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Pryazovskyi State Technical University (PSTU)

Perspective strengthening technologies of materials treatment

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The subject is to be taught for full-time students during their IX- term of masters' programme and for extra-mural students during their XI-term.

Duration: 18 weeks/ For full-time students it includes:

- 36 hours of lectures,
- 18 hours of laboratory works,
- 18 hours of practical training,
- 30 hours individual work, Total 102 hours or 3.4 Credit
- 6 hours of lectures are specified for extra-mural students, as well as 2 hours of laboratory works, 4 hours of practical training and one test paper.

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Prerequisites

Prerequisites:	Co-requisites (if necessary):
Student should possess the basic knowledge in the following disciplines: - Metal science; - Physics of solid state; - Physical and chemical basis of material science; - Theory and technology of heat treatment, thermo-chemical and thermomechanical treatments; - Alloys with specific physical properties; - Non-ferrous metals and alloys; - High strength machine building materials - Knowledge of analytical language and and terminology	- to pursue patent search - to analyze and systemize the results of the patent, literature and reference materials - get oriented in a variety of the functional materials, both known and projected for development - apply traditional methods and technologies of material strengthening basing yourself on the operational conditions

ECTS	Total student work load hours	Contact hours	Individual work hours
4,5	102	72	30

Aim of the module: competences foreseen by the study programme
- to obtain knowledge on scientific and physical regularities in phase and structural transformations which are integral part of today strengthening technologies aimed at enhancing the required properties; - to acquire skills in solving real-time application problems in production and research methods in treatment technologies

Learning outcomes of module (course unit)	Teaching/ learning methods	Assessment methods
To know: - main perspective strengthening technologies and tendencies in their optimization - physical effects and phenomena which are at the base of strengthening technologies - phase, structural and other transformations which enhance the properties of metallic materials - application areas of various strengthening technologies	Lecture Lab Practicals Problem-solving assignments	Written exam Reports on lab work Modular control
To be able to: analyse the patents and current publications in order to define the prospective advancements in optimizing the strengthening technologies and opportunities for the industrial applications	Independent studies Individual assigments	Interview Review of literature Discussion
To use methods of: - selecting the appropriate strengthening methods for machine parts and tools according to the operational conditions and specifications for enhancing their reliablity and life cycle - comparative evaluation of the effectiveness of different strengthening technologies according to the obtained mechanical, physical, chemical, technological and operational propeprties and with consideration of their economic efficiency	Practicals	Assessment of ability to solve the problem

The programme of the course of lectures

1. Requirements for the properties of high-strength materials.

Main strengthening mechanisms:

- solid solution alloying;
- strain hardening (cold working, dislocation's);
- grain size reduction; dispersion strengthening;
- deformation induced martensite transformation (DIMT).

Classification of the ways of strengthening treatment and technological provision of strengthening.

2. Perspective technological techniques of quenching:

- quenching from inter-critical *(α+γ)* area;
- stepped quenching;
- isothermal quenching;
- double quenching;
- quenching with stepped heating in *(α +γ)* and *(α +γ +carbide, carbide-nitride)* areas;
- quenching with sub-zero treatment;

3. Thermo-cyclic treatment (TCT).

Classification and technological schedules of TCT. Peculiarities of phase transformations and structural change in alloys, during TCT. TCT technologies, formation microstructure and properties for next materials:

- structural steels;
- tool steels;
- cast irons;
- non-ferrous alloys.

4. Thermomechanical treatment (TMT).

Classification of methods and basic technological schemes of TMT. Variety of TMT technologies:

- High-temperature thermomechanical treatment (HTMT);
- low-temperature thermomechanical treatment (LTMT);
- controlled rolling, high-temperature isothermal thermomechanical treatment (HTITMT);
- low-temperature isothermal thermomechanical treatment (LTITMT);
- hereditary thermomechanical treatment (HTMT);
- preliminary thermomechanical heat treatment (PTMT), etc.

Peculiarities of phase transformations and formation of structure during deformation and heating. The process of TMT for structural steel grades and their properties. TMT technology of non-ferrous alloys and formation of their properties. Application of TMT for regulation of martensite transformations in steels with meta-stable austenite. Strengthening by the following methods of surface plastic deformation:

- shot-blasting treatment;
- smooth rolling and roll knurling;
- vibration-strengthening treatment (caulking);
- Materials strengthening by hydro-extrusion.

5. Strengthening of materials by high velocity deformation.

The essence and classification of the modern methods of high velocity deformation:

- explosion treatment;
- application of energy of fast flying mass;
- using of impulse magnetic field;
- using of electrohydraulic deformation;
- application of laser beam.

Peculiarities of physical phenomena, phase and structural transformations in materials under conditions of high velocity deformation. Strengthening of materials and spheres of high velocity deformation application.

6. Heat treatment of steel parts in a magnetic field (HTMF).

Thermodynamic, mechanisms and kinetics of phase transformations in a magnetic field. Influence of magnetic fields upon martensite, pearlier and bainite transformations and the processes, occurring at tempering. Influence of HTMF upon mechanical and exploitation properties of machine parts and tools.

7. Ionic treatment of parts of machine.

The essence and classification of the process of ionic treatment. Physical and chemical processes and transformation, occurring inside the surface material layers at ionic bombardment. The process of ionic nitration and ionic carburization (using a glow discharge), their peculiarities and advantages over traditional methods of thermochemical treatment. Ionic implantation of various alloying elements into machine parts and tools surface.

8. Vacuum treatment of machine parts and tools.

Peculiarities and classification of types of vacuum treatment. The process of high-speed steel vacuum treatment and its advantages over traditional methods of treatment. The process of vacuum carburization and its advantages over traditional carburization.

9. High-speed heterogeneous heat treatment.

Using straight electric current application, heating with high frequency electric current. Influence of heating rate upon phase transformations and structural transformations in steels and alloys. The process of electroheating and its influence upon alloys' properties. New methods of heat treatment, based upon the principle of heterogenization of austenite and formation of heterophase meta-stable states:

- rapid high-temperature quenching from hetero-phase states.
- low-temperature quenching with heteroheneity station;
- quenching with stepped cooling;
- quenching with stepped heating in *(α +carbide, carbide-nitride)* areas;
- thermo-cyclic treatment with heterohenity austenitisation, etc.

10. Technologies of strengthening, based upon application of the effect of superplasticity.

The mechanisms, factors and conditions, causing the effect of superplasticity. The role of structure and phase transformations. The application of superplasticity effect for strengthening of materials.

11. Production of amorphous and single-crystal alloys. Composition of amorphous alloys and conditions of its amorphization. Properties of amorphous alloys and their application in engineering. Ways of making of single-crystal alloys, their properties and application in engineering. Formation of nano-structured states in alloys and nano-technologies.

12. Conclusion.

The comparative analysis of alternative methods of strengthening and selection of rational and high-efficiency technologies, ensuring improvement of mechanical and exploitation properties of machine parts and tools, as well as savings on materials.

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The list of laboratory works

1. Influence of the parameters of stepped heating for quenching upon the structure and properties of high-strength steels. (6 hours)

2. Influence of quenching with holding inside the inter-critical ($\alpha+\gamma$) area upon the structure and properties of steel. (4 hours)

3. Influence of thermo-cyclic treatment upon the structure and properties of steels and cast irons (4 hours)

4. Influence of the parameters of ionic-plasma treatment upon the structure and hardness of the surface parts' layers. (4 hours)

Comment: *themes laboratory work can be adjusted and changed proceeding from possibilities and specific university.*

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The list of practical training classes

1. Modern methods of quenching. (2 hours)
2. Thermo-cyclic treatment of steels and cast irons. (2 hours)
3. Modern methods of thermomechanical treatment (2 hours)
4. Methods of strengthening with application of high velocity deformation. (2 hours)
5. Parts heat treatment in a magnetic field (2 hours)
6. Methods of ionic and ionic-plasma treatment (2 hours)
7. Vacuum heat treatment and vacuum thermochemical teatment (2 hours)
8. Methods of high-speed heterogeneous treatment (2 hours)
9. Strengthening technology with application of the effect of superplasticity (2 hours)

Individual work specified for course, under the lecturer's guidance

Students' individual work is done while preparing for lectures, laboratory and practical training classes and also during individual learning of some subsections of the theoretical course and possible additional sections. The objective of students' individual work is acquisition of practical skills of work with research literature and reference books, unaided extension of knowledge, regarding perspective strengthening technologies of metallic materials treatment.

For individual work the students are given individual tasks, their marks obtained are taken into account for final assessment of knowledge.

The contents and teaching-procedure card of the discipline

№	The subject and its contents	Volume in hours			Type of control	Litera-ture (main)
		Lectu -res	Practical training (№)	Lab works (№)		
1.	Introduction. Requirements for properties of high-strength materials.	2	-	-	Current control	[11, 12, 15]
2.	Perspective technological techniques of quenching.	2	2 **(4.1)**	6 **(3.1)**	Current control, questioning	[1-15, 17]
3.	Thermo-cyclic treatment (TCT).	4	2 **(4.2)**	4 **(3.3)**	Current control, questioning	[18-25]
4.	Thermomechanical treatment (TMT).	6	2 **(4.3)**	-	Current control, questioning	[26-34]
5.	Strengthening of materials by means of high velocity deformation.	4	2 **(4.4)**	-	Current control, Test paper No1	[35-45]
6.	Heat treatment of steel parts in a magnetic field	4	2 **(4.5)**	-	Current control, questioning	[46-52]

№	The subject and its contents	Volume in hours			Type of control	Litera-ture (main)
		Lectu -res	Practica training (№)	Lab works (№)		
7.	Ionic treatment of parts of machine.	4	2 **(4.6)**	4 **(3.4)**	Current control, questioning	[53-57]
8.	Vacuum treatment of machine parts and tools.	2	2 **(4.7)**	-	Current control, test paper №2	[58-60]
9.	High-speed heterogeneous heat treatment.	2	2 **(4.8)**	4 **(3.2)**	Current control, questioning	[1,10-12, 61-67]
10	Technologies of strengthening, based upon application of the effect of superplasticity.	2	2 **(4.9)**	-	Current control, questioning	[68-81]
11.	Production of amorphous, single-crystal and nano-structured alloys.	2	-	-	Current control, test paper №3	[82-89]
12	Conclusion. Comparative analysis and selection of alternative strengthening technologies.	2	-	-	Current control, questioning	[1, 90]

Module-rating control

The following control forms are used:

- questioning of students, reports and discussion of the material of the discipline at practical and laboratory classes;

- module test papers;

- examination is the final control.

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Application of technical methods of teaching and control of knowledge

At lectures and practical training classes diagrams, schemes, drawings, diagrams, placards, posters and multi-media systems of personal computers are to be used.

Tasks for individual work (control work for extra-mural students)

Variant 1

- Technology of strengthening of structural steels by means of quenching from double-phase ($\alpha + \gamma$) *area, their structure and properties.*
- *Reasons of increase of steel properties caused by thermomechanical treatment.*
- *Application of heat treatment in a magnetic field for steels of austenite class.*

EXAMINATION QUESTIONS

1. The requirements for the properties of high-strength materials.
2. The basic mechanisms of strengthening of alloys.
3. Classification of the methods of strengthening treatment and technological provision of strengthening.
4. Perspective technological techniques of quenching from inter-critical ($\alpha + \gamma$) area, stepped, isothermal, double with stepped heating in ($\alpha + \gamma$) and ($\alpha + \gamma$ + carbide, carbide-nitride) areas, high-speed high-temperature from austenite's heterogeneous states.
5. Thermo-cyclic treatment (TCT) of alloys.
6. Classification and main technological schemes of TCT.
7. Peculiarities of phase and structural transformations at TCT.

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Total 62 questions.

Recommended literature (main)

1. Fundamental aspects of structural alloy design. – Ed.: R.I. Jaffee, B.A. Wilcox. Battle institute materials science colloquia, 1975. – Plenum Press, New York, 1977.
2. Голованенко С.А. Двухфазные низколегированные стали / С.А. Голованенко, Н.М. Фонштейн. – М: Металлургия, 1986. – 207 с.
3. Гриднев В. П. Фазовые и структурные превращения и метастабильное состояние в металлах / В. П. Гриднев, В. И. Трефилов. – Киев.: Наукова думка, 1988. – 264 с.
4. Чейлях А.П. Экономнолегированные метастабильные сплавы и упрочняющие технологии / А.П. Чейлях. – Мариуполь, ПГТУ, 2009. – 483 с.
5. Surface modification and alloying by laser, ion, and electron beams. – Ed.: J.M. Poate, G. Foti, D.C. Jacobson. – New-York and London: Plenum Press, 1983.
6. Application of particle and laser beams in materials technology / Ed. By P. Misaelides. – Dordrecht-Boston London: Kluwer Academic Publishes, 1994. – 678 p.
7. Cheilyakh A.P., Malinov L.S. Properties of and trasformations in corrosion-resistant chrome-manganese steels // Metal Science and Heat Treatment 1994. – vol. 36, №2. – pp. 103-109.
8. Cheiliakh Oleksandr P., Kolodyazhna Irina V. New Wear-Resistant Metastable Strain Hardenable Alloyed Cast Irons//Key Engineering Materials Vol. 457 (2011) pp 267-272 Trans Tech Publications, Switzerland.
9. Wang T.S. Nanocrystallization and a martensite formation in the surface layer of medium-manganese austenitic wear-resistant steel caused by shot penning / T.S. Wang, B. Lu, M. Zhang et al. – Materials Science and Engineering A, 2007. – Vol. 458. - P. 249-252.

And s.o.

Total: 90 pos. main literature and 25 pos. additional literature.

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Thank you for your attention!