Proceedings

The 7th International Congress of Serbian Society of Mechanics

Sremski Karlovci, June 24-26, 2019

Edited by:

Mihailo Lazarević
Srboljub Simić
Damir Madjarević
Ivana Atanasovska
Andjelka Hedrih
Bojan Jeremić

The 7th International Congress of Serbian Society of Mechanics

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Bojan Jeremić

Technical program

SUNDAY, June 23, 2019

19:30 *Welcoming Coctail* (Hotel Prezident, Main Hall)

MONDAY, June 24, 2019

8:00 – 8:45 *Registration of participants* (*Main Hall, The Karlovci Gymnasium)*

Chairs: Srboljub Simić, Mihailo Lazarević

8:45 – 9:20 (*Congress hall, The Karlovci Gymnasium)*

- Radovan Kovačević, *Director of the Karlovci Gymnasium, Welcome address*
- Academician Teodor Atanacković*, Novi Sad branch of SASA, Welcome address*
- Aleksandar Stojkecić, *Historical notes - Sremski Karlovci*
- Prof.Mihailo P. Lazarević, *the President of Serbian Society of Mechanics* ,*Welcome address*

Plenary Lectures (*Congress Hall*)
Chairman: Katica *R.* (Stevanović) Hedrih

9:20 - 10:05 P-1 Walter Lacarbonara
ASYMPTOTIC RESPONSE OF SYSTEMS AND MATERIALS WITH HYSTERESIS

10:05 - 10:50 P-2 Zdravko Terze, et al.
LIE GROUP DYNAMICS OF MULTIBODY SYSTEM IN VORTICAL FLUID FLOW

10:50 - 11:15 *Coffee Break* (*Main Hall*)

11:15 - 13:00 Parallel Sessions

Session	G1	S1	M4	C1
Hall	*Classroom 1*	*Classroom 2*	*Classroom 24*	*Classroom 25*
11:15	G1a	S1a	M4a	C1a
11:35	G1b	S1b	M4b	C1b
11:55	G1c	S1c	M4c	C1c
12:15	G1d	S1d	M4d	C1d
12:35	G1e	S1e	M4e	C1e
12:55		S1f	M4f	

13:10 - 14:40 *Lunch* *(Restaurant Bermet*)

Plenary Lecture (*Congress hall*)

Chairman: Srboljub Simić

14:40 - 15:25 P-3 HongGuang Sun, Yong Zhang
ANOMALOUS DIFFUSION: MODELING AND APPLICATION

15:30 -17:30 *Social program* (*excursion to Monasteries at Fruska Gora)*

17:30 - 19:10 Parallel Sessions

Session	G2	S2	M4	M1	M1
Hall	*Classroom 1*	*Classroom 2*	*Classroom 24*	*Classroom 25*	
17:30	G2a	S2a	M4g	M1p*	17:30
17:50	G2b	S2b	M4h	M1a	18:00
18:10	G2c	S2c	M4i	M1b	18:20
18:30	G2d	S2d	M4j	M1c	18:40
18:50	G2e	S2e	M4k	M1d	19:00
19:10		S2f	M4l	M1e	19:20

TUESDAY, June 25, 2019

Plenary Lectures (*Congress hall*)
Chairman: Zdravko Terze

9:00 - 9:45 P-4 Peter Van
CONTINUUM MECHANICS AND NONEQUILIBRIUM THERMODYNAMICS

9:45 - 10:30 P-6 Dušan. Zorica
HEREDITARINESS AND NON-LOCALITY IN WAVE PROPAGATION MODELLING

10:30 - 10:50 *Coffee Break* (*Main Hall*)

10:50 - 13:00 Parallel Sessions

Session	G3	M1	M2	M3	M3
Hall	*Classroom 1*	*Classroom 2*	*Classroom 24*	*Classroom 25*	
10:50	G3a	M1f	M2a	M3a	10:50
11:10	G3b	M1g	M2b	M3b	11:20
11:30	G3c	M1h	M2c	M3c	11:40
11:50		M1i	M2d	M3d	12:00
12:10		M1j	M2e	M3e	12:20
12:30		M1k	M2f		

12:50 - 14:15 *Lunch* (*Restaurant Bermet*)

Plenary Lecture (*Congress hall*)
Chairman: Dušan Zorica

14:15 - 15:00 P-07 N. Zorić
INTEGRATION AND IDENTIFICATION OF ACTIVE VIBRATION CONTROL SYSTEM FOR SMART FLEXIBLE STRUCTURES

15:00 - 15:20 *Coffee Break* (*Main Hall*)

15:20 - 17:20 Parallel Sessions

Session	S3	M1	M2	M3
Hall	*Classroom 1*	*Classroom 2*	*Classroom 24*	*Classroom 25*
15:20	S3a	M1l	M2g	M3f
15:40	S3b	M1m	M2h	M3g
16:00	S3c	M1n	M2i	M3h
16:20	S3d	M1o	M2j	M3i
16:40	S3e	M1r	M2k	M3j
17:00	S3f			

17:00 - 18:00 Round table: HARMONIZATION AND MODERNIZATION OF THE CURRICULUM IN ENGINEERING MECHANICS
17:00-17:15 Katica R. (Stevanović) *Hedrih, Academisian LJUBOMIR KLERIĆ (June 29, 1844- January 21, 1910); Dedicated to Jubilee 175 years from birthday*

18:00 - 19:00 General Assembly Meeting of Serbian Society of Mechanics (*Congress Hall*)

19:00-19:30 W*ine tasting (* winery "Bajilo")

20:00 - 22:30 *Gala Dinner* (*Restaurant Pasent*)

WEDNESDAY, June 26, 2019

Plenary Lecture *(Congress Hall*)

Chairman: HongGuang Sun

9:00 - 9:45 P-5 G. Karanasiou, D. Fotiadis
IN SILICO CLINICAL TRIALS: MULTISCALE MODELS AND STENT INDUSTRY TRANSFORMATION

9:45 - 10:30 P-8 Bojan Medjo et al.
MICROMECHANICAL CRITERIA OF STEEL WELDMENTS DUCTILE FRACTURE

10:30 - 12:10 Parallel Sessions

Session	I1	S4	M2	M5	M5
Hall	*Classroom 1*	*Classroom 2*	*Classroom 24*	*Classroom 25*	
10:30	I1a	S4a	M2l	M5a	10:30
10:50	I1b	S4b	M2m	M5b	11:00
11:10	I1c	S4c	M2n	M5c	11:20
11:30	I1d	S4d	M2o		
11:50	I1e	S4e	M2p		

12:10 - 12:35 *Coffee Break* (*Main Hall*)

12:35 - 12:55 B. Popkonstatinović,N.Mladenović, M.Stojićević, *Faculty of Mech. Eng.,*
Belgrade , Presentation book ESCAPEMENT DYNAMICS AND HOROLOGICAL ERRORS, *(Congress Hall*)

13:00 – 15:00 Parallel Sessions

Session	F1	S5	M2	M5
Hall	*Classroom 1*	*Classroom 2*	*Classroom 24*	*Classroom 25*
13:00	F1a	S5a	M2r	M5d
13:20	F1b	S5b	M2s	M5e
13:40	F1c	S5c	M2t	M5f
14:00			M2u	
14:20			M2v	
14:40			M2z	

15:00 Closing Ceremony (*Congress hall*)

List of Contributions

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G1 *Chairs: Katica R. (Stevanović) Hedrih, Sinisa Dj. Mesarović*

G1a: Katica R. (Stevanović) Hedrih
DYNAMICS OF A ROLLING HEAVY THIN DISK ALONG ROTATE CURVILINEAR TRACE IN VERTICAL PLANE ABOUT VERTICAL AXIS

G1b: Sinisa Dj. Mesarović
LATTICE CONTINUA FOR POLYCRYSTAL GRAINS

G1c: Borislav Gajić, Božidar Jovanović
CONNECTIONS AND CHAPLYGIN REDUCING MULTIPLIER IN CLASSICAL MECHANICS

G1d: Damir Madjarević, Srboljub Simić
ENTROPY GROWTH AND ENTROPY PRODUCTION RATE IN BINARYMIXTURE SHOCK WAVES

G1e: Andrijana A. Đurđević, Aleksandar A. Sedmak, Marko P. Rakin, Nina M. Anđelić,Đorđe D. Đurđević
THERMO MECHANICAL WELDING PROCESS - FRICTION STIR WELDING

G2 *Chairs: Borislav Gajić, Božidar Jovanović*

G2a: Borislav Gajić, Božidar Jovanović
ON TWO INTEGRABLE NONHOLONOMIC ROLLING BALL PROBLEMS

G2b: Dragan Rakić, Miroslav Živković,Milan Bojović
ELASTIC-PLASTIC CONSTITUTIVE MODEL FOR COHESIONLESS GRANULAR MATERIALS

G2c: Sreten Mastilović
SHATTERING IMPACT FRAGMENTATION

G2d**:** Sreten Mastilović
EFFECTS OF LATERAL CONFINEMENT ON PHENOMENOLOGY OF NANO-SCALE IMPACT FRAGMENTATION

G2e: Ivica Čamagić, Dragan Lazarević, Srđan Jović, Dragan Kalaba, Živče Šarkoćević
ASSESSMENT OF THE SAFETY OF WELDED JOINTS FROM THE ASPECT OF THE FRACTURE MECHANICS APPLICATION

G3 *Chairs: Milan Mićunović, Aleksandar Obradović*

G3a: B. Jeremić, R. Radulović, A. Obradović
REALIZING BRACHISTOCHRONIC MOTION OF A VARIABLE MASS BODY BY CENTRODES

G3b: Emina Dzindo, Simon A. Sedmak, Milan Travica
CRACK GROWTH AND FRACTURE OF WELDED STRUCTURE

G3c: Marko D. Topalović, Ljudmila T. Kudrjavceva, Milan V. Mićunović
TEMPERATURE DEPENDENT ELASTO-VISCOPLASTIC MATERIAL MODEL FOR ASPHALT

Mechanics of Solid Bodies (S)

S1 *Chairs: Vladimir Lj. Dunić, Dragan I. Milosavljević*

S1a: Vladimir Lj. Dunić, Miroslav M. Živković, Snežana D. Vulović, Jelena M. Živković, Vladimir P. Milovanović
PENALTY METHOD APPLIED TO STRUCTURAL STRENGTH ASSESSMENT OF THE AXIAL BALL JOINT

S1b:Marija M. Rafailović, Miroslav M. Živković, Jelena M. Živković, Milan Lj. Bojović, Vladimir P. Milovanović
CORRECTION OF THE STRAIN FIELD OF LINEAR TETRAHEDRAL FINITE ELEMENT USING STRAIN SMOOTHING METHOD

S1c: Emilija V. Damnjanović, Miroslav S. Marjanović
THREE-DIMENSIONAL STRESS ANALYSIS OF LAMINATED COMPOSITE PLATES USING FLWT-BASED FINITE ELEMENTS

S1d: Milena N.Rajić,Dragan B. Jovanović, Dragoljub S. Živković
STRESS AND DEFORMATION STATE IN FURNACE TUBE, SMOKE TUBES AND TUBE PLATE OF THE HOT WATER BOILER

S1e: Dragan I. Milosavljević, Žmindák Milan, Aleksandar Radaković
EXTENSIONAL WAVE PROPAGATION IN UNIDIRECTIONAL FIBRE REINFORCED COMPOSITE PLATE

S1f: Nevena A. Aranđelović, Buljak V. Vladimir
FEM ANALYSIS OF CORONARY STENT DEPLOYMENT

S2 *Chairs: Slaviša Šalinić, Vladimir Stojanović,*

S2a: Lidija Z. Rehlicki Lukešević, Marko B. Janev, Branislava B. Novaković, Teodor M. Atanacković
BIFURCATION ANALYSIS FOR A BIMODAL CASE OF A BEAM ON WINKLER FOUNDATION

S2b: Slaviša Šalinić, Aleksandar Nikolić
QUASI-STATIC RESPONSE OF PLANAR PARALLEL-CONNECTION FLEXURE HINGES MECHANISM

S2c: Nikola Despenić, Predrag Kozić
VIBRATION OF A FREE BEAM RESTING ON AN INFINITE KERR TYPE FOUNDATION

S2d: Dragan B. Jovanović
POTENTIAL STRAIN ENERGY SURFACES AT THE CRACK TIP VICINITY

S2e: Vladimir Stojanović, Dunja Milić, Marko D. Petković
STABILIZING EFFECTS OF CURVATURES IN NON-LINEAR VIBRATIONS OF COUPLED STRUCTURES

S2f: Ivan Pavlović, Ratko Pavlović, Predrag Kozić, Goran Janevski, Nikola Despenić
STOCHASTIC STABILITY OF A BEAM ON PASTERNAK VISCOELASTIC FOUNDATION LAYER UNDER WIDEBAND EXCITATION

S3 *Chairs: Zoran Perović, Stanko Ćorić*

S3a: Zoran B. Perović,Dragoslav M. Šumarac, Ivan Milojević
MODEL FOR DAMAGE IN LOW-CYCLE FATIGUE ANALYSIS OF UNIAXIAL STRESS STATE

S3b: Petar R. Knežević, Dragoslav M. Šumarac, Zoran B. Perović, Ćemal Dolićanin, Zijah Burzić
PREISACH MODEL FOR STRUCTURAL MILD STEEL UNDER MONOTONIC AXIAL LOADING

S3c:Svetlana M. Kostić, Biljana Deretić-Stojanović

COMPARISON OF DIFFERENT METHODS FOR VISCOELASTIC ANALYSIS OF COMPOSITE BEAMS

S3d:Stanko Ćorić
STABILITY ANALYSIS OF MULTI-STORY STEEL FRAMES SUBJECTED TO DIFFERENT AXIAL LOAD

S3e: Marija Lazović Radovanović, Biljana Deretić-Stojanović, Jelena Nikolić, Janko Radovanović
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S3f: Marina Ćetković
FINITE ELEMENT MODEL OF IMPERFECT PLATE IN THERMAL ENVIRONMENT

S4 Chairs: *Valentina Golubović-Bugarski, Marko Radišić*

S4a: Miloš Jočković, Gligor Radenković, Marija Nefovska-Danilović
FREE VIBRATION ANALYSIS OF CURVED SPATIAL BEROULLI-EULER BEAM WITH CIRCULAR CROSS SECTION USING ISOGEOMETRIC APPROACH

S4b: A. Borković, G. Radenković, V. Golubović-Bugarski, S. Milovanović, D. Majstorović, O. Mijatović
FREE VIBRATION ANALYSIS OF A CURVED BEAM BY THE ISOGEOMETRIC AND EXPERIMENTAL APPROACH

S4c: Marko Radišić, Emilija Damnjanović, Mira Petronijević
VIBRATIONS OF MASSLESS FLEXIBLE STRIP ON VISCO-ELASTIC HALF-SPACE

S4d: Nevena A. Arandjelović, Mihailo P. Lazarević
COMPARATIVE ANALYSIS OF THE STANDARD LINEAR SOLID MODEL

S4e: Nataša Trišović, Mirjana Misita, Wei Li, Ana Petrović, Zaga Trišović
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S5 Chairs: *Dragan Jovanović, Srđan Jović*

S5a: Marija D. Milojević, Marija T. Nefovska-Danilović, Miroslav S. Marjanović
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S5c: Nikola Nešić, Dragan Jovanović, Goran Janevski, Dušan Stojiljković, Srđan Jović
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Fluid Mechanics (F)

F1 *Chairs: Ivan Kostić, Kristina Kostadinović Vranešević*

F1a: Iva I. Guranov, Snežana S. Milićev, Nevena D. Stevanović
PRESSURE DISTRIBUTION IN MICROTUBES WITH VARIABLE CROSS SECTION

F1b: Kristina Kostadinović Vranešević, Anina Glumac, Ulf Winkelmann
PRESSURE FIELD ANALYSES OF A LOW-RISE BUILDING MODEL SURROUNDED BY NEIGHBOURING BUILDINGS IN URBAN AREAS

F1c: J. Sobot, I. Kostić, O. Kostić
CFD EVALUATION OF TRANSONIC FLOW ANALYSIS AROUND JET TRAINER AIRCRAFT

Control and Robotics (C)

C1 *Chairs: Sreten Stojanović,Jelena Vidaković*

C1.a: Sreten B. Stojanović, Milos M. Stevanović, Milan S. Stojanović,Dragutin LJ. Debeljković
FINITE-TIME STABILITY OF CONTINUOUS-TIME SYSTEMS WITH INTERVAL TIME-VARYING DELAY

C1b: Miloš M. Živanović
CONTINUOUSLY DIFFERENTIABLE VELOCITY CONTROL OF A MECHANICAL SYSTEM BASED ON SECOND-ORDER DECOMPOSITION PRINCIPLE

C1c: Petar D. Mandić, Mihailo P. Lazarević, Tomislav B. Šekara, Marko Č. Bošković, Guido Maione
ROBUST CONTROL OF ROBOT MANIPULATORS USING FRACTIONAL ORDER LAG COMPENSATOR

C1d: Petar D. Mandić, Mihailo P. Lazarević
FRACTIONAL ORDER VISCOUS FRICTION MODEL IN ROBOTIC JOINTS

C1e: Jelena Z. Vidaković, Vladimir M. Kvrgić, Mihailo P. Lazarević, Zoran Z. Dimić
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Interdisciplinary Areas (I)

I1 *Chairs: Miodrag Zigić, Predrag Elek*

I1a: Miodrag Zigić, Nenad Grahovac, Lothar Heinrich
FOUR COMPARTMENT PHARMACOKINETIC MODEL FOR TRANSDERMAL DRUG TRANSPORT

11b: Milica M. Glavšić, Predrag M. Elek
NUMERICAL ANALYSIS OF MINE BLAST ACTION ON A VEHICLE

I1c: J. Sobot, M. Jovanović
ANALYSIS OF THE IMPACT OF AILERON DEFLECTION ON AIRCRAFT SPIN

I1d: O. Ristić, D. Ristić
NUMERICAL CALCULATION OF GRID FINS IN SUBSONIC FLIGHT EGIME

I1e: Nemanja D. Zorić, Radoslav D. Radulović, Vladimir M. Jazarević
DEVELOPMENT OF SMALL ELECTRIC FIXED-WING vtol uav

M1 Minisymposium – Nonlinear dynamics

Organizers: *Katica R. (Stevanović) Hedrih, Ivana Atanasovska*
Mathematical Institute SASA, Belgrade

M1_1 *Chairs: Katica R. (Stevanović) Hedrih, Ivana Atanasovska*

M1p*: Alexander N. Prokopenya (*Invited lecture*)
DYNAMICS OF A BLOCK ON A HORIZONTAL ROUGH PLANE WITH VARIABLE COEFFICIENT OF FRICTION

M1a: Katica R. (Stevanović) Hedrih
DYNAMICS OF A ROLLING HEAVY BALL ALONG CURVILINEAR TRACE IN VERTICAL PLANE

M1b: Georgios Vasileiou
CAN A MODIFIED MATHIEU - DUFFING OSCILLATOR SIMULATE THE DYNAMIC TRANSMISSION ERROR OF A GEAR PAIR?

M1c: M. Minglibayev, A. Prokopenya, O. Baisbayeva
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M1d: Ljubinko B. Kevac, Mirjana M. Filipović, Živko D. Stikić
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M1e: Marina Trajković-Milenković, Otto T. Bruhns
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M1_2 *Chairs: Alexander Prokopenya, Mirjana Filipović*

M1f: Stevan R. Maćešić, Željko D. Čupić, Milorad M. Anđelković, Ana D. Stanojević, Vladimir M. Marković, Ljiljana Z. Kolar-Anić
REACTION PATHWAYS IN A MODEL WITH TWO SOURCES OF THE REACTANT

M1g: Ana Ivanović-Šašić, Željko Čupić, Stevan Maćešić, Ljiljana Kolar-Anić

POSSIBLE DYNAMIC STATES OF THE ACID SOLUTION OF IODIDE AND HYDROGEN PEROXIDE

M1h: Sreten Stojanović, Milos M. Stevanovic, Milan S. Stojanovic, Dragutin LJ. Debeljkovic
FINITE-TIME STABILITY OF DISCRETE-TIME SYSTEMS WITH INTERVAL TIME-VARYING DELAY

M1i: R. Radulović, B. Jeremić, A. Obradović
REALIZATION OF THE BRACHISTOCHRONIC MOTION OF A NONHOLONOMIC VARIABLE MASS MECHANICAL SYSTEM BY IDEAL HOLONOMIC CONSTRAINT

M1j: Mirjana M. Filipović
MATHEMATICAL MODEL OF VIBRATORY CONVEYORS MECHANISM FOR GRANULAR MATERIAL

M1k: Jelena M. Djoković, Ružica R. Nikolić, Saša M. Kalinović, ANALYSIS OF BEHAVIOR OF THE INTERFACE CRACK THAT IS APPROACHING THE THREE-MATERIAL JOINT

M1_3 *Chairs: Ivana Atanasovska, Jelena Đoković*

M1l: Ivana D. Atanasovska, Dejan B. Momcilovic, Snezana D. Vulović
THE INFLUENCE OF GROOVES ON THE BEHAVIOR OF STEEL TUBE SHOCK ABSORBERS

M1m: Danilo Karličić, Milan Cajić, Sondipon Adhikari
BIFURCATION ANALYSIS OF BASE EXCITED HARMONIC OSCILATOR WITH NONLINEAR ENERGY SINK

M1n: Branislav Milenković
MULTIFACTOR ANALYSIS OF DYNAMICS OF THE SLIDER-CRANK MECHANISM

M1o: Đorđe Jovanović
SCIENTIFIC CALCULATION: EXAMPLE OF GRAPHIC REPRESENTATION FOR MAIN FRACTIONAL ORDER MODES OF FRACTIONAL TYPE FORCED VIBRATIONS USING CONVOLUTIONAL INTEGRAL – *student work*

M1r: Stepa M. Paunović
HOLOGRAPHY IN PHOTOELASTICITY – AN OVERVIEW AND A BRIEF REVIEW OF PROF. VLATKO BRČIĆ'S CONTRIBUTION TO THIS FIELD

M2 Minisymposium - Bionegineering

Organizer: *Nenad Filipović,Faculty of Eng., Univer. of Kragujevac, BioIRC,Kragujevac*

M2_1 *Chairs: Nenad Filipović, Gordana Jovičić*

M2a: Aleksandar Milovanović, Igor Saveljić, Nenad Filipović, Slobodan Savić
3D RECONSTRUCTION AND NUMERICAL CALCULATION OF FRACTIONAL FLOW RESERVE IN ATHEROSCLEROTIC CORONARY ARTERIES

M2b: Igor Saveljić, Dalibor Nikolić, Tijana Djukić,Nenad Filipović
NUMERICAL MODEL OF THE BIO MOLECURAL PARAMETERS TRANSFER THROUGH THE CORONARY ARTERY WALL

M2c: Gordana Jovičić, Smiljana Djorović, Arso Vukicević, Nenad Djordjević, Nenad Filipović
INTEGRITY ASSESSMENT of HUMAN MANDIBLE BY USING FAILURE CRITERIA

M2d: Dejan A. Milenković, Ana D. Amić, Zoran S. Marković, Žiko B. Milanović
STRUCTURE AND REACTIVITY OF FOLIC ACID

M2e: Dejan Milenković, Dušan S. Dimić, Jasmina M. Dimitrić-Marković, Zoran S. Marković
THE MECHANISTIC STUDY OF THE HYDROGEN ATOM ABSTRACTION BETWEEN OCTOPAMINE/NOREPINEPHRINE AND DPPH

M2f: Dalibor Nikolić, Igor Saveljić,Nenad Filipović
COMBINING NUMERICAL METHODS AND PARAMETRIC OPTIMIZATION OF STENT DESIGN

M2_2 *Chairs: Miljan Milošević,J elena Đorović*

M2g: Jelena R. Đorović, Svetlana R. Jeremić, Zoran S. Marković, Dušan Dimić, Marijana Stanojević-Pirković
ASSESSMENT THE POTENTIAL OF 1,2,4-TRIHYDROXYXANTHONE TO INHIBIT P-GLYCOPROTEIN

M2h:Jelena R. Đorović, Dejan A. Milenković, Ljubinka G. Joksović, Milan D. Joksović, Zoran S. Marković

PROTEIN-LIGAND INTERACTIONS BETWEEN SELECTED TRIAZOLE COMPOUND AND FAD-LINKED SULFHYDRYL OXIDASE ALR

M2i:Bogdan Milićević, Raffaella Santagiuliana, Miljan Milošević, Vladimir Simić , Bernhard Schrefler, Miloš Kojić
COMPUTATIONAL PROCEDURE FOR COUPLING OF TUMOR GROWTH AND DRUG DISTRIBUTION MODEL

M2j: Miljan Milošević, Dusica Stojanović, Vladimir Simić, Bogdan Milićević, Andjela Radisavljević, Petar Uskoković, Miloš Kojić
NUMERICAL MODELS FOR DRUG RELEASE FROM DRUG-LOADED NANOFIBERS

M2k: Miloš Radović, Arso Vukićević, Alen Zabotti, Vera Milić, Salvatore De Vita, Nenad Filipović
DEEP LEARNING BASED APPROACH FOR THE ASSESSMENT OF PRIMARY SJÖGREN'S SYNDROME FROM SALIVARY GLAND ULTRASONOGRAPHY IMAGES

M2_3 *Chairs: Tijana Djukić, Miljan Milošević*

M2l:Smiljana M. Djorović, Igor B. Saveljić, Nenad D. Filipović,
COMPUTATIONAL MODELLING OF CAROTID ARTERY AND SIMULATION OF PLAQUE PROGRESSION

M2m: Tijana Djukić, Miloš Radović, Danijela Cvetković, Nenad Filipović
NUMERICAL SIMULATION OF THE INFLUENCE OF THE ELECTROMAGNETIC FIELD ON CANCER CELL LINES

M2n: Vladimir Simić, Miljan Milošević, Bogdan Milićević, Miloš Kojić
APPLICATION OF THE CSFE FINITE ELEMENT IN LIVER MODEL WITH TUMORS

M2o:Žiko B. Milanović, Edina H. Avdović, Srećko R. Trifunović, Svetlana R. Jeremić, Zoran S. Marković
INVESTIGATION INTERACTION BETWEEN A PALLADIUM (II) COMPLEXES WITH A COUMARIN LIGANDS AND SUBSTANCE P-RECEPTOR

M2p: Žiko B. Milanović, Edina H. Avdović, Srećko R. Trifunović, Zoran S. Marković

MOLECULAR DOCKING AND MOLECULAR DYNAMIC INVESTIGATION OF INTERACTIONS BETWEEN THYROID HORMONE RECEPTOR ALPHA (TR-ALPHA) AND NEW COUMARINE DERIVATIVES

M2_4 *Chairs: Žarko Milošević,Nenad Filipović*

M2r: Ana Vulović, Milašinović Danko, Dragan Sekulić, Aleksandar Tomić, Nenad Filipović
NUMERICAL ANALYSIS OF BLOOD FLOW IN FEMORAL ARTERIES - PATIENT SPECIFIC CASE

M2s: Vladimir Geroski, Milos Kojić, Miljan Milošević,Vladiimir Simić, Bogdan Milićević, Nenad Filipović
COUPLED ELECTROPHYSIOLOGICAL AND MECHANICAL FINITE ELEMENT MODEL OF THE HEART WALL

M2t: Žarko Milošević, Dalibor Nikolić, Ana Vulović, Nenad Filipović
HOLOGRAM AND AUGMENTED REALITY BIOMECHANICAL MODELS OF A VIRTUAL BALANCE PHYSIOTHERAPIST

M2u: Aleksandra Vulovć, Nenad Filipović
EFFECT OF THE FEMORAL BONE MATERIAL PROPERTIES ON THE NUMERICAL SIMULATION RESULTS

M2v:Tijana Šušteršič, Gorkem Muttalip Simsek, Nihal Engin Vrana, Nenad Filipović
COMPUTATIONAL MODELLING OF CORROSION PROCESS IN MEDICAL IMPLANT SURFACES

M2z: Marko N. Živanović, Dalibor D. Nikolić, Nenad D. Filipović
USE OF POLYETHYLENE GLYCOL AND POLYCAPROLACTONE IN 3D-BIOPRINT SCAFFOLD PRODUCTION

M3 Minisymposium – Turbulence

Organizer: Đorđe Čantrak ,University of Belgrade, Faculty of Mech. Eng.

M3_1 *Chairs: Aleksandar Ćoćić, Dejan Cvetinović*

M3a: Andrea Ianiro, (*Invited lecture*)
SOME THOUGHTS ON THE MEANINGFULNESS OF INSTANTANEOUS HEAT TRANSFER MAPS IN TURBULENT FLOWS

M3b: Đorđe M. Novković, Jela M. Burazer, Aleksandar S. Ćoćić, Milan R. Lečić, IMPLEMENTATION OF HAMBA *k-ε* TURBULENCE MODEL IN OPENFOAM SOFTWARE

M3c: Milan M. Raković, Aleksandar S. Ćoćić, Milan R. Lečić,
NUMERICAL STUDY ON AERODYNAMIC DRAG REDUCTION OF A TRACTOR-TRAILER MODEL

M3d: Jelena Svorcan, Marija Baltić, Toni Ivanov, Ognjen Peković, Milica Milić,
NUMERICAL EVALUATION OF AERODYNAMIC LOADS AND PERFORMANCES OF VERTICAL-AXIS WIND TURBINE ROTOR

M3e: Dejan B. Ilić, Djordje S. Čantrak, Novica Z. Janković, Milan Pajić,
EXPERIMENTAL INVESTIGATIONS OF THE FLOW UNIFORMITY AND JET DEVELOPMENT ON THE FREE JET CALIBRATION WIND TUNNEL

M3_2 *Chairs: Jelena Svorcan, Dejan Ilić*

M3f: Dejan Cvetinović, Rastko Jovanović, Jiří Vejražka, Jaroslav Tihon, Kazuyoshi Nakabe, Kazuya Tatsumi,
MATHEMATICAL MODELLING OF VORTEX STRUCTURES OF THE TURBULENT AXISYMMETRIC AIR JET MODIFIED BY LOW-AMPLITUDE OSCILLATIONS

M3g: Suzana Lj. Linić, Bojana M. Radojković, Marko D. Ristić, Ivana V. Vasović,
ONE METHOD FOR ORDERING TURBULENCE MEASURING PLACES APPLIED TO FREE-CONVECTION FLOW AROUND THERMAL PLANT COAL MILL

M3h: Mohammad Sakib Hasan, Jelena Svorcan, Aleksandar Simonović, David Daou, Bojan Perić,
CFD ANALYSIS OF A HIGH ALTITUDE LONG ENDURANCE UAV WING

M3i: Bojan Perić, Aleksandar Simonović, Aleksandar Kovačević, Dragoljub Tanović, Miloš Vorkapić,
NUMERICAL ANALYSIS OF AERODYNAMIC PERFORMANCE OF OFFSHORE WIND TURBINE

M3j: Jelena T. Ilić, Novica Z. Janković, Slavica S. Ristić, Đorđe S. Čantrak,
UNCERTAINTY ANALYSIS OF 3D LDA SYSTEM

M4: Mini-symposium- Waves and diffusion in complex media

Organizers: *Milan Cajić, Danilo Karličić, MI SASA,Belgrade*
Zhuojia Fu, College of Mech. and Materials, Hohai University, Nanjing,China

M4_1 *Chairs: Trifce Sandev, Zhuojia Fu*

M4a: Zhuojia Fu, Liwen Yang, Qiang Xi
SELF-REGULARIZATION SINGULAR BOUNDARY METHOD FOR WAVE PROPAGATION ANALYSIS UNDER HOMOGENEOUS SOLID CONTAINING MULTIPLE INCLUSIONS

M4b:Ji Lin, Yongxing Hong, Alexander H.-D. Cheng,
A LOCALIZED MESHLESS SCHEME COMBINED WITH ASELF-CORRECTING PREDICTION MODEL TO SIMULATE THERMAL FIELD IN PIPE COOLING CONCRETE STRUCTURE

M4c:Aleksandar Tomović, Slaviša Šalinić, Aleksandar Obradović, Mihailo Lazarević, Zoran Mitrović,
THE EXACT NATURAL FREQUENCY SOLUTION OF A FREE AXIAL-BENDING VIBRATION PROBLEM

M4d:Qiang Xi, Zhuojia Fu, Nikola Spasojević, Dušan Zorica,
FRACTIONAL HEAT CONDUCTION EQUATION ON BOUNDED TWO-DIMENSIONAL DOMAIN

M4e: Milan Cajić, Stepa Paunović, Danilo Karličić, Sondipon Adhikari,
BAND STRUCTURE OF FRACTIONALLY DAMPED PHONONIC CRYSTALS

M4f: Marija Stamenković Atanasov, Vladimir Stojanović,
FORCED VIBRATION OF THE UNDAMPED ROTATING NANOBEAM

M4_2 *Chairs: Ji Lin, Milan Cajić*

M4g: Trifce Sandev, Alexander Lomin, Ljupco Kocarev,
DIFFUSION AND RANDOM SEARCHES ON COMB STRUCTURES

M4h: Qiang Xi, Zhuojia Fu,

INVERSE CAUCHY PROBLEMS OF STEADY HEAT CONDUCTION IN 3D FUNCTIONALLY GRADED MATERIALS BY A SEMI-ANALYTICAL BOUNDARY COLLOCATION SOLVER

M4i:Dongbao Zhou, Yong Zhang, Hongguang Sun,
APPLICATION OF TIME FRACTIONAL MOBILE-IMMOBILE MODEL IN SIMULATING NON-FICKIAN TRANSPORT IN SELF-AFFINE FRACTURES OF A NON-UNIFORM AFG CANTILEVER BEAM WITH A TIP BODY

M4j:Danilo Karličić, Milan Cajić, Stepa Paunović, Sondipon Adhikari,
DYNAMICS OF NONLINEAR VISCO-ELASTIC METASURFACE WITH BOUC-WEN HYSTERESIS

M4k:Stepa Paunović, Milan Cajić, Danilo Karličić,
INFLUENCE OF THE ATTACHED MASSES ON THE DYNAMIC RESPONSE OF A CANTILEVER BEAM UNDER AN IMPULSE SUPPORT MOVEMENT

M4l:Nikola Nešić, Milan Cajić, Danilo Karličić,
FRACTIONALLY DAMPED NONLINEAR PARAMETRIC VIBRATION OF A FUNCTIONALLY GRADED NONLOCAL BEAM

M5 Biomechanics and Mathematical Biology

(*Organizers: Andjelka Hedrih, MI SASA, Belgrade,*
Ricardo Ruiz Baier,MI, Oxford University, UK)

M5_1 *Chairs: Ljiljana Z. Kolar-Anić, Ricardo Ruiz Baier*

M5a: Ricardo Ruiz Baier, Alessio Gizzi, Alessandro Loppini
MODELLING CARDIAC BIOMECHANICS USING STRESS-ASSISTED DIFFUSION AND THERMO-ELECTRIC EFFECTS

M5b: Jochen Mau,
THEORY OF FUNCTIONAL AGING IN HIERARCHICAL DYNAMICS

M5c: Ivana D. Atanasovska, Dušan Šarac, Nenad Mitrović
THE FINITE ELEMENT ANALYSIS OF DENTAL IMPLANT INFLUENCE ON STRAIN STATE IN JAWBONE

M5_2 *Chairs: Jochen Mau***,** *Ivana Atanasovska*

M5d: Željko D. Čupić, Ljiljana Z. Kolar-Anić, Stevan R. Maćešić, Johannes W. Dietrich
ANALYSIS OF COMPLEX STOICHIOMETRIC NETWORKS – hpt AXIS

M5e: Ljiljana Z. Kolar-Anić, Željko D. Čupić, Ana Stanojević, Johannes W. Dietrich
ON THE MODELLING OF COMPLEX NONLINEAR PROCESS: THYROID HORMONE SYNTESIS

M5f: Andjelka N. Hedrih, Katica (Stevanović) Hedrih,
FRACTIONAL ORDER FORCED OSCILLATORY MODES OF ELEMENTS OF THE MITOTIC SPINDLE

M3 Minisymposium – Turbulence

Organizer: Đorđe Čantrak ,University of Belgrade, Faculty of Mech. Eng.

M3a: Andrea Ianiro, (*Invited lecture*)

SOME THOUGHTS ON THE MEANINGFULNESS OF INSTANTANEOUS HEAT TRANSFER MAPS IN TURBULENT FLOWS

This talk will present recent results of our group measuring and analysing instantaneous convective heat transfer maps in turbulent flows. The measurements are based on the use of IR thermography coupled with a heated thin foil heat transfer sensor. The large thermal inertia of heat transfer sensors typically inhibits high quality instantaneous heat transfer measurements. Following seminal work by Nakamura's group (Nakamura, 2009 and Nakamura and Yamada 2013) our group has developed feature-oriented filtering tools enabling high quality instantaneous heat transfer measurements despite the large thermal inertia of the sensor (Raiola et al. 2017).

Recent works employ the instantaneous heat transfer maps for statistical modal analysis, providing insights on the mechanisms underlying turbulent transport (Mallor et al. 2019).

While the design of synchronized flow field and heat transfer measurements presents several complexities -thus explaining the rather limited amount of synchronized flow field and heat transfer measurements- numerical simulations provide instantaneous data over the full flow field. A numerical dataset was thus exploited (Antoranz et al. 2018) to identify the opportunities offered by such experiments, showing the impressive capability of describing complex turbulent transport problems with a limited set of modes.

M3b: Đorđe M. Novković, Jela M. Burazer, Aleksandar S. Ćoćić, Milan R. Lečić,

IMPLEMENTATION OF HAMBA *k-ε* TURBULENCE MODEL IN OPENFOAM SOFTWARE

The paper presents implementation of anisotropic eddy viscosity turbulence model in OpenFOAM software and its usage for numerical calculations of swirling flow in a straight circular pipe. The paper also contains a concise overview of turbulence modeling using RANS turbulence models. Certain advantages and disadvantages of individual RANS turbulence models are presented, with special emphasis on RANS turbulence models with anisotropic turbulent viscosity term in transport equations. From this group of models, the most modern model developed by Fujihiro Hamba has been selected and explained in this paper. This model includes effects of time nonlocal turbulent transport, which has significant influence on swirling flow dynamics. The main principles of coordinate transformation and its usage in the process of this model's implementation in OpenFOAM software has been presented. The computations performed with implemented model confirmed the validity of the exposed model implementation process. The analysis of the obtained results is presented as well.

M3c: Milan M. Raković, Aleksandar S. Ćoćić, Milan R. Lečić,
NUMERICAL STUDY ON AERODYNAMIC DRAG REDUCTION OF A TRACTOR-TRAILER MODEL

Numerical investigation of the flow structure and computations of drag force around Generic Conventional Model (GCM) of tractor-trailer is analyzed in this paper. Starting from original GCM, three additional changes on geometry have been made, and external air flow around all the models has been simulated for four different cruising speeds in open road conditions. OpenFOAM, an open-source CFD software has been used in that purpose, with RANS approach and $k-\omega$ SST model. Results shows reductions in the drag from 17-26% in comparison to the drag of the original model. Obtained results on drag reduction and drag coefficients are in agreement with the results from other authors on similar models of tractor-trailer.

M3d: Jelena Svorcan, Marija Baltić, Toni Ivanov, Ognjen Peković, Milica Milić,
NUMERICAL EVALUATION OF AERODYNAMIC LOADS AND PERFORMANCES OF VERTICAL-AXIS WIND TURBINE ROTOR

Three-dimensional, unsteady, turbulent, incompressible flow simulations of isolated vertical-axis wind turbine (VAWT) high-solidity rotor consisting of three straight blades at seven different operational regimes have been performed in ANSYS FLUENT by finite volume method. Aerodynamic analysis of this type of wind turbine rotors is interesting and extremely complex because the blades pass through a wide range of angles-of-attack during one revolution, and many flow instabilities as well as flow separation occur. Furthermore, the simulation of high-solidity rotors is even more difficult, due to the significant interference between the blades, or more precisely, between the wake of the advancing blade and the retracting blade.
The rotational motion of the blades is solved by the unsteady Sliding Mesh (SM) approach. Flow field is modeled by Unsteady Reynolds Averaged Navier-Stokes (URANS) equations with k-ω SST turbulence model and hybrid Scale-Adaptive Simulation (SAS) used for closure. Quantitative and qualitative examinations of the obtained numerical results are done by comparison to the available wind tunnel data. In particular, aerodynamic loads acting on a blade per revolution as well as power coefficient curves are investigated in detail and comparisons between the two turbulence models are made. Final distinguishing between the simpler and more complex approach to turbulence modeling is made by visualizations of turbulent flow structures separating from the blades throughout a cycle at both non-optimal (starting) and optimal working regimes.

M3e: Dejan B. Ilić, Djordje S. Čantrak, Novica Z. Janković, Milan Pajić,
EXPERIMENTAL INVESTIGATIONS OF THE FLOW UNIFORMITY AND JET DEVELOPMENT ON THE FREE JET CALIBRATION WIND TUNNEL

Results of experimental investigations of the flow uniformity and axisymmetric jet development on the free jet wind calibration tunnel are presented in this paper. At the outlet of calibration tunnel a profiled Witoshinsky nozzle is located, with outlet diameter of D = 145 mm. Flow uniformity measurement for 34 flow regimes was conducted, in the jet cross-

section located at horizontal distance of x = 30 mm from the outlet of the nozzle. Velocity profile measurements were performed with Pitot probes. Based on the measurement results for the calibration tunnel, it can be concluded that flow is uniform to within ± 1 % across the test section with radius of 58-60 mm. In addition, development of the jet in the near-field region ($0 < s/D < 4.828$) is investigated by measurements of mean velocity profile in several streamwise cross-sections for four different regimes. Axisymmetric nature of the jet is proved. It was also shown that velocity profiles in the jet core are uniform, as well as that the jet geometry does not depend on the air flow velocity. This confirms calibration possibilities of this free jet calibration wind tunnel for velocity probes of various types.

M3f: Dejan Cvetinović, Rastko Jovanović, Jiří Vejražka, Jaroslav Tihon, Kazuyoshi Nakabe, Kazuya Tatsumi,

MATHEMATICAL MODELLING OF VORTEX STRUCTURES OF THE TURBULENT AXISYMMETRIC AIR JET MODIFIED BY LOW-AMPLITUDE OSCILLATIONS

Roll-up of the vortex structures can be controlled by adding small amplitude modulation of the nozzle exit velocity by an external source of low-amplitude oscillations or self-sustained oscillations generated in the operation of the specially designed whistler nozzles. The aim of experimental investigations, mathematical modeling and numerical simulations provided during project evaluation is to widely investigate properties and the vortex structures of acoustically modified and not modified jet and to find an efficient way of to control them because they are assumed to have great importance in the heat transfer process.

In the paper are presented results of mathematical modeling and numerical simulation of free and impinging turbulent axisymmetric air jet, not modified and modified by low-amplitude oscillations. Results of mathematical modeling showed good agreement with experimental results that demonstrated the ability to control vortex structures in the jet by sound modulations of the nozzle exit velocity. This study can serve as a base for the development and optimization of the technological processes that involve air jet.

M3g: Suzana Lj. Linić, Bojana M. Radojković, Marko D. Ristić, Ivana V. Vasović,

ONE METHOD FOR ORDERING TURBULENCE MEASURING PLACES APPLIED TO FREE-CONVECTION FLOW AROUND THERMAL PLANT COAL MILL

The investigations of the turbulence in the flow are one of the most expensive, thus the improvement of existing ones and the research related to the new methods are in continual development. The multidisciplinary approach led to the application of the infrared thermography in the turbulent boundary layer observations with the endpoint goal of energy and cost savings in its early stages. This work presents the use of the industrial type infrared thermography for identification of the turbulent zones in the free convective flow, so far the less investigated problem related to convection heat transfer. It was shown that the transient spot temperature difference, measured on the complex geometry of the real-scale coal ventilation mill, of the Thermal plant “Kostolac B”, by an infrared camera, is a good parameter for identification of the most influenced positions by turbulence. The defined fields with maximal transient temperature difference are in accordance with theory and

values calculated by numerical simulations for clean geometry, confirming the assumptions. The described method is also convenient for use in cases when the other methods are not applicable because of the complex geometry, unapproachable, or for the other similar reasons. The results from this work would support the more precise measurements with the research type infrared camera, the other methods for measurements.

M3h: Mohammad Sakib Hasan, Jelena Svorcan, Aleksandar Simonović, David Daou, Bojan Perić,

CFD ANALYSIS OF A HIGH ALTITUDE LONG ENDURANCE UAV WING

The aerodynamic performance of an airfoil provides specific information on wing design of HALE UAV and is considered as eminent for enhancing its flight conditions. In this paper, numerical investigation of a wing is conducted to predict its preliminary aerodynamic quality. A concise comparison of lift and drag curve obtained from numerical analysis conducted in two different programs, will be the scope of this research. Preliminary aerodynamic performance study including 12 different wings were previously performed in Fortran program 'GLAUERT-trapezoidal wing. From those 12 wings, one wing was selected which has the best aerodynamic performance at an operational altitude of 15000 m. Computational fluid dynamic (CFD) software package, ANSYS Fluent is used for numerical analysis of the selected wing. Two different turbulence models were simulated in this work. Lift and drag coefficients were calculated respectively by varying angle of attacks. Hence, the resulted lift and drag curve generated in GLAUERT were compared with those obtained from ANSYS FLUENT. Additionally, other parameters like flow separation, pressure and velocity contours obtained by different turbulent models were also discussed.

M3i: Bojan Perić, Aleksandar Simonović, Aleksandar Kovačević, Dragoljub Tanović, Miloš Vorkapić,

NUMERICAL ANALYSIS OF AERODYNAMIC PERFORMANCE OF OFFSHORE WIND TURBINE

The increasing size of wind turbine blades leads to various flow phenomena which are influenced by aerodynamic design of blade. Detailed information of flow separation and wake development are important for wind turbine blade designers to optimize blade design. In order to obtain detailed information on the flow field, CFD (computational fluid dynamics) modeling is the topic in many research studies.

In this paper aerodynamic analysis of the reference DTU 10 MW HAWT rotor using finite volume method was done. Numerical simulations are realized in a commercial software package ANSYS FLUENT. Flow field is modeled by Reynolds Averaged Navier-Stokes (RANS) equations using transition SST viscous model. The pressure-based SIMPLEC pressure-velocity coupling and 2nd order spatial discretization schemes were used for calculation. Obtained numerical results for mechanical power, power coefficient, thrust, thrust coefficient, pressure coefficient and relative velocity contours at rated wind speed were considered. The results were compared with the reference results and conclusions were derived.

NUMERICAL ANALYSIS OF AERODYNAMIC PERFORMANCE OF OFFSHORE WIND TURBINE

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Abstract:

The increasing size of wind turbine blades leads to various flow phenomena which are influenced by aerodynamic design of blade. Detailed information of flow separation and wake development are important for wind turbine blade designers to optimize blade design. In order to obtain detailed information on the flow field, CFD (computational fluid dynamics) modeling is the topic in many research studies.

In this paper aerodynamic analysis of the reference DTU 10 MW HAWT rotor using finite volume method was done. Numerical simulations are realized in a commercial software package ANSYS FLUENT. Flow field is modeled by Reynolds Averaged Navier-Stokes (RANS) equations using transition SST viscous model. The pressure-based SIMPLEC pressure-velocity coupling and 2nd order spatial discretization schemes were used for calculation. Obtained numerical results for mechanical power, power coefficient, thrust, thrust coefficient, pressure coefficient and relative velocity contours at rated wind speed were considered. The results were compared with the reference results and conclusions were derived.

Key words: HAWT, finite volume method, transition SST model, RANS

1. Introduction

Need for a renewable source of energy has led to the significant development of wind turbines in recent decades. The development of new technologies prompted a new generation of wind turbines with a nominal power of 10 MW. The power of potential wind turbines that are investigated are 10-20 MW [1]. Considering the fact that there is trend to increase the diameter of the wind turbine rotor, calculation of the aerodynamic loads is essential for the structural calculation of the blades as well as for the other components of the wind turbine.

In order to estimate blade aerodynamic characteristics, usually four types of aerodynamic models have been used, i.e. BEM (blade element momentum) model, CFD (computational fluid dynamics), actuator type model and vortex model [2-5].

Due to the complex geometry of modern wind turbine blades, with many flow phenomena, e.g. unsteadiness, dynamic stall, flow separation, etc., flow field is hard to simulate correctly. CFD modeling approach coupled with different viscous models is able to provide high levels of accuracy of final results, as well as various flow visualizations around the blade. Compared to BEM, vortex and actuator type models, CFD model is more computationally demanding. However, given that the other aerodynamic models cannot provide such detailed information on the surrounding flow field, which is very important for wind turbine designers, CFD model applied to DTU 10MW offshore wind turbine blade has been investigated in this study [6, 7]. The obtained numerical results have been compared to data available in [1]. RANS equations governing the rotational flow field were closed by a four-equation transition SST turbulence model [8]. The main goals of the performed study combine the validation of the adopted numerical approach with the investigation of the turbulence effects to wind turbine aerodynamic performances.

2. Transition SST Model

The Transition SST (γ-Re_θ) model is particularly derived for transitional flows. This viscous model is based on the *k-ω* SST model that is coupled with the two other, additional transport equations. One equation refers to the intermittency γ and the other to the transition onset Reynolds number. The initial two equations are similar to the *k-ω* SST model.

The transport equation for the intermittency γ is defined as [8]:

$$\rho\frac{\partial\gamma}{\partial t}+\rho u_j\frac{\partial\gamma}{\partial x_j}=P_{\gamma 1}-E_{\gamma 1}+P_{\gamma 2}-E_{\gamma 2}+\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_\gamma}\right)\frac{\partial\gamma}{\partial x_j}\right], \tag{1}$$

The transition source with:

$$P_{\gamma 1}=C_{a1}F_{length}\rho S\left[\gamma F_{onset}\right]^{c_{\gamma 3}}, \tag{2}$$

$$E_{\gamma 1}=C_{e1}P_{\gamma 1}\gamma, \tag{3}$$

where S is the strain rate magnitude, F_{length} is an empirical correlation that controls the length of the transition region, and C_{a1} and C_{e1} hold the values of 2 and 1, respectively. The destruction/relaminarization sources are defined as follows:

$$P_{\gamma 2}=C_{a2}\rho\Omega\gamma F_{turb}, \tag{4}$$

$$E_{\gamma 2}=C_{e2}P_{\gamma 2}\gamma, \tag{5}$$

The transport equation for the transition momentum thickness Reynolds number $\widetilde{\mathrm{Re}}_{\theta t}$ is:

$$\rho\frac{\partial\widetilde{\mathrm{Re}}_{\theta t}}{\partial t}+\rho u_j\frac{\partial\widetilde{\mathrm{Re}}_{\theta t}}{\partial x_j}=P_{\theta t}+\frac{\partial}{\partial x_j}\left[\sigma_{\theta t}\left(\mu+\mu_t\right)\frac{\partial\widetilde{\mathrm{Re}}_{\theta t}}{\partial x_j}\right], \tag{6}$$

Additional information of transition SST model can be found in ANSYS FLUENT Theory Guide 14.0 [8].

3. Wind turbine model

This section describes the blade of the DTU 10 MW reference wind turbine (Figure 1).

Fig. 1. 3D geometric model of DTU 10MW RWT

DTU 10 MW RWT was designed as part of the Light Rotor project. The focus of the project is to optimize the rotor design in order to increase aerodynamic, aero-servo-elastic and structural characteristics. This turbine is inspired by the NREL 5 MW reference wind turbine and obtained by its up-scaling. The turbine is three-bladed, pitch and speed regulated for offshore sitting with 10 MW rated power. This work investigated aerodynamic performance of stiff structure with a range of wind speeds [5 m/s, 25 m/s]. The main global parameters necessary for blade computation are: collective blade pitch angle [0°, 22.975°], rotor speed [6 rpm, 9.6 rpm] and rotor radius R = 89.15 m. The blade includes six airfoils i.e. FFA-W3-600GF, FFA-W3-480GF, FFA-W3-360, FFA-W3-301, FFA-W3-241 and NACA 0015 close to the tip of the blade [1].

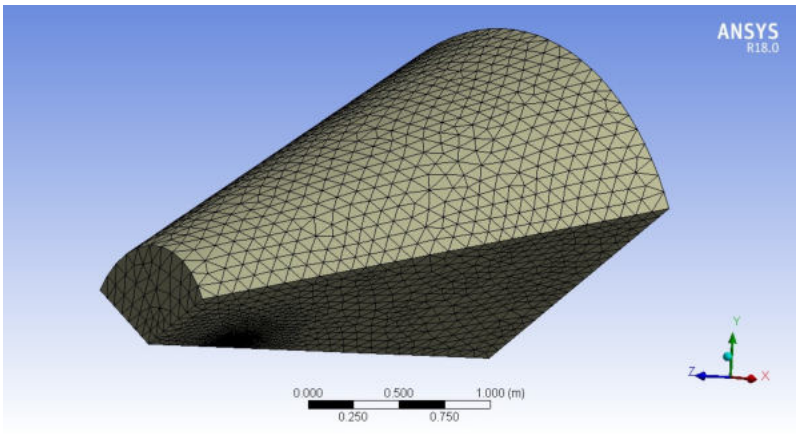
4. Numerical method

4.1 Geometry description

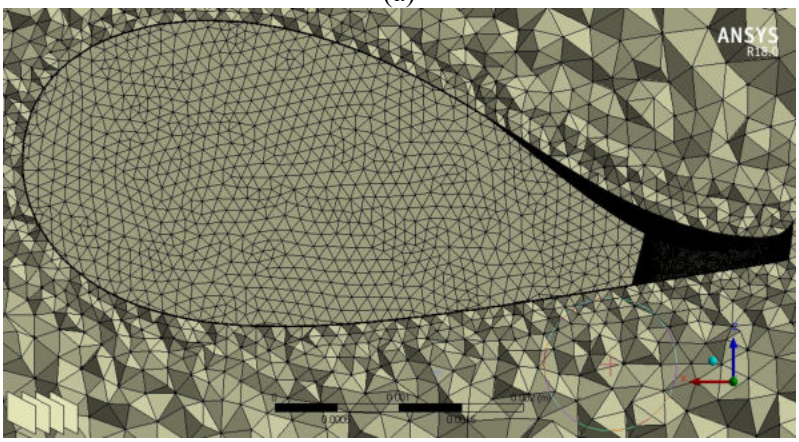
Computational domain was defined as a 120° radial stream tube segment around a single blade. Fluid domain is modeled as a 1/3 rotational frustum. The smaller, top base with a 6R radius is located 6R upstream from the blade, while the outlet, greater base with a 20R radius is placed 20R downstream from the blade.

4.2 Grid generation

After an appropriate grid convergence study the final computational mesh was adopted. It is hybrid unstructured and contains approximately 8.2 million cells, Figure 2. Twenty layers of prismatic cells surrounding the blade surface were generated for better calculation accuracy. Non-dimensional wall distance y^+ is less than 5. In order to additionally refine the mesh, a spherical zone of 1.3R diameter is defined around the blade.



(a)



(b)

Fig. 2. (a) Computational mesh; (b) mesh around a cross-sectional airfoil

4.3 Numerical setting and boundary conditions

Numerical simulations were performed in ANSYS Fluent v16.2. Reynolds-averaged Navier-Stokes equations were closed by the transition SST viscous model (four-equation γ-Re_θ model). Air (fluid) was considered as incompressible gas of constant dynamic viscosity. The imposed zonal and boundary conditions are:

- the rotational effects in the form of additional terms in the equations are considered in the whole computational domain (steady *Frame of Reference* computational approach),
- wind velocity and corresponding turbulent quantities are assigned to the two inlet (frontal and outer) surfaces,
- pressure equaling atmospheric is defined along the outlet surface,
- two lateral/longitudinal faces form a periodic interface, and
- wind turbine blade surface is considered as no-slip rotating wall.

Frame motion (angular velocity) is applied to the whole computational domain. Three parameters are set, wind speed V_0 = 11 m/s, rotor rotational speed ω = 8.836 rpm and pitch angle θ_0 = 0°. Pressure-based SIMPLEC pressure-velocity coupling is used for solving the flow

equations. Spatial discretization schemes are of 2nd order. Computations were performed until reaching converged values of power and thrust coefficients, between 1500 and 3000 iterations.

5. Numerical results and discussion

Computed numerical results of the DTU 10MW RWT blade are compared to available nominal (up-scaled) values. Obtained power, thrust force, power coefficient, thrust coefficient curves as functions of wind speed and tip-speed ratio as well as relative velocity contours and chordwise pressure coefficient are illustrated in Figures 3, 4 and 5. Tested numerical settings produce good matching with reference results. Numerical results obtained by transition SST can be considered satisfactory.

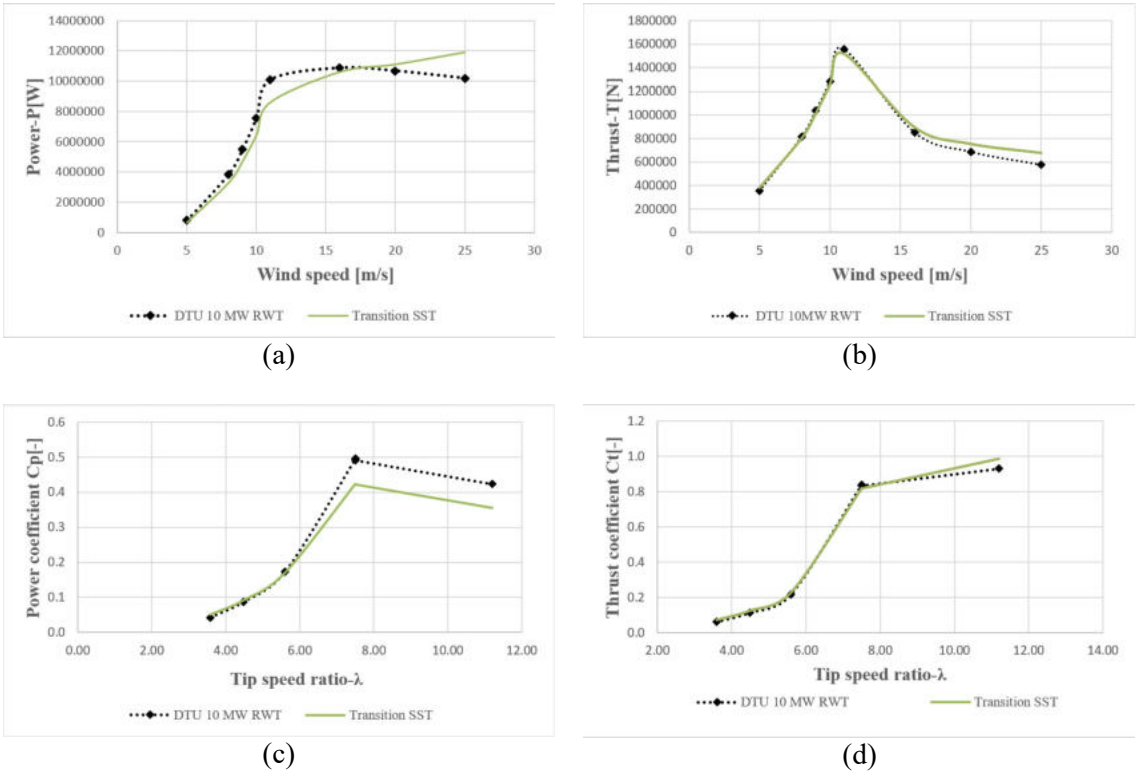


Fig. 3. (a) Comparison of the computed mechanical power P as function of wind speed V_0 to the nominal values of the blade, (b) Comparison of the computed thrust force T as function of wind speed V_0 to the nominal values of the blade, (c) Comparison of the computed power coefficient Cp as function of tip-speed ratio λ to the nominal values of the blade, (d) Comparison of the computed thrust coefficient Ct as function of tip speed ratio λ to the nominal values of the blade

Considering the presented power and power coefficient curves, it can be concluded that CFD model provides accurate results for lower wind speeds [5 m/s, 10 m/s] while thrust force and thrust coefficient curves can be considered satisfactory.

General conclusion on the applicability of the considered computational approach with respect to tip-speed ratio λ presented in Figure 3(c) and 3(d) show that optimal working regime corresponds to $\lambda \approx 7$. Tested numerical model reproduces well the trends of the coefficient curves. As expected, taking into account the significantly increased computational time, the advantage of

the RANS approach closed with transition SST model allows widened range of wind speeds at which the rotor flow can be simulated.

In order to visualize the field of relative velocity around the blade, seven different cross sections are defined. Cross sections located along the blade at relative longitudinal coordinate x/R = [0.33, 0.44, 0.55, 0.66, 0.77, 0.88, 0.94] are chosen for illustration.

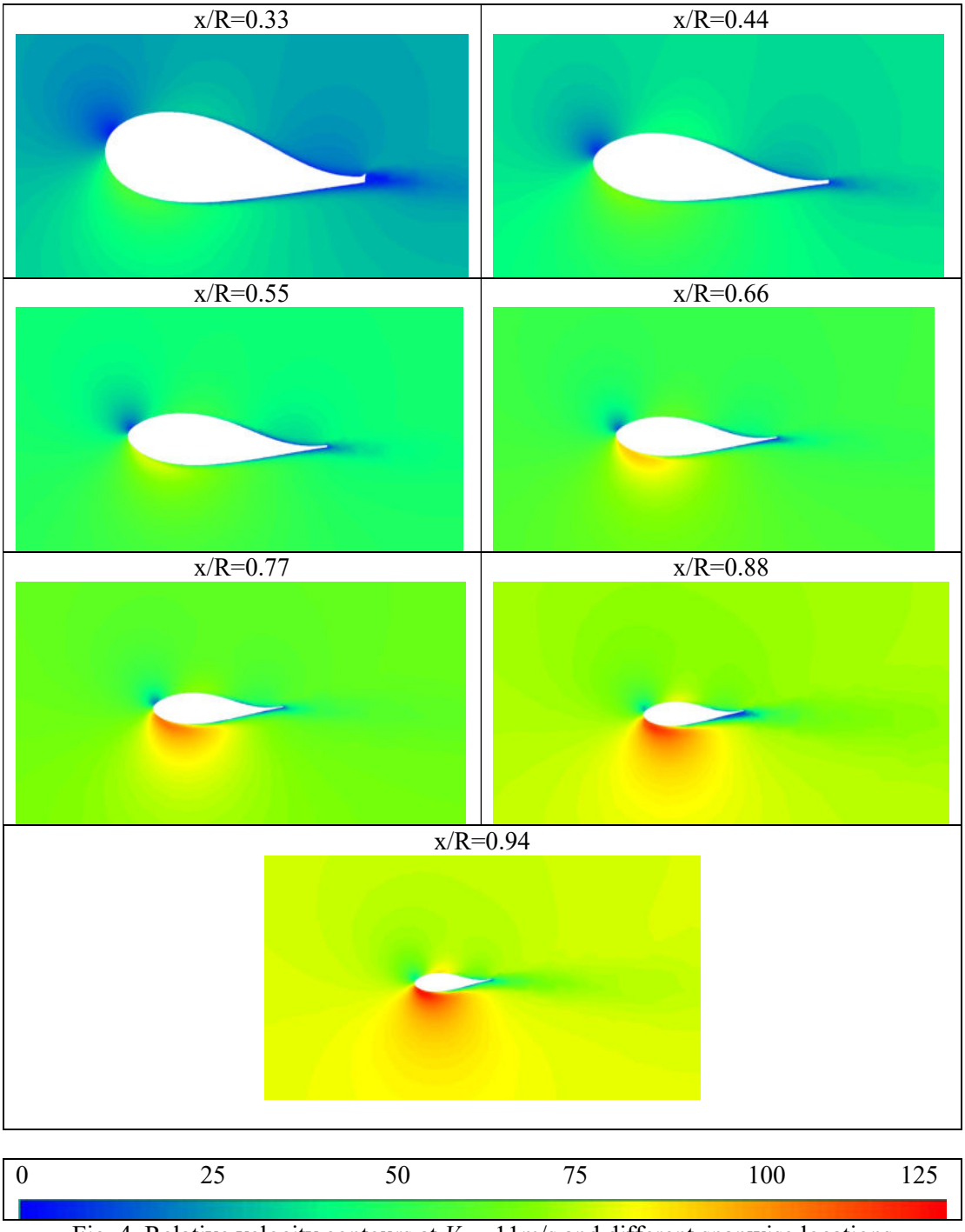


Fig. 4. Relative velocity contours at V_0 = 11m/s and different spanwise locations

Relative velocity around the blade at V_0 = 11 m/s is displayed in Figure 4. The range of velocity contour goes from 0 [m/s] to 125 [m/s]. Figure 4 shows that the relative velocity increases along the blade as well as blade twist. As expected, in the rated operational regime no significant flow separation or vortex shedding occurs. However, the situation changes at lower and higher values of wind speeds which can also be observed by the discrepancies of the computed and expected, nominal values of global parameters presented in Fig. 3.

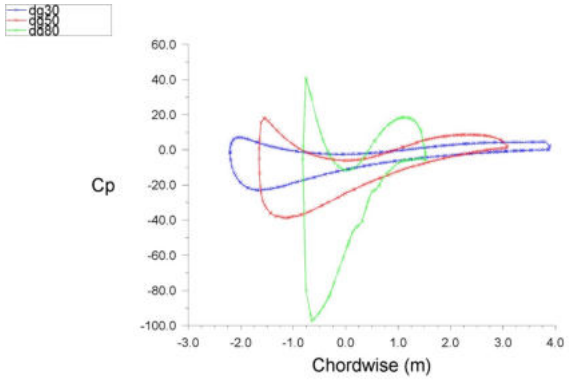


Fig. 5 Chordwise pressure coefficient at three different spanwise locations at V_0 = 11m/s

The pressure coefficient distributions along three representative sections/airfoils are presented in Figure 5. Cross-sections are located at 30 m, 50 m and 80 m measuring from the blade root. As expected pressure coefficient values are nearly 1 in the vicinity of the leading edge (stagnation point). The flow quickly accelerates along the upper surface of the blade (pressure coefficient decreasing), and then slowly decelerates towards the trailing edge (pressure coefficient increasing). Apart from the fact that different cross-sections operate in quite different working conditions (i.e velocity triangles), different airfoils applied along the blade also demonstrate somewhat different aerodynamic behavior.

6. Conclusions

Aerodynamic performances of a representative off-shore wind turbine rotor are estimated by CFD approach using transition SST turbulence model and a comparison between the obtained and available, nominal results is made.

As generally recognized, frame of reference approach has the advantage of a much shorter computational time. Results show very good matching with nominal values of the blade. The presented methodology could be used for initial performance estimation. The transition SST model employed in this numerical approach is important for accurate prediction of aerodynamic performances of wind turbine blade as it matches satisfactorily to the nominal values. Rated wind speed (around 11 m/s) obtained by computation corresponds to the reference value.

It was demonstrated that this numerical approach can be used in preliminary design phases since it can provide results of 10% accuracy. Regardless of the blade scales and Reynolds numbers, CFD approach enables performing simulations of improved precision for an extended range of wind speeds (up-to 20 m/s) compared to other simpler computational approaches. Furthermore, solving the complete flow field permits deeper analyses of local flow features, especially at non-nominal operating conditions, thus enabling the design of a more efficient wind turbine blade. For these purposes, a quasi-steady approach closed by transition SST turbulence model presents a satisfactory tool.

Acknowledgement

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