials & Design.
2. Malekipour, E., & El-Mounayri, H. (2018). Common defects and contributing parameters in powder bed fusion AM process and their classification for online monitoring and control: a review. The International Journal of Advanced Manufacturing Technology.
3. Haeri, S., Wang, Y., Ghita, O., & Sun, J. (2017). Discrete element simulation and experimental study of powder spreading process in additive manufacturing. Powder Technology.

Additional reading

1. Ladewig, A., Schlick, G., Fisser, M., Schulze, V., & Glatzel, U. (2016). Influence of the shielding gas flow on the removal of process by-products in the selective laser melting process. Additive Manufacturing.

2. Beitz, S., Uerlich, R., Bokelmann, T., Diener, A., Vietor, T., & Kwade, A. (2019). Influence of powder deposition on powder bed and specimen properties. Materials.

Digital **Man**ufacturing Master's degree to set specialists for the dawn of the industry 4.0



Project number:
2019-1-RO01-KA203-063486

Manual de Fusão em Cama de Pós – Feixe Laser

(Power Bed Fusion – Laser Beam (PBF-LB) Manual)

Notas de ensino

Índice

Apresentação 3
Objetivo 3
Público-alvo 3
Objetivos da aprendizagem 4
Tarefas 4
Estrutura 5
Carga horária 5
Avaliação 5
Informação adicional 5
Leitura obrigatória 5

UNIDADE DIDÁTICA 12

TÍTULO DA UNIDADE: Manual de Fusão em Cama de Pós – Feixe Laser (*Power Bed Fusion – Laser Beam (PBF-LB) Manual)*

Apresentação

O processo de manufatura aditiva por Fusão em Cama de Pós – Feixe Laser está em constante melhoria para produzir diretamente peças metálicas muito próximas do produto final, incluindo peças funcionais. Este processo apresenta uma liberdade de desenho ilimitada: formas complexas com uma forma rápida, flexível e económica, onde as técnicas tradicionais mostram os seus limites. Estabilidade e peso reduzido tornam esta tecnologia adequada para o sector médico, mas também para os setores automóvel e aeroespacial. No entanto, esta tecnologia também apresenta desafios: custos de material elevados, montagem lenta, pós-processamento trabalhoso e restrições na compatibilidade de materiais. Devido às técnicas modernas, as peças de Fusão em Cama de Pós próximas da densidade total podem ser fabricadas com propriedades mecânicas ao mesmo nível das peças convencionais, por vezes superiores. Esta tecnologia é fortemente adequada para metais porque oferece uma flexibilidade quase ilimitada de geometria e complexidade, juntamente com a possibilidade de ter peças totalmente densas geradas sem quaisquer outras infiltrações. A Fusão em Cama de Pós através de Feixe Laser é um dos possíveis processos que utiliza um feixe laser para fundir pós metálicos para formar uma peça.

Objetivo

Este módulo permitirá aos estudantes compreenderem os princípios dos processos de Fusão em Cama de Pós – Feixe Laser , a matéria-prima do processo e as limitações do processo.

Público-alvo

O público-alvo da palestra para o manual de Fusão em Cama de Pós – Feixe Laser no projeto DIGIMAN são principalmente estudantes de mestrado nas áreas de mecânica, material, engenharia química, informática, e indústria 4.0.

Conteúdo

-Introdução ao Processo de Fusão em Cama de Pós – Feixe Laser (Introdução geral à Fusão em Cama de Pós, em específico à Fusão em Cama de Pós – Feixe Laser, Classificação, Vantagens e Desvantagens, Mecânica do Processo)
-Estratégia de fabrico de Fusão em Cama de Pós – Feixe Laser (Fixação, Posicionamento e Nidificação, Espessura de camadas, Fator de dosagem, Interação entre Camadas (Efeito dos salpicos na altura da camada de pó, Efeito da desnudação na altura da camada de pó), Evitar Distorção (Evolução ao longo do processo de construção, Condutividade Térmica do Pó Metálico e Efeito do Gás Ambiente, Taxa de Refrigeração, Tensões Térmicas, Soluções), Taxa de Depósito/Taxa de Produção, Estratégias de Fabrico Híbridas, Ajustes de Parâmetros ao longo da camada, Estratégia de Digitalização)
-Equipamento e acessórios (Sistemas óticos, Sistema de alimentação, Sistema de Tratamento de Pó, Sistema de Gás, Direção de Deposição, Peneiras e Filtros)
- Defeitos (Fontes dos Defeitos, Controlo dos Defeitos)
-Pós-processamento
-Consumíveis (Materiais, gás de processo e sistema de gás)

Objetivos da aprendizagem

Ao concluir com sucesso este módulo, o/a estudante deve ter conhecimentos sobre:

-Sistemas de Fusão em Cama de Pós – Feixe Laser
-Características do Laser
-Construção da plataforma
-Pó
-Gases
-Materiais processados com Fusão em Cama de Pós
-Parâmetros e variáveis do processo Fusão em Cama de Pós – Feixe Laser, incluindo operações de pós-processamento

Tarefas

Não há tarefas específicas para além de assistir e participar na palestra, ler, e

compreender os materiais.

Estrutura

- Palestras síncronas e assíncronas
- Aulas laboratoriais

Carga horária

Duração de cada disciplina: 2h/semana x 14 semanas 1h/semana x 14 semanas	 28 horas teóricas 14 horas práticas
Total de horas de aprendizagem	42 horas

Avaliação

Os/as estudantes serão avaliados/as no final do semestre, através de um teste com perguntas de escolha múltipla baseado.

Informação adicional

Os/as estudantes/as devem ser encorajados/as a recolher informação adicional sobre Fusão em Cama de Pós – Feixe Laser para o seu próprio interesse pessoal.

Leitura obrigatória

1. Oliveira, J. P., LaLonde, A. D., & Ma, J. (2020). Processing parameters in laser powder bed fusion metal additive manufacturing. Materials & Design.
2. Malekipour, E., & El-Mounayri, H. (2018). Common defects and contributing parameters in powder bed fusion AM process and their classification for online monitoring and control: a review. The International Journal of Advanced Manufacturing Technology.
3. Haeri, S., Wang, Y., Ghita, O., & Sun, J. (2017). Discrete element simulation and experimental study of powder spreading process in additive manufacturing. Powder Technology.

Leitura Adicional

1. Ladewig, A., Schlick, G., Fisser, M., Schulze, V., & Glatzel, U. (2016). Influence of the shielding gas flow on the removal of process by-products in the selective laser melting process. Additive Manufacturing.
2. Beitz, S., Uerlich, R., Bokelmann, T., Diener, A., Vietor, T., & Kwade, A. (2019). Influence of powder deposition on powder bed and specimen properties. Materials.