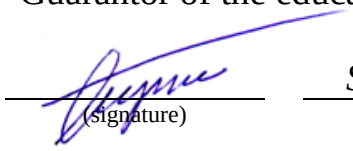
Ministry of Education and Science of Ukraine
National Aerospace University
"Kharkiv Aviation Institute"

Department *Aircraft engine design* (No. *203*)

APPROVED

Guarantor of the educational program



(signature) *Serhii BEZUGLYI* (first and last name)

" *30* " *08* 2023

SYLLABUS OF A *MANDATORY* ACADEMIC DISCIPLINE

MAINTENANCE, REPAIR AND USE OF AIRCRAFT ENGINES IN LAND POEWER PLANTS

(academic discipline)

Field of education *13 «Mechanical Engineering»*
(code and name of a field of education)

Field of study *134 «Aerospace Engineering»*
(code and name of field of study)

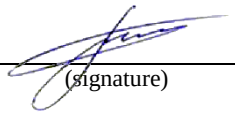
Educational program *Design, Operational Diagnostics, Maintenance and Repair of Aircraft Engines and Power Plants*
(name of Educational program)

Form of study: full-time

Academic degree: *First (Bachelor)*
(academic degree)

Kharkiv 2023

Persons, who developed the syllabus

Yevhen MARTSENIUK, senior lecturer 
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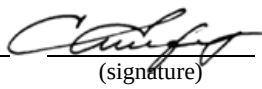
Serhii SYKHOVII, Assoc. Prof., PhD 
(author, position, academic degree and rank) (signature)

The syllabus was approved at the meeting of the department
Aircraft Engine Design (No. 203)
(department)

Minutes No. *1* dated *" 28 "* *August* 2023.

Head of the department *DSc., Professor*  *Serhii YEPIFANOV*
(academic degree and rank) (signature) (first and last name)

1. Description of the discipline

<table>
<tr><td rowspan="2">Characteristics</td><td>Branch of science,
specialization,
academic degree</td><td>Description of the discipline
(full-time tuition)</td></tr>
<tr><td>Field of education:
13 «Mechanical Engineering»
(cipher and name)</td><td>Mandatory</td></tr>
<tr><td>Modules – 2</td><td rowspan="4">Field of study:

134
«Aerospace Engineering»
(cipher and name)</td><td>Academic year:</td></tr>
<tr><td>Semantic modules – 4</td><td>2023 / 2024</td></tr>
<tr><td>Individual task
unavailable</td><td rowspan="2">Semester</td></tr>
<tr><td>(title)</td></tr>
<tr><td rowspan="3">Total number of academic hours – 60*/105</td><td rowspan="5">Educational program:
Design, Operational Diagnostics, Maintenance and Repair of Aircraft Engines and Power Plants
(name)</td><td>8-th</td></tr>
<tr><td>Lectures [1)]</td></tr>
<tr><td>36 a.h.</td></tr>
<tr><td rowspan="2">Number of academic hours for full-time tuition:
auditorium – 5
independent work – 3.75</td><td rowspan="3">Practices, seminars [1)]
–
Laboratory activities [1)]</td></tr>
<tr><td rowspan="3">Higher education:
First (Bachelor)</td></tr>
<tr><td>24 a.h.</td></tr>
<tr><td>Independent work</td></tr>
<tr><td>45 a.h.</td></tr>
<tr><td>Form of examination</td></tr>
<tr><td>Modular control,
exam</td></tr>
</table>

The ratio of hours of classes to independent work is: for full-time education – 60 / 45.

[1)] *Auditory load can be reduced or increased by one hour, depending on the schedule of classes.*

2. Goals and purposes of discipline

Goal: forming knowledge about structure and operation of land gas turbine engine, features of GTE application in land power plants and instrumental methods of GTE condition control.

Task: The course is based on the knowledge from disciplines as Theory and Calculation of Impeller Machines, theory of air-jet engines, mechanics of materials and structures, design of machine elements, theory of mechanisms and machines, aviation materials science, fluid and gas dynamics, thermodynamics and heat transfer etc. The program shows logical interaction among the studied matters and partitions of the previously studied disciplines.

According to the requirements of the educational-professional program, students must achieve such **competencies:**

General competencies: *GC5 – Ability to work both independently and in a team with representatives of other professional groups. GC6 – Ability to generate new ideas (creativity). GC7 – Ability to make informed decisions in normal and special situations and implement them correctly. GC8 – Ability to learn and master modern knowledge.*

Special (professional) competencies: *SC2 – Ability to use the positions of hydraulics, aero- and gas dynamics to describe the interaction of bodies with gaseous and hydraulic environment. SC9 – Possession of the basics of operation and maintenance of aircraft, engines and their systems. SC10 – Ability to develop measures to diagnose and eliminate malfunctions and failures of engine systems, to analyze the causes of their occurrence, to develop and implement measures to prevent them. SC11 – Ability to perform official duties in accordance with applicable regulations based on knowledge of aviation technology and the influence of the human factor.*

Program learning outcomes: *PLO4 – To explain their decisions and the basis for their adoption to specialists and non-specialists in a clear and unambiguous form. PLO5 – To have the skills of self-study and autonomous work to refreshing professional skills and solve problems in a new or unfamiliar environment. PLO13 – To understand features of workflow in hydraulic, pneumatic, electrical and electronic systems used in aerospace engineering. PLO18 – To understand the structure and operating principles of onboard and navigation equipment of aerospace engineering. PLO19 – To understand and justify design features and basic aspects of workflow in systems and elements of aerospace engineering. PLO24 – Have basic knowledge of the organization of maintenance and repair of aircraft. PLO25 – Have a basic knowledge of methods and tools for diagnosing aircraft, engines and their systems.*

Pre-requisites: *Engineering Materials Science, Aviation Materials Science, Fundamentals of Machinery Design, Mechanics of Materials and Structures, Theory and Calculation of Impeller Machines, Theory of Air-Jet Engines, Design and Dynamics of AE and PP*.

Co-requisites: *Design, Dynamics and Strength of AE and PP (TW)*.

3. Course content

MODULE 1
Semantic module 1
CONSTRUCTIVE SCHEMES AND CYCLES OF LAND GTE

TOPIC 1. Areas of gas turbine engine possible use. Classification of ground use gas turbine power plants. World companies in the field of propulsion engineering.

TOPIC 2. Scheme of land and marine GTE: single-shaft GTE; GTE with free turbine; GTE with “bonded” low-pressure compressor.

TOPIC 3. Simple cycle of gas turbine engine. Classification of GTE by thermodynamic cycle. GTE with heat recovery. Intercooled gas turbine. GTE with intermediate heating. Gas turbine plant with exhaust heat utilization. Air-storage gas turbine power plant. Closed-cycle GTE. Attached GTE.

Combined steam-gas system. Systems with steam injection: simple STIG-system and STIG-system with condenser. GTE with steam cooling.

Modular testing

Semantic module 2

GTE IN POWER PLANTS

TOPIC 4. Use of aircraft engines to protect non-flaming fountains from being self-ignited. Inert gas generators based on aircraft GTE for firefighting. Problems of docking a ship at cold period. Gas-jet machines. Mobile installation for disinfection with gas turbine module.

TOPIC 5. Main reasons of GTE use in electric power industry. Requirements to GTE used in gas turbine power station (GTPS). Arrangement of gas turbine engine in GTPS. Possible variants of GTE usage as a drive of an electric generator. Comparison of railway mobile gas turbine power plant with such installation based on steam turbine. Marine electrical power plant.

TOPIC 6. Main problems of marine GTE and power plants. Classification of marine GTE. Classification of marine gas turbine power plants. Influence of marine conditions on GTE operation. Filtering the air supplied to GTE. The corrosion of turbine. Protective coatings of blades. Mechanical and air noise of GTE in the ship. The problem of ship propeller reversal.

TOPIC 7. GTE in railway transport. Generic diagram and operation of railway transport power plant based on gas turbine. Examples of experimental and serial trains with gas turbine power plant. Modern turbo-trains. Prerequisites of GTE appearance in power plant of tanks. Comparison of gas turbine powered tank with piston powered tank. Main features of tank GTE arrangement.

Modular testing

Semantic module 3

INSTRUMENTAL METHODS OF DIAGNOSING AND CONTROLLING THE GTE

TOPIC 8. Purpose and classification of aircraft instruments (AI). Operating conditions of the AI, and measuring and computing complexes. Main definitions and structure of instrumentation complex. Modern state and perspectives of instrumentation complexes development. Fuel-measuring systems and flow meters. Appointment, functions and composition of power plants control instruments.

TOPIC 9. Analysis of failures and malfunctions of aircrafts. Known methods for failures and malfunction diagnostics: method of methods of successive approximations, “laboriousness-probability” method, method of “middle point”, substitution method. Inspection and replacing the system components in engine mockup. Defects that can be detected by nondestructive testing (NDT). Review of NDT methods and their application area. Comparison of these methods.

TOPIC 10. Optical-visual methods of aircraft diagnostic. Basic rules and order of visual inspection of aircraft and helicopter. Visual inspection of GTE gas path. Existing devices for visual inspection of GTE gas path. Main rules of engine gas path inspection. Access ports on the engine for gas path inspection.

MODULE 2

Semantic module 4

RELIABILITY OF THE GAS TURBINE ENGINE

TOPIC 11. Introduction. Economical aspects of reliability. Basic concepts.

TOPIC 12. Probability. Conditional probability. Independent Events.

TOPIC 13. Continuous probability distribution. Constructing a Probability distribution for random variable. Expectation and Variance of discrete Random Variables. Normal Distribution. Load-Strength model.

TOPIC 14. Larson-Miller equation. Serial and parallel reliability calculations. Reliability indexes. Bathtub curve. Mathematical models of infant, normal and wear periods.

TOPIC 15. Reliability calculation of turbine blade. Reliability calculation subject to sudden failures. Required safety factor determining.

Modular testing

4. Course arrangement

Names of Modules and Topics	Number of hours full-time tuition				
	total	namely			
		lec	pr	lab	i.w.
1	**2**	**3**	**4**	**5**	**6**
Module 1					
Semantic module 1 CONSTRUCTIVE SCHEMES AND CYCLES OF LAND GTE					
TOPIC 1. Areas of gas turbine engine possible use. Classification of ground use gas turbine power plants. World companies in the field of propulsion engineering.	4	2	-	-	2
TOPIC 2. Scheme of land and marine GTE.	4	2	-	1	1
TOPIC 3. Use of complex cycles in GTE	13	6	-	1	6
Modular testing	0.5	0.5	-	-	-
Totally for the semantic module 1	**21**	**10**	**-**	**2**	**9**
Semantic module 2 GTE IN POWER PLANTS					
TOPIC 4. Gas generators based on GTE.	4	2	-	-	2
TOPIC 5. Application of GTE in electric power industry.	4	2	-	-	2
TOPIC 6. Marine GTE and power plants.	4	2	-	-	2
TOPIC 7. GTE in land transport.	4	2	-	-	2
Modular testing	0.5	0.5	-	-	-
Totally for the semantic module 2	**16**	**8**	**-**	**-**	**8**
Semantic module 3 INSTRUMENTAL METHODS OF DIAGNOSING AND CONTROLLING THE GTE					
TOPIC 8. Aircraft instruments.	4	-	-	2	2
TOPIC 9. Analysis of failures and malfunctions of aircrafts and nondestructive testing methods.	4	-	-	2	2
TOPIC 10. Optical-visual methods of aircraft diagnostic.	8	-	-	6	2
Modular testing	0.5	-	-	0.5	-
Totally for the semantic module 3	**16**	**-**	**-**	**10**	**6**
Module 2					
Semantic module 4 RELIABILITY OF THE GAS TURBINE ENGINE					
TOPIC 11. Introduction. Economical aspects of reliability. Basic concepts.	2	2	-	-	-
TOPIC 12. Probability. Conditional probability. Independent Events.	2	2	-	-	-
TOPIC 13. Continuous probability distribution. Constructing a Probability distribution for random variable. Expectation and Variance of discrete Random Variables. Normal Distribution. Load-Strength model.	7	7	-	-	-
TOPIC 14. Larson-Miller equation. Serial and parallel reliability calculations. Reliability indexes. Bathtub curve.	7	7	-	-	-
TOPIC 15. Reliability calculation of turbine blade.	34	-	-	12	22
Modular testing	0	2	-	-	-
Totally for the semantic module 3	**52**	**18**	**-**	**12**	**22**
Totally	**105**	**36**	**-**	**24**	**45**

5. Seminars

#	Topic	Hours
1	---	0
	Totally	**0**

6. Practical activities

#	Topic	Hours
1	---	0
	Totally	**0**

7. Laboratory activities

#	Topic	Hours
1	Design features of gas turbine plant, converted from aircraft engine	2
2	Means for converting, transmitting and computing flight data	2
3	Analysis of failures and malfunctions of aircrafts and nondestructive testing methods	2
4	Visual diagnostics of GTE gas-path	6
5	Reliability calculation subject to sudden failures	6
6	Required safety factor determining	6
	Totally	**24**

8. Independent work

#	Topic	Hours
1	Study of main parameters and constructive scheme of aircraft engines: D-20P, AI-20, NK-12, NK-16ST, NK-8, TV3-117	3
2	Study of design features of complex cycle GTE	6
3	Gas-jet plant, based on GTE	2
4	Application of GTE as a drive in the electric power industry	2
5	GTE in power plants of land and marine transport	4
6	Types of sensitive elements used in aircraft instruments. Study of functional schemes and operation principles of sensors, which are installed on an engine.	2
7	Study of troubleshooting methods	2
8	Study of non-destructive control methods	2
9	Reliability calculation subject to progressive failures	12
10	Reliability calculation of parts at reloading	10
	Totally	**45**

9. Independent work

Unavailable.

10.Learning methods

Basic forms of learning:

- lectures;
- laboratory works;
- independent work;
- exam.

Lecture gives to student basic conceptions, bases of theory, relations which necessary to prepare for laboratory works and individual task.

Lecture solves one didactic problem only – gives primary knowledge about subject of topic, formulates main problems.

Laboratory works are based on verbal (analytic) description of the object (engine, unit or component) and its material presentation using special didactic materials (mockups, posters, drawings etc.). During laboratory works, team-based approach of students work is applied.

Main form of learning is independent work. It cannot be done without preliminary knowledge given in lecture. During independent work, students study lecture material, prepare to laboratory works, make calculation-graphic task.

11. Control methods

11.1. Testing

For this purpose, the material of the subject is divided into four modules:

1. Constructive schemes and cycles of land GTE.
2. GTE in power plants.
3. Instrumental methods of diagnosing and controlling GTE.
4. Reliability

Modules 1, 2, 3 are passed during 8-th week of 8-th semester (one attempt), module 4 is passed during 14-th week of 8-th semester (one attempt).

Before passing modulus, student must make all laboratory and independent works of this modulus.

Execution of laboratory works – in *writing form*, defense – *orally*.

Semester 8 – examination.

11.2. Questions for the test

Topics on engine schemes and cycles

Module 1

Semantic module 1

1. Probable application areas of GTEs.
2. GTE as a mechanical drive of industrial equipment. Application of GTE, requirement to the drive.
3. GTE as an electric generator drive.
4. Classification of GTEs used in ground power plants.
5. Stationary GTEs: requirements and features.
6. Ground GTEs converted from aircraft engines.
7. Microturbines.
8. Main advantages and disadvantages of GTEs of various structural schemes. Application of each scheme.
9. GTE classification by thermodynamic cycle.
10. GTE with complex thermodynamic cycles: operation features, construction features, principal schemes.
11. Application and operating principal of air-storage gas-turbine unit. Advantages of power plants made by such schemes.
12. Closed cycle GTEs. Features, operating principal. Selection of working fluid for closed cycle GTE.
13. Combined-cycle steam-gas plants: operating principle, economic effect.
14. Operating principle of STIG unit. Types of STIG-systems. Problems associated with the realization of such schemes.

Topics on power plants with GTE

Module 1

Semantic module 2

1. Using of aircraft engines for protection of non-burning gusher against of ignition: operating principal, engine-prototype, limits for application of such units.
2. Using the inert gas generators based on aircraft engines in firefighting units: requirement for these units, principal scheme and examples of such units.
3. Gas-jet units for airdrome cleaning.
4. Classification of marine GTE.
5. Main features of marine GTE: increased level of impact loads, air and structure-borne noise, water ingress into the flow channel, salt deposition in the gas-path, requirements of reliability and efficiency, task of reversing the ship propeller.
6. Ways to solve the problems of GTE operation in a marine environment.
7. Transport GTEs: railroad, armored vehicles.

Topics on instrumental methods and aircraft instruments

Module 1

Semantic module 3

1. Aircraft instruments: application, classification, operation conditions.
2. Operating principal of velocity flowmeters.
3. Main sensing elements of pressure sensors.
4. Scheme and operating principal of pressure indicator.
5. Scheme and operation principal of inductive pressure sensor.
6. Classification of thermometers by operating principal.
7. Operating principal of bimetal thermometer.
8. Operating principal of thermo-electrical thermometer.
9. Probable methods of rotation speed measurement.
10. Operating principal of inductive rotation speed sensor.
11. Scheme and operating principal of piezoelectric vibration transducer.
12. Scheme and operating principal of inductive vibration transducer.
13. Methods of installing of vibration transducers on engine.
14. Operating principal of semi-wave acoustic oscillation damper.
15. What defects can be detected by visual-optic diagnostic?
16. Probable damages of rotor blades and vanes of compressor and turbine.
17. Methodology of damage size identification by endoscope.
18. Existing endoscope types: short description, main parts, operation principal, scheme.
19. Procedure carried out while visual inspection of GTE air-gas channel.
20. How do we get access into the engine while visual inspection of its gas path?

Topics on reliability of the gas turbine engine

Module 2

Semantic module 4

1. Economical aspects of reliability.
2. Basic concepts.
3. Probability.
4. Larson-Miller equation.
5. Expectation and Variance of discrete Random Variables.
6. An introduction to the Normal Distribution.
7. Serial and parallel reliability calculations.
8. Examples of Normal Distribution application.
9. Linear combinations of Normal random variables
10. Conditional probability
11. Independent Events.

12. Reliability indexes
13. Buthtub curve.
14. Weibull distribution
15. Combination of Normal and Exponential distribution
16. Reliability Block Diagram.

12.Evaluation criteria and distribution of the points that the students get

12.1. Distribution of the points that the students get (quantitative evaluation criteria)

Components of educational work	Points for one lesson (task)	Number of lessons (tasks)	Total number of points
Module 1			
Work at lectures	0…0.5	5	0…2.5
Execution and defense of laboratory (practical) works	0.5…1	1	0.5…1
Modular testing	9.5…14	1	9.5…14
Module 2			
Work at lectures	0…0.5	4	0…2
Execution and defense of laboratory (practical) works	0.5…1	0	0
Modular testing	9…13	1	9…13
Module 3			
Work at lectures	0…0.5	0	0
Execution and defense of laboratory (practical) works	0.5…1	5	2.5…5
Modular testing	8.5…13	1	8.5…13
Module 4			
Work at lectures	0…0.5	9	0…4.5
Execution and defense of laboratory (practical) works	0.5…1	6	3…6
Modular testing	27…39	1	27…39
Total for semester			**60…100**

Semester testing (examination) is held in case the student gives up points of modular testing and is permitted to the examination. The permission is given if the student has finished and passed all laboratory and practical works.

Maximum total score of the examination is 100 points.

The examination card is composed of four theoretical questions. The questions are distributed as follows:

– the first question is on classification and constructive schemes of ground GTE; complex cycles of ground GTE (Semantic module 1);

– the second question is on features of the GTE application in power complexes;

– the third and fourth questions is on reliability (Semantic module 4).

– the fifth question is on topics of laboratory and practical activities (Semantic module 3, 4).

The practical task concerns elements of the engine parts strength analysis.

Maximum number of points for each question is 20.

12.2. Qualitive evaluation criteria

To get positive mark, the student must

know:

– main types and features of land gas turbine engines, and requirements to them;

– generic schemes of land and marine GTE;

– ways of GTE efficiency improvement, complex thermodynamic cycles and design concept for complex cycle implementation;
– features of engine operation under increased dust content;
– problem of air/fuel mixture preparation and its combustion in land engines;
– ecological problems of ground use GTE;
– purpose and functions of control instruments of power plant;
– nondestructive testing methods and their application;
– main reliability indexes;
– methods of reliability indexes determining;
– models of reliability indexes distribution vies maintenance time;
– methods of complex systems reliability determining.
– methods of reliability increasing by reserving.

know how:

– calculate the fuel nozzle when changing the liquid fuel to gaseous one;
– calculate main parts of GTE transmission;
– disassemble, inspect and repair oil and fuel filters, fuel nozzle and igniter;
– visually inspect GTE gas path, find and measure damages of its parts.
– determine main reliability indexes;
– determine parameters of reliability indexes models for different maintenance period;
– determine reliability of GTE details;
– determine reliability of complex systems.

12.3. Criteria of the student evaluation during semester

Satisfactory (60-74). The student must have the required minimum of knowledge. He must finish and pass all laboratory and practical activities, pass modular testing with positive mark. He must know areas of gas turbine engine possible use. He must know the constructive schemes of ground GTE. He must explain what is the complex thermodynamic cycle. He must know about the problems of ground GTE application. He must know the list of objects on which GTE works in the marine environment. He must know purposes and operational conditions of aircraft instruments. Know main nondestructive control methods. Has an idea about the procedure order during visual inspection of aircraft and helicopter. Must understand the importance of vibration occurring during engine operation. Know what are the main reliability metrics. He must explain the main methods of reliability providing.

Good (75-89). The student must be proficient in minimum knowledge. He must finish and pass all laboratory and practical activities, pass modular testing with positive mark. Student must have an idea about the ratio between different sectors of the economy in terms of the number of GTE used. Student must explain why different constructive schemes of GTE are more appropriate for different applications. Must know the ways of improving the economy of ground GTE. Must have an idea of what complex cycles that can be implemented in GTE. Student must know what problems are correspond to ground application of GTE and how to solve these problems. Must know the problems of marine application of GTE. Student must know the main features of ground GTE combustion chamber. Student must explain the procedures for replacing the oil or fuel filter and fuel nozzle. Know the functions, design and operating principles of engine control devices. Know the causes and types of defects that can be detected by available non-destructive control methods. Know which parts can be checked with an endoscope. Have an idea of the procedure of engine gas path visual inspection. Know how to attach vibration transducers to the engine. Know what are the main reliability metrics, different distribution laws, optimal reliability term. He must explain the main methods of reliability providing and calculation.

Excellent (90-100). The student must finish and pass all laboratory and practical activities, pass modular testing with excellent mark (one or two modules with “good” mark and minimum 80 points

are permitted). Know main and additional material in full scale. Be able to compare the various complex thermodynamic cycles of the GTD in terms of efficiency and overall economic effect of the plant. Student must be able to explain the operating principle and draw the schematic diagram and "i-s" diagram of the most common complex cycles of GTE. Must know how the problems of marine application of GTE can be solved. Must have an understanding of the factors that lead to formation of harmful substances in GTE exhaust gas. Student must know and be able to explain examples of existing ground GTE combustion chambers designed to reduce emissions. Must know the purpose, classification and operating principle of the endoscope. Must be able to carry-out the visual inspection of the GTE gas path, find and measure damage of the engine components. Must know how the state of bearing unit is monitored. Know what are the main reliability metrics, different distribution laws, optimal reliability term, confidence criteria, particularities of different periods of life time. He must explain the main methods of reliability providing and calculation, reliability calculation subject sudden, progressive failures.

12.4. Grade scales: national and ECTS

Grade scale	National scale	
	For exam, course project (work), practice	For test
90-100	“excellent”	Passed
75-89	“good”	
60-74	“satisfactory”	
0-59	“non-satisfactory”	Not passed

13.Methodical support

1. Tutorials for different topics of the course.
2. Didactic materials (manuals, Power point presentations, posters etc.).
3. Mockups of TJEs, TFEs, TPEs, TShEs in 103 and 124 rooms.
4. Prepared aircraft instruments.
5. Endoscope.
6. Laboratory equipment for natural frequencies of engine and bearing unit researching.
7. Laboratory equipment for acoustic panel efficiency researching.

14.Recommended literature for the course

Main

1. Gas Turbines: A Handbook of Air, Land and Sea Applications / Claire Soares – Elsevier Science, 2014. – 1020 p.
2. Ширков, В.Т. Визуальная диагностика элементов проточной части ГТД / В.Т. Ширков, В.С. Чигрин, Ю.А. Гусев. – Учеб. пособие по выполнению лабораторной работы. – Нац. аэрокосмический ун-т «Харьк. авиац. ин-т», 2001. – 39 с. http://library.khai.edu/library/fulltexts/metod/_Shirkov_Vizualnaya.pdf
3. Чигрин, В.С. Виброакустика авиационных двигателей [Текст]: лабораторный практикум / В.С. Чигрин, Ю.А. Гусев, О.М. Бугаенко, А.И. Попуга. – Х.: Нац. аэрокосм. ун-т «Харьк. авиац. ин-т». – 2014. – 52 с. http://library.khai.edu/library/fulltexts/metod/Chigrin_Vibroakustika.pdf
4. Чигрин, В.С. Конструкция турбовального ГТД Д-136 [Текст] : учеб. пособие / В. С. Чигрин, В. Н. Денисюк, В. Г. Харченко. – Х. : Нац. аэрокосм. ун-т им. Н. Е. Жуковского «Харьк. авиац. ин-т», 2015. – 104 с. http://library.khai.edu/library/fulltexts/metod/Chigrin_Konstrukcija.pdf
5. Design for reliability / managing editor, Dana Crowe; technical editor, Alec Feinberg; o-authors, Carl Bunis ... [et al.].

6. Reliability Handbook UG-311 One Technology Way • P.O. Box 9106 • Norwood, MA 02062-9106, U.S.A. • Tel: 781.329.4700 • Fax: 781.461.3113 • www.analog.com
7. System reliability theory/ Marvin Rausand, Arnljot Hsyland, a John Wiley & sons, inc., publication. 2004.

Additional

1. Ивченко А.Г. Авиационный турбовинтовой двигатель АИ-20А. Техническое описание / А.Г. Ивченко – М.: Оборонгиз, 1962. – 133 с.
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