AEROSPACE ENGINEERING (LM52)

(Brindisi - Università degli Studi)

Teaching METALLIC MATERIALS FOR AERONAUTICS

GenCod A003322

Owner professor Benedetto BOZZINI

Teaching in italian METALLIC MATERIALS FOR AERONAUTICS

Teaching METALLIC MATERIALS FOR AERONAUTICS

SSD code ING-IND/21

Reference course AEROSPACE ENGINEERING

Course type Laurea Magistrale

Credits 9.0

Teaching hours Ore-Attivita-frontale: 81.0

For enrolled in 2017/2018

Taught in 2018/2019

Course year 2

Language INGLESE

Curriculum MAIN COURSE

Location Brindisi

Semester Primo-Semestre

Exam type Orale

Assessment Voto-Finale

Course timetable https://easyroom.unisalento.it/Orario

BRIEF COURSE DESCRIPTION

Overview - This is a self-contained course specifically designed for aerospace engineering students that will allow them to handle the key concepts related to the implementation of metallic materials in aircraft and will provide them with design guidelines and insight into maintainance, durability and safety of metallic components and metal-based on-board devices. Moreover, this course will provide basic information on aerospace batteries and fuel-cells in view of next-generation hydrid and electrical propulsion.

REQUIREMENTS

Prerequisite: Sufficiency in calculus, physics, chemistry and basic metallurgy.

COURSE AIMS

Learning Outcomes; after the course the student should be able to
*Describe the metallurgical basis of the mechanical resistance, fracture toughness and corrosion-cracking performance of alloys implemented in aeronautic devices. Both stuctural and propulsion systems will be addressed. Moreover the students will acquire a working knowledge of aerospace batteries and fuel cells relevant to in present- and next-generation aerospace systems.
*Formulate and solve simple alloy design tasks for aluminium and titanium alloys, superalloys and aeronautic steels and stainless steels.
*Derive the yield strength, fracture toughness and stress-corrosion cracking tolerance of aeronautic alloys from microstructural considerations.
*Illustrate durability and maintainence issues relevant to in-service and life-extension protocols.
Examination: written and oral.
The written part of the exams consists in carrying out simple computational tasks, designed to assess that the Student has a solid conceptual and quantitative grasp of the of key topics of the course.
The oral part of the exam consists of an oral interview (typical duration 45 min) in which the student will be asked to expound three topics: (i) a theoretical one concering the strengthening mechanisms relevant to aeronautic alloys; (ii) one concerning a specific aeronatic application, addressing its properties, metallurgical structure and heat treatments and (iii) one concerning fracture behaviour, durability issues or the simple notions on aeronautic batteries/fuel cells.
The interview is aimed at determining to what extent the student has: 1) the ability to identify and use data to formulate responses to practical problems in aerospace alloy use and design, 2) problem solving abilities and the capacity to integrate different concepts and tools.

TEACHING METHODOLOGY

Teaching Methods: The course provides the basic physics and engineering tools to define and carry out metallic material design tasks for aerospace applications, including a specialized theory of stengthening mechanisms, fracture mechanics, aeronautic alloy design, corrosion, mechamochemical damaging modes an prevention, and aerospace coatings. Moreover, elementary, but accurate information is provided on electrical energy storage devices (fuel cells and batteries) that are cutting-edge applications of metal science for next-generation electrical and hybrid aircraft systems. After a fundamental assessment of the individual topics, technological aspects are addresses and a selection of case-studies is analyzed in depth. Constant reference is made throughout the course to physical meaning, experimental aspects and practical engineering problems. The key methodological highlight of the course is the unceasing tension to rationalise each content and each conceptual step expounded and to represent an attitude to the quantification with fully formalized approaches, though with simplification and approximations appropriate for the knowledge level of the Students.

ASSESSMENT TYPE

Examination: written and oral.
The written part of the exams consists in carrying out simple computational tasks, designed to assess that the Student has a solid conceptual and quantitative grasp of the of key topics of the course.
The oral part of the exam consists of an oral interview (typical duration 45 min) in which the student will be asked to expound three topics: (i) a theoretical one concering the strengthening mechanisms relevant to aeronautic alloys; (ii) one concerning a specific aeronatic application, addressing its properties, metallurgical structure and heat treatments and (iii) one concerning fracture behaviour, durability issues or the simple notions on aeronautic batteries/fuel cells.
The interview is aimed at determining to what extent the student has: 1) the ability to identify and use data to formulate responses to practical problems in aerospace alloy use and design, 2) problem solving abilities and the capacity to integrate different concepts and tools.

FULL SYLLABUS

Course Contents

Hour 1) Introduction to the course: scientific and technological background.

Hour 2) Introduction to the course: application of metals in airframe, jet engine and landing gear.

Hour 3) Introduction to the course: application of metals in fuel tanks, electrical systems and batteries.

Hour 4) Overview of corrosion problems and coatrings in aeronautics.

Hour 5) Atomistic interpretation of metal strength.

Hour 6) Young's modulus for a perfect single crystal from electrostatic principles.

Same for shear deformation.

Hour 7) The physical bases of crystalline arrangement in metals. Energetics of a crystal surface. Pointwise defects, equilibrium concentration of 0D self-defects.

Hour 8) Point defects. Equilibrium defect concentration.

Complex point defects. Diffusion of point defects.

Hour 9) Introduction to dislocations.

Hour 10) Dislocation geometry and reactions among dislocation. Stacking faults in FCC crystals. Glide, climb and cross-slip of dislocations.

Hour 11) Elastic theory of a screw and edge dislocation.

Hour 12) Forces of dislocation. Dislocation interactions.

Hour 13) Details on dislocation geometry, elastic enegy energy, forces on dislocations and dislocation intereactions.

Hour 14) Line tension of a dislocation and introduction to dislocation pinning.

Hour 15) Dislocation pinning.

Hour 16) Dislocation sources.

Hour 17) Frank-Read sources: equilibrium and out-of-equilibrium conditions.

Hour 18) Grains in metals: introduction to the formal theories of nucleation and growth.

Hour 19) i) Nucleation energetics and critical nucleus. ii) Surface tension effects on nucleation energetics and kinetics. iii) Excursus on effective energy, DG and surface tension. iv) Polycrystalline structure by impact of growing nuclei

Hour 20) Equilibrium shape of a crystal. Isotropic surface tension.

Hours 21-22) Equilibrium shape of a crystal. Anisotropic surface tension.

Hour 23) Chemical potential, introduced after insightful discussion of effective work notion.

Hour 24) i) Chemical equilibrium conditions for a pure species. ii) Theory of solutions: fundamental defintions and equations.

Hour 25) Derivation of the the Gibbs-Duhem equation. Formal aspects of mixing processes.

Hour 26) Background material for a derivation of equations of state for ideal mixtures.

Hour 27) Ideal solutions and their thermodynamic properties.

Hour 28) i) Real mixtures and Dgmix(x) curves. ii) Regular solution model of non-ideality.

iii) Deduction of partial molal quantities from Dgmix(x) curves

Hour 29) Comparing Dgmix(x) curves. Common tangent construction and two-phase systems.

Hours 30-31) Discussion of binary phase diagrams in terms of Dgmix curves.

Hour 32) Morphologies resulting from eutectic solidification and eutectoidic decomposition.

Hour 33) Lamellar structure in eutectoidic decomposition.

Hour 34) Solidification structures resulting from peritectic phase diagrams. Brief description of phases and constituents in the Fe-C system and key austenitising and ferritising alloying elements.

Hour 35) i) Introduction to the heat treatment of steels and gerenalisations to other types of heat-treatable alloys. ii) Kinetic and mass transport bases of heat-treatment processes.

Hour 36) Metallographic structures resulting from heat treatment of steel.

Hour 37) TTT and CCT curves.

Hour 38) Heat-treatments of steels with heating above the critical points.

Hour 39) Heat-treatments of steels with heating below the critical points.

Hours 40-41) Morphologies developing from growth front instabilities.

Hour 42) Introduction to fracture mechanics.
Hour 43) Phenomenology and mechanisms of ductile fracture.
Hour 44) Phenomenology and mechanisms of brittle fracture.
Hour 45) Mechanical framework for the definition of a FOM for fracture toughness.
Hour 46) Stress intensity factor: linear elastic theory. Introduction to the quantification of fracture toughness.
Hour 47) Fracture toughness: theory, measurements and applications.
Hour 48) i) Steels for aeronautic applications: introduction, classification, ii) Low-alloy steels.
Hour 49) Secondary hardening and precipitation hardening high-strenght steels.
Hour 50) Maraging steels: generalities and martensitic transformations.
Hour 51) Maraging steels: precipitation hardening.
Hour 52) Maraging steels: welding and other technological properties.
Hour 53) Maraging steels: shaping, coating, corrosion.
Hour 54) i) Stainless steels: introduction and classification. ii) Stainless steels: sigma phase precipitation.
Hour 55) Effects of alloying elements on corrosion performance and mechanical properties of stainless steels.
Hour 56) Stainless steels: carbide precipitation.
Hour 57) Corrosion behaviour of stainless steels: (i) Generalised corrosion, Galvanic coupling; (ii) Localised corrosion in stainless steels: Pitting, crevice, SCC
Hour 58) Aluminium alloys for aeronatics: generalities.
Hour 59) Aluminium alloys for aeronatics: classification, key compositions, hardening mechanisms and hardening processes.
Hour 60) Precipitation hardening of aluminium alloys.
Hour 61) Au-Cu alloys for aeronatics.
Hour 62) Au-Li alloys for aeronatics.
Hour 63) Titanium alloys for aeronautics: chief types and properties.
Hour 64) Titanium alloys for aeronautics: main applications and properties.
Hour 65) Basic physical metallurgy and heat treatments of Ti alloys.
Hour 66) The principal alpha, alpha+beta and beta Ti alloys for aeronautic applications.
Hour 67) Introduction to superalloys: g+g' structures and specific strengthening mechanisms (Superdislocations, dislocation trapping)
Hour 68) Lattice matching of gamma and gamma' phases: stabilisation of grain dimensions and rafting.
Hour 69) Superalloys: effects of alloying elements.
Hour 70) Superalloys: heat treatments, single-crystal alloys.
Hour 71) Corrosion for aerospace applications – Introduction and main processes.
Hour 72) Corrosion for aerospace applications – Mass balances and current balances.
Hour 73) Corrosion for aerospace applications – Applications to the key aerospace alloys.
Hour 74) Basic principles of aerospace batteries. Brief presentation of the key type of batteries and fuel cells used in aerospace applications.
Hour 75) Electrical aspects of corrosion systems and components of the electrochemical loop.
Hour 76) Corrosion for aerospace applications – The three key overvoltage types.
Hours 77-78) Design of actions to mitigate corrosion of aircraft components.
Hour 79) Passivating alloys. Hydrogen embrittlement
Hour 80) Stress corrosion cracking.
Hour 81) Corrosion fatigue.

References

[1] Handouts.
[2] P. Brozzo. Metallurgia fisica, ECIG (Genova) 1975.
[3] M.A. Meyers, K.K. Chawla. Mechanical Behaviour of Materials. Cambridge University Press (Cambridge) 2009.

[4] G.E. Dieter, D. Bacon. Machanical Metallurgy. McGraw Hill (New York) 1990.
Useful material can be found in the website of the Metallurgy Group of Cambridge University:
Department of Materials Science & Metallurgy of the University of Cambridge (https://www.msm.cam.ac.uk/)

REFERENCE TEXT BOOKS

References
[1] Handouts (see above in this menu).
[2] P. Brozzo. Metallurgia fisica, ECIG (Genova) 1975.
[3] M.A. Meyers, K.K. Chawla. Mechanical Behaviour of Materials. Cambridge University Press (Cambridge) 2009.
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