Al-FARABI KAZAKH NATIONAL UNIVERSITY
FACULTY MECHANICS AND MATHEMATICS
Educational program on specialty «050603-Mechanics»

Approved
at the meeting of Academic Council
of the faculty of Mechanics and Mathematics

Protocol №___from « ____»_____ 2015
Dean of the Faculty _____ Bektemesov M.A.

GAS DYNAMICS

SYLLABUS

2-nd year master students «050603-Mechanics»,
Fall semester, 3 credits

Lecturer/Labs Teacher: Yerzhan Belyayev, Doctor PhD
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Activities under the program of the course is set in the form of lectures. Practical fastening of the lecture materials is carried out in a laboratory studies and IWMT (independent work of a master student with a teacher) in accordance with the schedule and the program. Tasks for IWM (independent work of a master student) and verification of IWM is carried out by lecturer. Midterm exams takes Labs teacher.

Aim of the course. To teach students the fundamentals of Gas Dynamics, the basic research methods of gas dynamics, to teach them to understand the basic equations and to introduce the fundamental axioms, hypotheses and modern approach in modeling of gas dynamical flows. The purpose of discipline is familiarize students with the basic internal and external flows, which are covered with practical applications. Concept of the course is based on the book “Fundamentals of Gas Dynamics” by Robert D. Zucker and Oscar Biblarz. As a result of studying the course, students should know the basic laws and characteristics of gas dynamics, to be able to recognize and simulate problems in gas dynamics.

Objectives of the course. To teach students to build mathematical models, to understand the basics of gas dynamics such as compressibility, shock waves, Mach number, diffusion etc. and instill skills to recognize specifically behavior of that effects during solving internal and external flow problems. Gas dynamic flow are one of the main types of flow encountered in many practical problems. As it is well known, experimental studies of gas dynamic processes, in particular at high Mach number are costly and unwieldy. So today it is popular to use methods of CFD (Computational fluid dynamics). The main problem in modeling this kind of flow is the numerical solution of nonlinear convective term in the system of equations for compressible viscous (inviscid) gas. This system of equations for a compressible gas describes processes such as the interaction of shock wave structure, shear flows, wake after the body etc. Moreover, for a more detailed and accurate prediction of flow with discontinuities is used schemes of high order of accuracy (TVD, ENO, WENO), which are based on the physical conditions of the prob-

lem, for example, entropy condition. In order to understand all of these issues it is need a basic theoretical knowledge of the program of gas dynamics, which will be taught in this course.

Learning outcomes. Necessary knowledge in the basics of gas dynamics and skills to solve the problems of compressible flows.

General competence:

- instrumental – the ability to assess the methodological approaches to carry out their critical analysis;
- interpersonal – ability to independently develop and deepen their knowledge and acquire new skills in a professional manner; knowledge of a foreign language in an amount sufficient to communicate freely in arbitrary topics;
- system – the ability to plan the steps of solving professional problems and implement them in time; demonstrate independence and original approach to problem solving, the ability to justify and make decisions.

Subject specific competences: owning a deep fundamental theoretical knowledge in the gas dynamics, modern problems of gas dynamics.

Prerequisites: "Fluid Mechanics", "Continuum Mechanics", "Differential Equations", "Mathematical Physics", "Thermodynamics", "CFD".

Post requisites: "Gas Dynamics", "Thermodynamics", "Acoustics", "CFD".

STRUCTURE AND CONTENT OF THE SUBJECT

Week	Title of the theme	Hour	Grade
1	**Lecture 1.** Introduction to gas dynamics. Review of elementary principles. **Lab.1.** The system of equations for compressible flows. **IWM 1.** Conservation Laws. Various form of the energy equations.	2 1	14
2	**Lecture 2.** Control volume analysis. **Lab.2.** Test problems. **IWM 2.** Test problems.	2 1	14
3	**Lecture 3.** Introduction to compressible flow. **Lab.3.** Equation of perfect gases in terms of Mach number. **IWM 3.** Example problem.	2 1	14
4	**Lecture 4.** Varying-area adiabatic flow. **Lab.4.** Nozzle operations. **IWM 4.** Diffuser performance. Example problem.	2 1	14
5	**Lecture 5.** Standing normal shocks. **Lab.5.** Supersonic wind tunnel operation. **IWM 5.** Test problems.	2 1	14
6	**Lecture 6.** Moving and oblique shocks. **Lab.6.** Oblique shock analysis: perfect gas. **IWM 6.** Test problems.	2 1	14
7	**Lecture 7.** Shock analysis – general fluid. **Lab.7.** Boundary condition of pressure equilibrium. **IWM 7.** Test problems.	2 1	16
	1st control test	1	**100**
	Midterm exam	1	**100**

8	**Lecture 8.** Prandtl-Meyer Flow. **Lab.8.** Analysis of Prandtl-Meyer Flow. **IWM 8.** Test problems.	2 1	12
9	**Lecture 9.** Fanno Flow. **Lab.9.** Correlations with Shocks. **IWM 9.** Test problems.	2 1	12
10	**Lecture 10.** Rayleigh Flow. **Lab.10.** Working equations for perfect gases. **IWM 10.** Test problems.	2 1	12
11	**Lecture 11.** Real gas effects. **Lab.11.** Real gas behavior, equations of state and compress-ibility factors. **IWM 11.** Test problems.	2 1	12
12	**Lecture 12.** Propulsion systems. **Lab.12.** Propulsion Engines. **IWM 12.** Test problems.	2 1	12
13	**Lecture 13.** Propulsion systems. **Lab.13.** Air-breathing propulsion systems performance pa-rameters. **IWM 13.** Test problems.	2 1	12
14	**Lecture 14.** Propulsion systems. **Lab.14.** Rocket propulsion systems performance parameters. **IWM 14.** Test problems.	2 1	12
15	**Lecture 15.** Engineering applications. **Lab.15.** Simulation software for gas dynamical problems. **IWM 15.** Prepare a presentation.	2 1	16
	2nd control test	1	100
	Exam		**100**
	TOTAL		**(1CT+2CT)/2*0.6 +0.1*MT+0.3*EX AM**

LIST OF LITERATURE

Main:

1. Robert D. Zucker, Oskar Biblarz Fundamentals of Gas Dynamics // Second Edition, John Wiley & Sons, Inc. 2002, ISBN 0-471-05967-6, P. 493.
2. Г. Г. Черный Газовая динамика // Москва «НАУКА» 1988, 424 с.
3. В. П. Стулов Лекции по газовой динамике // Москва ФИЗМАТЛИТ 2004, 191 с.
4. А. Н. Крайко, А. Б. Ватажин, А. Н. Секундов Газовая динамика // Москва ФИЗМАТЛИТ 2001, 761 с.

5. Genick Bar-Meir Fundamentals of Compressible Fluid Mechanics // 7449 North Washtenaw Ave Chicago, IL 60645, P. 399.
6. Г.В.Липман, А.Рошко, *Элементы газовой динамики*, М., ИИЛ, 1960.
7. Л.Г.Лойцянский, *Механика жидкости и газа*, М., ГИТТЛ, 1957.
8. Ю. В. Лапин, М. Х. Стрелец Внутренние течения газовых смесей // Москва «Наука» 1989, 366 с.

Additional:

1. Г.Н.Абрамович, *Прикладная газовая динамика*, М., Наука, 1969.
2. Л.И.Седов, *Методы подобия и размерности в механике*, М.,Наука, 1987.
3. Я.Б.Зельдович, Ю.П.Райзер, *Физика ударных волн и высокотемпературных явлений в газах*, М., Наука, 1966.
4. М.А.Лаврентьев, Б.В.Шабат, *Проблемы гидродинамики и их математические модели*, М.,Наука, 1977.
5. Б.Л.Рождественский, Н.Н.Яненко, *Системы квазилинейных уравнений и их приложения к газовой динамике*, М., Наука, 1968.
6. Л.Д.Ландау, Е.М.Лифшиц, *Гидродинамика*, М., Наука, 1986.
7. Н. Ф. Краснов, В. Н. Кошевой, В. Т. Калугин Аэродинамика отрывных течений //Москва «Высшая школа» 1988, 347 с.
8. П. Чжен Отрывные течения // Издательство «Мир», Москва, 1972.

GUIDLINES

All the assignments must be completed until due date. Students, who could not earn 50% out of 100% during first or second midterm and final, will be able to work off during an additional term. Late assignment is not accepted except for extenuating circumstances (e.g. field trip, hospitalization). Student, who failed to meet all kinds of work, is not allowed for passing an exam. In addition, the assessment takes into account the activity and attendance of students during class.

Be tolerant and respect other people's opinions. The objections should be formulated in a correct manner. Plagiarism and other forms of cheating are not allowed. Cheating is not accepted during independent work of student (IWS), midterm and final exam, copying solved problems from others, passing the exam to another student are not allowed also. Student convicted of falsifying any information about the course, any unauthorized upload to the “Intranet” using cheat sheets, will be graded with a final grade «F». For advice on the implementation of IWS, submitting and defending, as well as additional information on the studied material and all the other issues that arose upon studying the course, contact the instructor during his office hours.

Letter grade	Numerical equivalency	% (percentage)	Grading in a traditional way
A	4,0	95-100	Excellent
A-	3,67	90-94	
B+	3,33	85-89	Good
B	3,0	80-84	
B-	2,67	75-79	
C+	2,33	70-74	Satisfactory

C	2,0	65-69	
C-	1,67	60-64	
D+	1,33	55-59	
D-	1,0	50-54	
F	0	0-49	Unsatisfactory
I (Incomplete)	-	-	«The course is incomplete» (this isn't taken into account when calculating the *GPA)*
P (Pass)	-	-	«Passed» (this isn't taken into account when calculating the *GPA)*
NP (No Pass)	-	-	«Not passed» (this isn't taken into account when calculating the *GPA)*
W (Withdrawal)	-	-	«the course is withdrawn» (this isn't taken into account when calculating the *GPA)*
AW (Academic Withdrawal)			Withdrawn because of academic issues (this isn't taken into account when calculating the *GPA)*
AU (Audit)	-	-	«Audit» (this isn't taken into account when calculating the *GPA)*
Att.		30-60 50-100	Attested
Not att.		0-29 0-49	Not attested
R (Retake)	-	-	Retaking the course

Considered in department meeting
Protocol № __ from «__» _____

Head of the department of Mechanics _____ Z. Rakisheva

Lecturer _____ Ye. Belyayev