Abstracts and Program Book

1st Russia-Japan Joint Workshop on Composite Materials

日露複合材料ワークショップ 2019

October 31 - November 1, 2019

Lomonosov Moscow State University

Co-organized by

Lomonosov Moscow State University, Russia

Lomonosov Moscow State University

JSMS Committee on Composite Materials (JCOM), Japan

CREATION WITH COMPOSITES

JSME Materials and Processing Division, Japan

Supported by The Kyoto University Foundation

Company Sponsor: KURIMOTO, Anisoprint

Workshop Chair (Russia)

Prof. E.V. Lomakin

Lomonosov Moscow State University

Workshop Chair (Japan)

Prof. K. Nishiyabu

Kindai University, JCOM Chair

Message

It is a great pleasure to announce the first Russia-Japan Joint Workshop on Composite Materials to be held in Moscow, Russia on October 31st and November 1st, 2019. The goal of the workshop is to provide new opportunities for increasing mutual exchange of cutting-edge research outputs in the composite field among academic researchers of Russia and Japan. The workshop addresses the recent advances of composites science and technology. Let's enjoy the workshop and build a good relationship between Russia and Japan!

Workshop is organized by

Workshop Chair

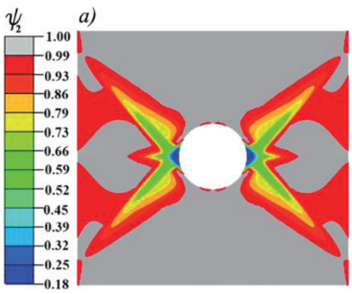
- E. V. Lomakin, Lomonosov Moscow State University, Russia
- K. Nishiyabu, Kindai University, Japan

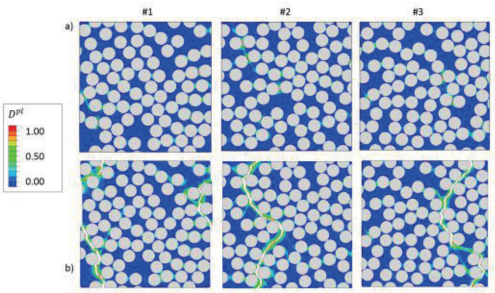
Organizing Committee

- E. V. Lomakin, Lomonosov Moscow State University, Russia
- B. N. Fedulov, Lomonosov Moscow State University, Russia
- K. Nishiyabu, Kindai University, Japan (JCOM, Chair)
- M. Nishikawa, Kyoto University, Japan

Workshop Advisory Members

- A. Hosoi, Waseda University, Japan (JSME M&P, Manager)
- R. Matsuzaki, Tokyo University of Science, Japan
- S. Minakuchi, The University of Tokyo, Japan
- H. Nakatani, Osaka City University, Japan
- J. Noda, Kindai University, Japan (JCOM, Manager)
- K. Obunai, Doshisha University, Japan
- S. Ogihara, Tokyo University of Science, Japan (JSME M&P, Chair)
- D. Tanabe, National Inst. of Tech., Wakayama College, Japan
- M. Ueda, Nihon University, Japan
- S. Yashiro, Kyushu University, Japan
- T. Yokozeki, The University of Tokyo, Japan
- A. Yoshimura, Nagoya University, Japan





Keynote Lecture 1

Prof. B.N. Fedulov

Lomonosov Moscow State University,

Faculty of Mechanics and Mathematics

Title: Nonlinear deformation effects of composite materials and their implementation into engineering practice

Keynote Lecture 2

<u>Prof. V. V. Vasiliev</u> *and Dr. A.F. Razin*

Central Research Institute
for Special Machinery (CRISM)

Title: Anisogrid composite lattice structures
for aerospace applications

Website: http://www.tsniism.ru/en/

The Central Research Institute for Special Machinery, Joint Stock Company (CRISM JSC) founded in 1963 in Khotkovo and reorganized into a joint stock company in 1993 is a leading Russian enterprise in design and production of structures on the basis of advanced polymer composite materials for rocket & space engineering, transport, power, petrochemical machinery and other industries. **(*Cited from the website)**

Keynote Lecture 3

Prof. T. Aoki

The University of Tokyo,
Department of Aeronautics
and Astronautics

東京大学大学院工学系研究科
航空宇宙工学専攻

Website: http://www.aerospace.t.u-tokyo.ac.jp/english/index.html

Title: Challenges to the Improvements of Mechanical Capabilities of Lattice Structures

Keynote Lecture 4

Prof. M. Hojo

Kyoto University,
Department of Mechanical
Engineering and Science

京都大学
KYOTO UNIVERSITY

Website: https://www.me.t.kyoto-u.ac.jp/en

Title: In-situ high-resolution microscopic characterization on mode II fatigue delamination in CFRP laminates

Invited Lecture 1

Prof. Vladimir P. Vavilov

School of Nondestructive Testing, National Research Tomsk Polytechnic University

Website: https://tpu.ru/en

Title: Infrared thermographic nondestructive testing of composites: Short history, state-of-the-art and trends

Vladimir Vavilov Short CV

Vladimir Vavilov graduated and received his PhD degree from Tomsk Polytechnic University (TPU), Russia, City of Tomsk. Presently, he works as a full professor and head of Thermal Testing laboratory at TPU. For many years, Vavilov has been collaborating with many world research teams in the area of infrared thermographic nondestructive testing (NDT). He has co-authored over 300 papers and 16 books and holds over 30 patents. Vavilov is a co-editor of two international and three national journals and a member of the ISO technical group. He is Level III in thermal NDT and has delivered IR thermography training courses in a number of countries. Vavilov is a vice-president of Russian NDT Society and Russian Federation Science Prize Winner.

Invited Lecture 2

Mr. Anatoly Gaydanskiy
General Director of JSC "AeroComposit"

Anatoly Gaydanskiy is the General Director of JSC "AeroComposit", which is known for building a composite wing for the short/medium range MC-21 civil transport aircraft. The company specializes in manufacturing of primary composite structures installed in the aircraft wing, using the vacuum infusion method. He will visit our workshop and make a presentation on the experience of composite materials applications in aircraft building.

Title: Applications of polymer composite materials in MC-21-300 project

1. Automatic layup of dry carbon tape: difficult issues of in-production implementation. Methods and solutions of the manufacturing task.

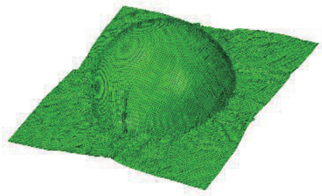
2. Technology of manufacturing long-size highly integral structures.

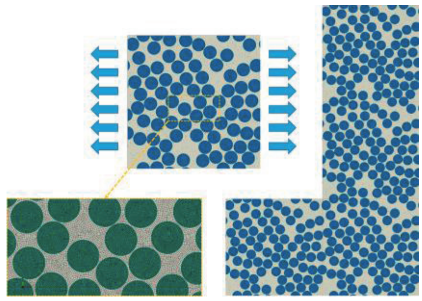
3. Hot forming of stringers with complex geometry.

Address: Moscow, Leningradsky Prospekt 47, bld.2, ent.2
tel.:+7(495) 940-87-10; **fax:** +7(495) 940-87-11

Workshop Topics (not limited to the following)

- Composites for aerospace and automotives
- Mechanics of composite materials and structures
- Experiments, micromechanics, damage mechanics
- Novel materials, process, structure design
- Manufacturing of composite materials and structures
- Process modeling and optimization
- Multiscale and multiphysics





Other JCOM Activities

- Japan Conference on Composite Materials (JCCM)

JCCM is the largest conference on composite materials in Japan, and the conferences have been co-organized by JCOM and Japan Society for Composite Materials (JSCM) since 2010. The 11th conference will be held on March 17-19, 2020 in Osaka University (Nakanoshima Center).

- Future Generation Symposium on Composite Materials

Future Generation Symposium on Composite Materials 2019 organized by JCOM was held as the 10th memorial international symposium on August 26-27, 2019. The 11th symposium will be planned next year.

- International Conference on Green Composites (ICGC)

JCOM has organized international workshops on green composites since 2002 and it has played leading roles on the researches on a wide variety of green composites. The 11th conference is under planning.

- Composite Symposium for Automotive Applications

The 11th Composite Symposium for Automotive Applications will be held on November 15, 2019, in Doshisha University.

- Asian-Australasian Conference on Composite Materials (ACCM)

The 12th Asian-Australasian Conference on Composite Materials (ACCM-12) will be held in China next year.

Venue: Lomonosov Moscow State University

Main Building

Faculty of Mechanics & Mathematics

119991, Leninskiye Gory, MSU, Moscow, Russia

MSU website: http://www.math.msu.su/

Workshop Secretariat (Russian side):

B. N. Fedulov, Lomonosov Moscow State University

Email address: fedulov.b@mail.ru

Workshop Secretariat (Japanese side):

M. Nishikawa, Kyoto University

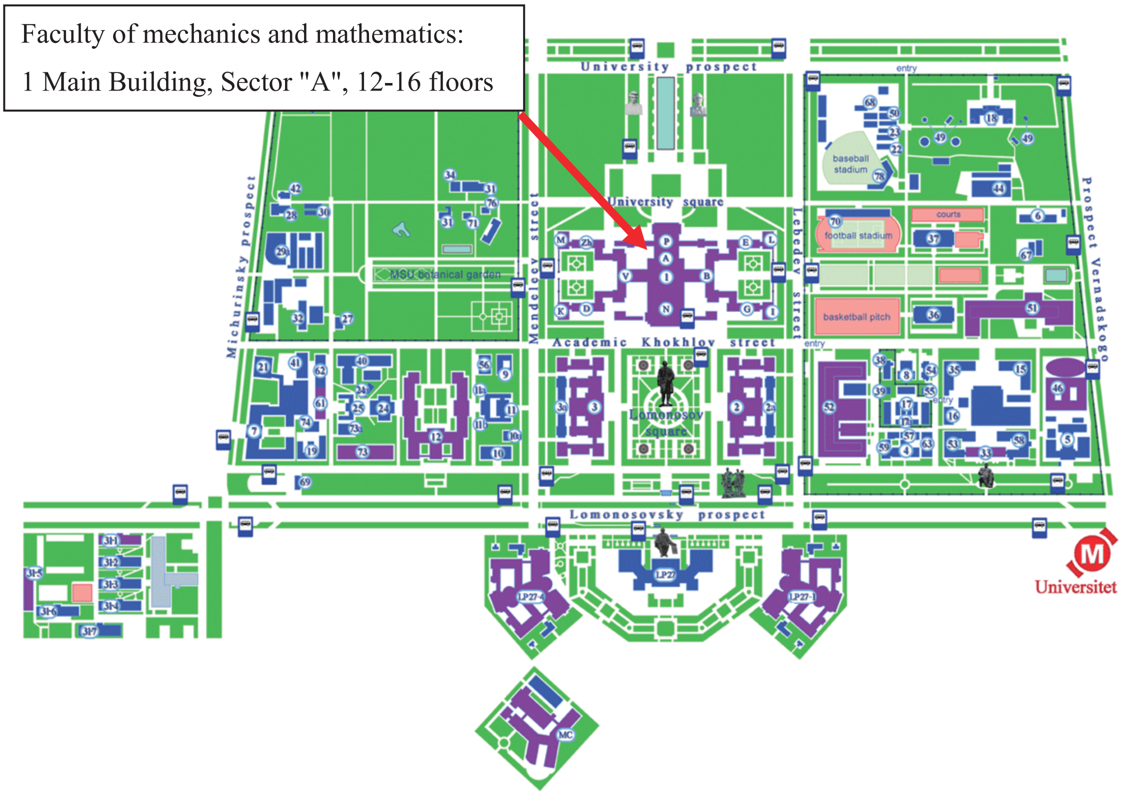
Email address: nishikawa@me.kyoto-u.ac.jp

Workshop Venue

Faculty of Mechanics and Mathematics

MSU, Faculty of Mechanics and Mathematics, Russia, 119991, Moscow,
GSP-1, 1 Leninskiye Gory, Main Building
Telephone (495) 939-12-44
Fax (495) 939-20-90
WWW http://www.math.msu.su/
E-mail mmmf@mech.math.msu.su

Venue Map



Workshop Dinner

Workshop dinner will be scheduled on October 31, 2019.

Information

Extended Abstracts of
1st Russia-Japan Joint Workshop
on Composite Materials
日露複合材料ワークショップ 2019

Extended Abstracts Download

User: user

Pass: cSIRIKw0#Y

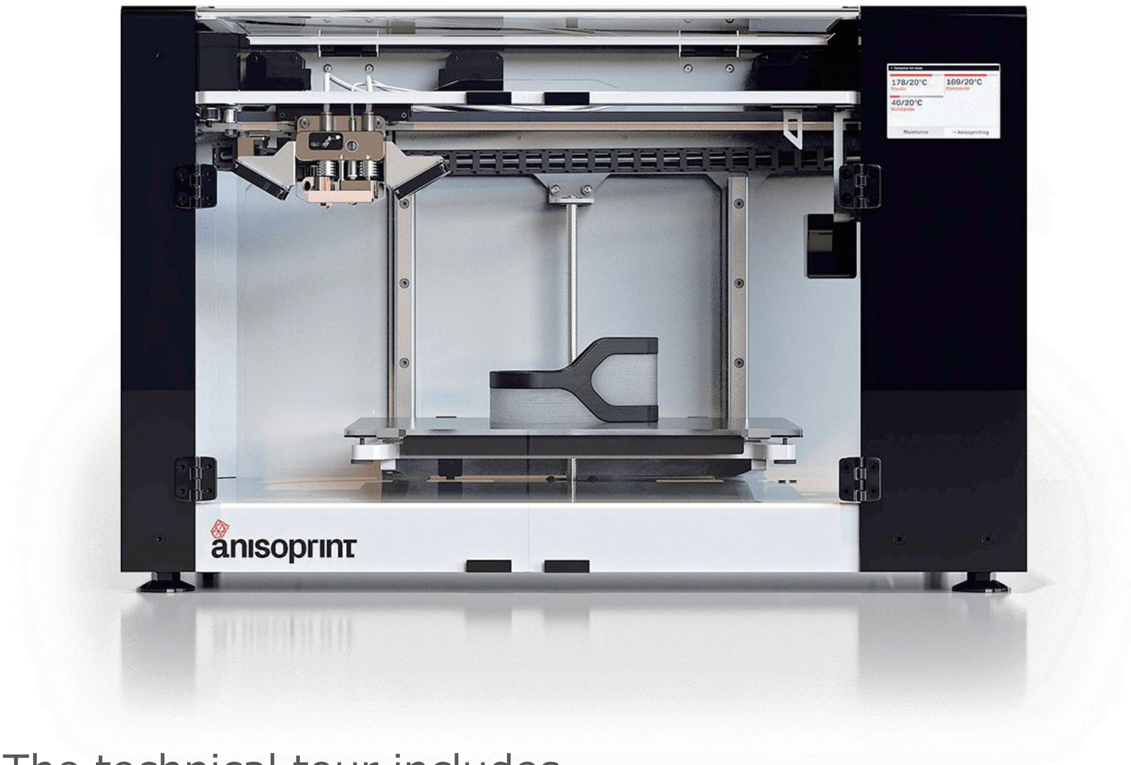
You can download at

http://ams.me.kyoto-u.ac.jp/workshop/

Russia-Japan/download.html

Technical Tour (Day 2: November 1, 2019)

Anisoprint @Skolkovo Innovation Center



The technical tour includes

- Anisoprinting technology presentation

- 3D printer Composer A4 demonstration

Invited lectures from Anisoprint:

- Dr. Aleksey Khaziev, "Anisoprinting - Design and Manufacturing of New Generation Composite Structures"

- Ms. Tatiana Latysheva, "Structural and Topology Optimization of 3D Printed Composite Parts"

Tour Location: Skolkovo Innovation Center

(Cited from Skolkovo IC web: https://www.skolcity.ru/en/location/)

Anisoprint Website: http://anisoprint.ru/

<u>Representative office (sales and support)</u>

Anisoprint LLC
143026, Bolshoi bulvar 42-1,
Skolkovo innovation center, Moscow, Russia
+7 (495) 142-57-31, info@anisoprint.com

Case — Anisoprint, 2019

STAMP FOR HELICOPTER FACTORY

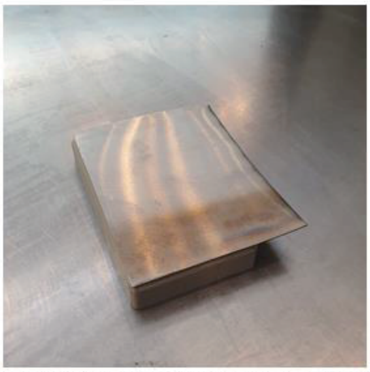
4X lower price, higher durability

Goal:
make a die for sheet metal forming that bears 400 bar pressure

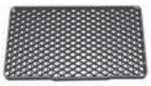
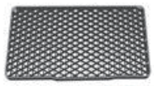
Helicopter factory needs a mold for sheet metal forming. The die must bear 400 bar pressure.

Plywood's — traditional material — lifespan is too short. The metal die would work longer but costs significantly more. The best option to extend a lifespan and reduce costs is to print a die with continuous composite fiber on an Anisoprint Composer 3D printer.

Anisoprinting technology reduces costs 2-4 times while raising durability.



Anisoprinting is the technology for design and production of optimal composite structures through composite fiber co-extrusion. Thermoplastic polymers are reinforced with continuous fibers, consolidated and cured within a single-stage fully automated process, with no post-processing required. The inner part of the fixture has lattice (isogrid) structure: during printing, fibers are layed up along the loading direction to achieve the best combination of strength and weight.

	 ULTEM (high performance plastic)	 PETG + CCF (plastic + composite carbon fiber)	 PETG + CBF (plastic + composite basalt fiber)
Pressure 400 bar	100% plastic infill — STRENGTH LIMIT	30% composite isogrid infill — INCREASE STRENGTH BY RAISING INFILL DENSITY	30% composite isogrid infill — INCREASE STRENGTH BY RAISING INFILL DENSITY
Price	€300	€150	€80

anisoprint

anisoprint.com

Website Links

- Lomonosov Moscow State University
http://www.math.msu.su/
- JSMS Committee on Composite Materials (JCOM)
http://compo.jsms.jp/index-e.html
- JSME Materials and Processing Division
http://compo.jsms.jp/index-e.html
- The Kyoto University Foundation
http://www.kyodai-zaidan.or.jp/

- AeroComposit
http://aerocomposit.ru/
- Anisoprint
http://anisoprint.ru/
- The Central Aerohydrodynamic Institute named after N.E. Zhukovsky (TsAGI)
http://www.tsagi.com/
- Central Research Institute for Special Machinery (CRISM)
http://www.tsniism.ru/en/
- National Research Tomsk Polytechnic University
https://tpu.ru/en

- Kindai University
https://www.kindai.ac.jp/english/
- Kyoto University
https://www.kyoto-u.ac.jp/en/
- The University of Tokyo
https://www.u-tokyo.ac.jp/en/index.html
- Doshisha University
https://www.doshisha.ac.jp/en/index.html
- National Institute of Tech., Wakayama College
https://www.wakayama-nct.ac.jp/English/
- Osaka City University
https://www.osaka-cu.ac.jp/en
- Shinshu University
https://www.shinshu-u.ac.jp/english/
- Waseda University
https://www.waseda.jp/top/en
- KURIMOTO, LTD.
https://www.kurimoto.co.jp/composite/

Registration

Registration Fee

	Registration Fee (including workshop dinner)	Registration Fee (without workshop dinner)
Early Registration (General) (No later than August 2)	6000 RUB	3000 RUB
Late/On-site Registration (General)	8000 RUB	5000 RUB
Student Registration	3000 RUB	1500 RUB

Recommended Hotel Information

Hotel 1: Korston Hotel Moscow

35 min walk (or by GUP Mosgortrans bus) to Lomonosov Moscow State University

[ADD] 15 Kosygina Street, Moscow, 119334, Russia

[TEL] 7-495-9398000 [FAX] 7-495-9398008

Hotel 2: Hotel Universitetskaya

20 min walk to Lomonosov Moscow State University

[ADD] 8/29 Michurinskiy Prospekt, Moscow, 119192, Russia

[TEL] 7--4991472062

Hotel 3: Hotel Sputnik

45 min walk (or by GUP Mosgortrans bus) to Lomonosov Moscow State University

[ADD] Leninsky Prospekt 38, Moscow, 119334, Russia

[TEL] 7-495-9303097 [FAX] 7-495-9301988

Participants List (scheduled)

Russian Participants

E.V. Lomakin	Lomonosov Moscow State University
B.N. Fedulov	Lomonosov Moscow State University
K.A. Khvostunkov	Lomonosov Moscow State University
A.N. Sakharov	Lomonosov Moscow State University
S.V. Sheshenin	Lomonosov Moscow State University
I. Faskheev	Lomonosov Moscow State University
E. Sharaborin	Lomonosov Moscow State University
E.D. Martynova	Lomonosov Moscow State University
T.A. Beliakova	Lomonosov Moscow State University
A. Gaydanskiy	AeroComposit
A. Khaziev	Anisoprint
T. Latysheva	Anisoprint
S. Dubinskii	The Central Aerohydrodynamic Institute named after N.E. Zhukovsky (TsAGI)
V.V. Vasiliev	Central Research Institute for Special Machinery (CRISM)
V.P. Vavilov	National Research Tomsk Polytechnic University

Japanese Participants

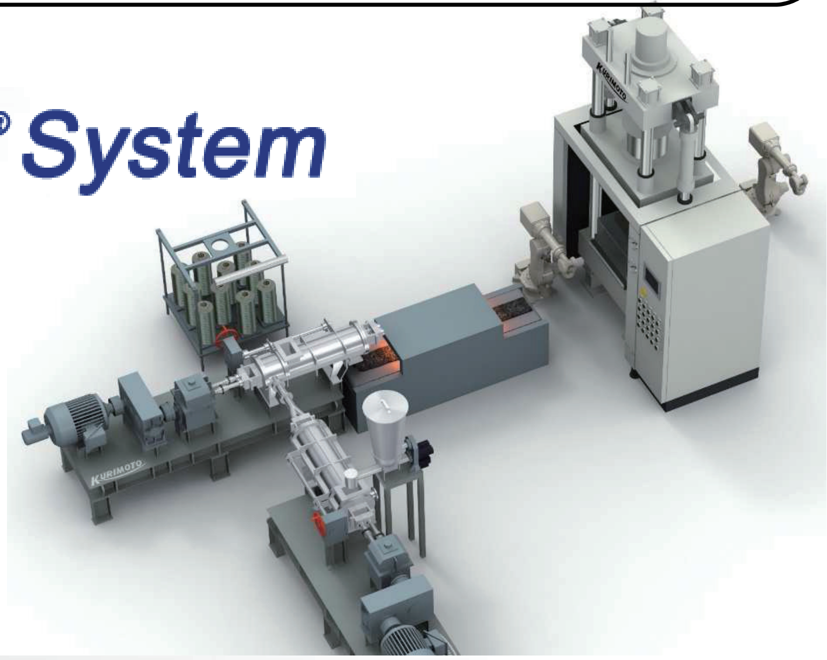
K. Nishiyabu	Kindai University
J. Noda	Kindai University
Y. Kataie	Kindai University (Graduate Student)
M. Hojo	Kyoto University
M. Nishikawa	Kyoto University
Y. Abo	Kyoto University (Graduate Student)
T. Aoki	The University of Tokyo
S. Minakuchi	The University of Tokyo
R. Higuchi	The University of Tokyo
K. Obunai	Doshisha University
D. Tanabe	National Institute of Tech., Wakayama College
H. Nakatani	Osaka City University
Q.-Q. Ni	Shinshu University
N. Hisaji	Waseda University (Graduate Student)
K. Saito	Waseda University (Graduate Student)
M. Suzuki	Waseda University (Graduate Student)
T. Fukui	KURIMOTO, LTD.

KURIMOTO

Company Sponsor: KURIMOTO, LTD. (Japan)

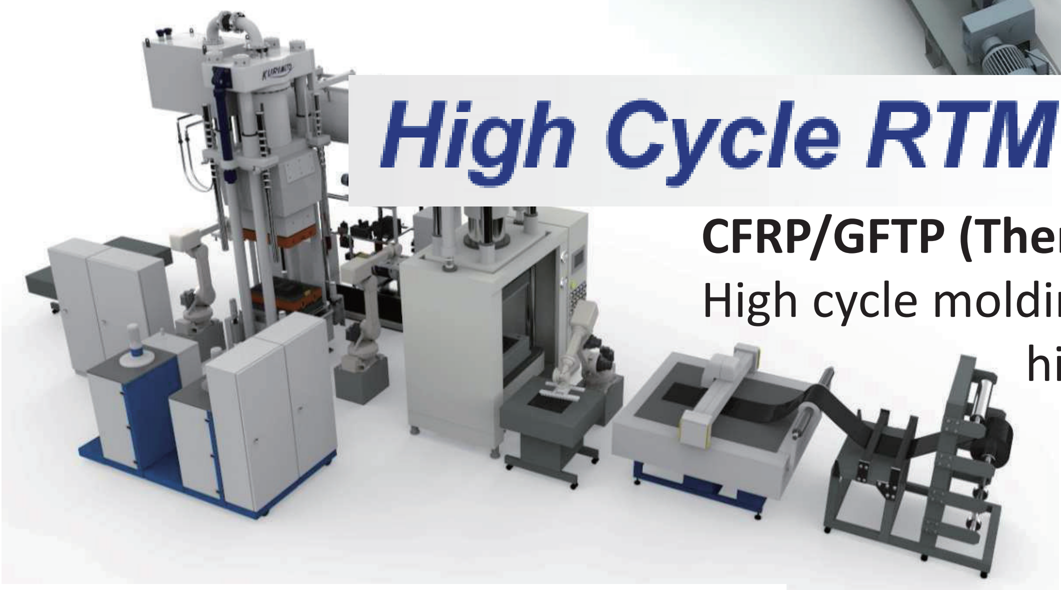
Guest Speaker: *Executive Officer*
General Manager of Composite Project Div.
Takehisa Fukui (Workshop dinner, Day 1)

Carbon-LFTD® System



CFRTP/GFRTP
Long fiber thermoplastic direct molding process

High Cycle RTM System



CFRP/GFTP (Thermoset)
High cycle molding process for high quality FRP

Composite center

Demonstration Plant
In Shiga Japan

Website: https://www.kurimoto.co.jp/composite/

Day 1(Oct 31)

Time	Title	Presenter	Affiliation
8:00	Bus from Korston Hotel to Moscow State Univ.		
8:30	**Registration**		
9:00	**Opening remarks** (**Prof. Lomakin** (Lomonosov Moscow State Univ.) and **Prof. Nishiyabu** (Kindai Univ., JCOM chair))		
9:15-9:55 (40min)	**Keynote Lecture 1 (Russia):** Nonlinear deformation effects of composite materials and their implementation into engineering practice	**Boris Fedulov**	Lomonosov Moscow State University
9:55-10:25 (30min)	**Keynote Lecture 2 (Japan):** In-situ high-resolution microscopic characterization on mode II fatigue delamination in CFRP laminates	**Masaki Hojo** (1), Yu Adachi (2), Aya Mamishin (1), Rikuo Somiya (1), Narumichi Sato (2), Naoki Matsuda (1), Masaaki Nishikawa (1), Manato Kanesaki (3)	(1) Dept. Mechanical Engineering and Science, Kyoto University, Japan (2) Toray Industries, Inc., Japan (3) Dept. System Engineering, Okayama Prefectural University, Japan
10:25-10:40	Break		
10:40-11:00	**Invited Speaker 1(Russia):** The Evaluation of Damage Tolerance Criteria for Composite Airframe	**Stanislav Dubinskii** (1), Yuri Feygenbaum (2)	(1) The Central Aerohydrodynamic Institute named after N.E. Zhukovsky (TsAGI) (2) The State Scientific Research Institute of Civil Aviation (GosNII GA)
11:00-11:20	**Invited Speaker 2(Russia):** Effect of the Component Properties on the Creep Life Prediction of Composites	**Khvostunkov K.A.**, Telicin D.P., Kiiko V.M., Korzhov V.P.	Faculty of Mechanics and Mathematics, Lomonosov Moscow State University Institute of Solid State Physics RAS
11:20-11:40	**Invited Speaker 3(Japan):** Multi joining technology for advanced thermoplastic composites manufacturing	**Daiki Tanabe** (1), Kazuaki Nishiyabu (2)	(1) Intelligent Mechanical Engineering, National Institute of Tech., Wakayama (2) Faculty of Science and Engineering, Kindai University
11:40-12:00	**Invited Speaker 4(Japan):** Approaches to damage modeling for advanced composite materials and structures based on peridynamics	**Masaaki Nishikawa**, Naoki Matsuda, Masaki Hojo	Department of Mechanical Engineering and Science, Kyoto University
12:00-13:00	Lunch		
13:00-13:40 (40min)	**Keynote Lecture 3 (Russia):** Anisogrid composite lattice structures for aerospace applications	**V. V. Vasiliev**, A.F. Razin	Central Research Institute for Special Machinery (CRISM)
13:40-14:20 (40min)	**Keynote Lecture 4 (Japan):** Challenges to the Improvements of Mechanical Capabilities of Lattice Structures	**Takahira Aoki** (1), Tomohiro Yokozeki (1), Atsushi Shitanaka (2) and Fukunin Tou	Department of Aeronautics and Astronautics, University of Tokyo
14:20-14:40	Break (Research Introduction)		

Day 1（Oct 31）

Time	Title	Presenter	Affiliation
14:40-15:20 (40min)	**Invited Lecture 1 (Russia):** Infrared Thermographic Nondestructive Testing of Composites: Short History, State-of-the-Art and Trends	**Vladimir P. Vavilov**	School of Nondestructive Testing, National Research Tomsk Polytechnic University
15:20-16:00 (40min)	**Invited Lecture 2 (Russia):** Applications of polymer composite materials in MC-21-300 project	**Anatoly Gaydanskiy**	General Director of JSC "AeroComposit"
16:00-16:10	Break		
16:10-16:30	**Invited Speaker 5(Russia):** Rubber-cord modeling: Moment Properties, Moderately Large Strains and Energy Loss	**S.V. Sheshenin**	Lomonosov Moscow State University, Faculty of Mechanics and Mathematics
16:30-16:50	**Invited Speaker 6(Japan):** Multiscale damage analysis of thin-ply composite laminates	**Ryo Higuchi**, Ryoma Aoki, Tomohiro Yokozeki	Department of Aeronautics and Astronautics. The University of Tokyo
16:50-17:10	**Student Speaker 1(Japan):** Effects of molecular weight of matrix resin on tensile and fiber/resin interfacial properties of continuous fiber reinforced composites with in-situ polymerized phenoxy resin	**Megumi SUZUKI** (1), Masafumi MIYATA (1), Masahito FUJIMOTO (1), Kazuya ETO (2), Tetsuya SUGIYAMA (2), Akihiro NISHINO (2), Toshiaki MIYANAGA (2), Atsushi HOSOI (1),(3), Hiroyuki KAWADA (1),(3)	(1) School of Fundamental Science and Engineering, Waseda University (2) NIPPON STEEL Chemical & Material Co., Ltd. (3) Kagami Memorial Research Institute for Materials Science and Technology, Waseda University
17:10-17:30	**Student Speaker 2(Japan):** The effect of nano-structured surface of aluminum alloy directly bonded to CFRTP on fatigue delamination growth	**Kei SAITO** (1), Kristine Munk JESPERSEN (2), Hiroki OTA (1), Keita WADA (1), Kazuki OKAMOTO (1), Atsushi HOSOI (3),(4),(5) and Hiroyuki KAWADA (3),(4),(5)	(1) Department of Applied Mechanics, Waseda University (2) Kanagawa Institute of Industrial Science and Technology (3) Department of Applied Mechanics and Aerospace Engineering, Waseda University (4) Department of Materials Science, Waseda University (5) Kagami Memorial Research Institute for Materials Science and Technology, Waseda University
17:30-17:50	**Invited Speaker 7(Russia):** Simulation of porous two-phase media	**Igor Faskheev**	Faculty of Mechanics and Mathematics, Lomonosov Moscow State University
17:50-18:10	**Invited Speaker 8(Japan):** Ply curving termination: suppressing delamination in composite ply drop-off	**Shu Minakuchi**, Nobuo Takeda	The Graduate School of Engineering, Department of Aeronautics and Astronautics, The University of Tokyo
18:45	To the workshop dinner		
19:30-21:30	**Workshop dinner (Guest Speaker: T. Fukui, KURIMOTO)**		
22:00	To Korston Hotel Moscow		

Day 2(Nov 1)

Time	Title	Presenter	Affiliation
7:00	Bus from Korston Hotel to Moscow State Univ.		
7:45	**Registration**		
8:00-8:20	**Student Speaker 3(Russia):** Multiscale modeling of viscous flow in a porous medium	**Evgenii Sharaborin**, Aslan Kasimov	Center for Design, Manufacturing and Materials Skolkovo Institute of Science and Technology
8:20-8:40	**Student Speaker 4(Russia):** Determination of parameters values in the models of microstructure evolution under superplastic deformation conditions	**T.A. Beliakova**, I.A. Goncharov	Faculty of Mechanics and Mathematics, Lomonosov Moscow State University
8:40-9:00	**Student Speaker 5(Russia):** Determination of the averaged characteristics of periodic elastic frames	**E.D.Martynova**	Faculty of Mechanics and Mathematics, Lomonosov Moscow State University
9:00-9:20	**Invited Speaker 9(Russia):** Dilatancy Effect in Solid Mechanics	**Sakharov A.N.**	Faculty of Mechanics and Mathematics, Lomonosov Moscow State University
9:20-9:40	**Invited Speaker 10(Japan):** Effect of Cellulose Nano Fiber Addition on Fatigue Properties of Carbon Fiber Reinforced Plastics	**Kiyotaka OBUNAI** (1), Kazuya OKUBO (2) and Kenta HAYASHI (1)	(1) Faculty of Science and Engineering, Doshisha University (2) Graduate School of Science and Engineering, Doshisha University
9:40-10:00	**Invited Speaker 11(Japan):** Estimation of R-curve for mode II interlaminar fracture toughness from tensile strength of CFRP laminates with fiber discontinuities	**H. Nakatani**, T. Warabino, and K. Osaka	Department of Mechanical & Physical Engineering, Osaka City University
10:00-10:20	**Invited Speaker 12(Japan):** Development of Tsunami shelter structure using green composites	**Junji Noda**, Taisei Yamanaka and Takahiro Miyamoto	Faculty of biology-oriented science and technology, Kindai University
10:20-10:30	Break		
10:30-11:00 (30min)	**Invited Lecture 3(Russia):** Anisoprinting - Design and Manufacturing of New Generation Composite Structures	**Aleksey Khaziev**	Chief Researcher, Anisoprint
11:00-11:30 (30min)	**Invited Lecture 4(Russia):** Structural and Topology Optimization of 3D Printed Composite Parts	**Tatiana Latysheva**	Anisoprint
11:30-11:40	Break		

Day 2(Nov 1)

Time	Title	Presenter	Affiliation
11:40-12:00	**Invited Speaker 13(Japan):** Characterizations and Applications of Nanocarbon Materials for Electromagnetic Shielding	**Qing-Qing Ni**, Hong Xia	Dept of Mechanical Engineering & Robotics, Shinshu University
12:00-12:20	**Student Speaker 6(Japan):** Twist measurements under tensile loading for anti-symmetric CFRP laminates	**Yuko Kataie** (1), Junji Noda (2), Satoshi Bando (2)	(1) Graduate school of biology-oriented science and technology, Kindai University (2) Faculty of biology-oriented science and technology, Kindai University
12:20-12:40	**Student Speaker 7(Japan):** Selection of synthesis conditions for improving mechanical properties of untwisted CNT yarn	**Naruki HISAJI** (1), Kazuyoshi SOGO (1), Kouichi OKUMO (1), Kazuhiko TAKAHASHI (2) , Keiichi SHIRASU (3), Atsushi HOSOI (1),(4) and Hiroyuki KAWADA (1),(4)	(1) School of Fundamental Science and Engineering, Waseda University (2) Toyota Motor Corporation (3) Fracture and Reliability Research Institute, Tohoku University (Now at National Institute for Materials Science) (4) Kagami Memorial Research Institute for Materials Science and Technology, Waseda University
12:40-13:00	**Student Speaker 8(Japan):** Experimental evaluation of formability in preforming process using CFRTP preforms	**Y. Abo** (1), Y. Tanaka (1), M. Nishikawa (1), M. Iwashita (2), K. Yamada (2), K. Kawabe (2), M. Nishi (3), N. Matsuda (1), M. Hojo (1)	(1) Department of Mechanical Engineering and Science, Kyoto University (2) Industrial Technology Center of Fukui Prefecture (3) JSOL Corporation
13:00	**Closing Remark**		
13:15	Bus to the technical tour		

Technical tour (Skolkovo Innovation Center)

14:00	Lunch		
15:00	**Welcome talk**	Fedor Antonov	CEO, anisoprint
	Anisoprinting technology presentation		
	3D printer Composer A4 demonstration		
17:00	**Closing remark of technical tour**		
17:30	Bus to Korston Hotel Moscow		

Optional event(Social dinner fee is not included in the registration fee)

18:30	**Social dinner in Korston Hotel Moscow**

Nonlinear deformation effects of composite materials and their implementation into engineering practice

Boris Fedulov
Faculty of Mechanics and Mathematics, Lomonosov Moscow State University

Abstract

In the analysis of complex heterogeneous materials, structural composites, which are increasingly used in industry, occupy a special place.

Analysis of the strength characteristics of products made from such kind of materials, it is necessary to take into account almost the entire history of the development of the part, from the method of placement of reinforcing fibers, to a complete analysis of the temperature regime of curing. The process of positioning reinforcing elements affects both the strength and stiffness characteristics of the future product. The cooling mode, as well as the nature of the placement of the reinforcing elements, affects the degree of shrinkage of the material, which in turn leads to warpage of the product and the appearance of residual stresses. It is worth noting that not only shrinkage, as a consequence of temperature changes in volume, is important, but also shrinkage associated with the ongoing chemical reactions and internal structural changes in the material. In this case, a change in the phase state leads to curing, that is, to a change in the stiffness of the material, which, as a result, affects the values of residual stresses in the produced detail. Thus, the task of analyzing the strength of a composite material becomes related to the analysis of its manufacture, which includes many factors.

Considering composites based on polymer matrices, one can distinguish thermoset and thermoplastic classes of such materials. In the first case, the process of phase transformation is associated with polymerization, in the second, with crystallization of the matrix. There are more scientific studies on modeling the placement of reinforcing elements in the form of prepregs, dry preforms, or filling molds with a matrix filled with chopped fiber, than for thermoplastic analogues. However, a general approach to modeling this process, satisfying most reinforcement options, has not been developed. From the point of view of phase transition and modeling the kinetics of polymerization and crystallization of polymers, there are more or less established models. A significant problem lies in the next step -- the assessment of the strength of the manufactured composite, both under conditions of subsequent

operation, and at the stage of predicting defects or the formation of defects in the process, for example, the technological step of cooling the material.

This research discusses the approach to assessing the strength of products made from composite materials, including the modeling of the process and following of all the transition parameters or the necessary process steps. The discussed approach allows us to evaluate the strength and stiffness of the final product, as well as the possible nucleation of defects in the manufacturing process.

In-situ high-resolution microscopic characterization on mode II fatigue delamination in CFRP laminates

Masaki Hojo[1,*], Yu Adachi[1], Aya Mamishin[1], Rikuo Somiya[1], Narumichi Sato[2], Naoki Matsuda[1], Masaaki Nishikawa[1] and Manato Kanesaki[3]

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Abstract

Interlaminar fatigue crack propagation behavior under mode II loading was investigated in detail by using 3-point End Notched Flexure tests. In situ fatigue experiments (1Hz) using high-resolution optical microscope were carried out to characterize the micromechanisms of fatigue delamination. Fatigue tests were carried out by controlling the maximum energy release rate using computer-controlled systems. Figure 1 indicates an example of in-situ high-resolution microscopic observation. The in-situ observations showed fiber de-bonding (micro-delamination) ahead of the main crack tip, creating a preferential damage path, followed by resin damage (microcrack and plastic deformation) near the fiber/resin de-bonding due to stress concentration. Then, the critical mechanism of fatigue crack growth for the present laminates is probably the fiber/resin de-bonding. Ex situ fatigue experiments (10Hz) using optical microscopy, scanning electron microscopy and X-ray CT were also carried out to evaluate the micromechanisms from various viewpoints and at different crack propagation rates. The observed crack propagation mechanisms agreed with those of in-situ tests. Comparison with other laminates indicates that the relative contribution of fiber/resin interface and resin strengths strongly affects the fatigue delamination micromechanisms.

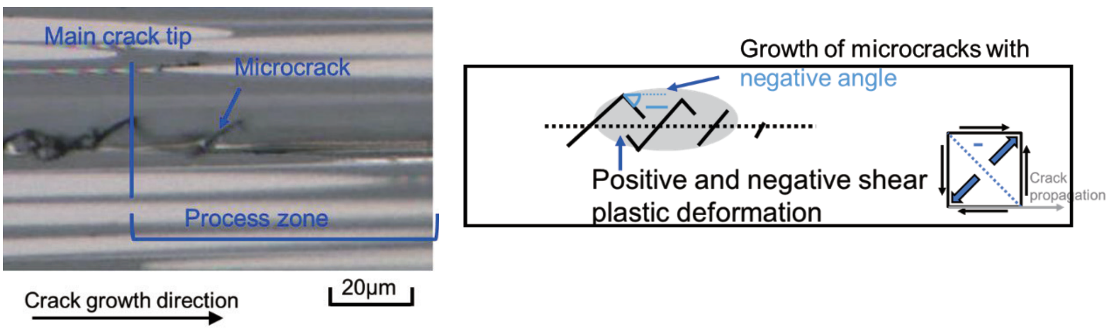

Fig. 1. In-situ observation of side surface. 1Hz, da/dN=10-6 m/cycle, Δa=700 cycle.

The Evaluation of Damage Tolerance Criteria for Composite Airframe

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Abstract

A major safety challenge known for composite aircraft is the problem of internal delaminations, occurring mostly due to accidental impacts in operation. To mitigate the related threats it is accepted by aircraft manufacturers, that any impact damage in the composite structure either should be detected or should not reduce the structural strength below ultimate load capability. Because of the risk to miss hidden damage during inspection, the energy metrics along with detectability metrics has to be introduced into the composite damage tolerance approach. That means that damage is to be determined by two criteria: threshold of detectability, (e.g. Barely Visible Impact Damage or BVID) and realistic cut-off energy, whichever comes first.

The series of experimental and analytical studies to identify and prove the adequate levels for those two criteria with account for local operating conditions and service experience were conducted.

For BVID evaluation the visual tests to understand how inspection conditions and service factors affect the detectability during standard field control procedures were performed. The probability of surface damage detection as a function of damage size was experimentally evaluated on representative structures in relation to qualification of inspectors, paint color, viewing distance and surface contamination. The significance of those factors for BVID criteria was estimated by non-parametric methods of mathematical statistics.

For estimation of cut-off energy the local field data characterizing aircraft accidental in-service damage was collected, sorted and processed. The typical scenarios were identified and the qualitative distribution of impact intensities was obtained. Using the original analytical method, the metal dent sizes were converted into energies and energy probabilistic distributions were established. It was shown that the relationships generated on domestic data are consistent with similar foreign results obtained on considerably different aircrafts. Along with realistic impact damage scenarios, the high energy impact events were considered.

Effect of the Component Properties on the Creep Life Prediction of Composites

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Abstract

The failure time coincides with the time when the measure of damage achieves its maximum. The kinetic equation governing the measure of damage is obtained on the basis of the dissipation potential which, in its turn, depends on some energy variable associated with the measure of damage. This energy variable depends on the thermodynamic potential that occurs in the local energy-balance equation and the Clausius-Duhem inequality. The failure time is determined by the energy dissipation due to the breakdown of the interface and the friction resulting from the discontinuity of the interface displacement field.

This contribution aims at developing an analytical model for durability of a three-component anisotropic media. The model is supposed to provide an insight into the relationship between the properties of the interface and durability of composite materials in the presence of creeping and under complex loading in the interface zone.

Multi joining technology for advanced thermoplastic composites manufacturing

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Abstract

Carbon fiber reinforced thermoplastic (CFRTP) composites can be manufactured by press-forming, hybrid injection molding and auto tape laying are attracting attention recently in aircraft and automobile applications. However, CFRTP components have rather simple geometry due to the limited deformation allowed for the reinforcing fibers and high viscosity of thermoplastics. Thus, continuous molding technology and joining technology are necessary for the manufacturing process of CFRTP structures. Moreover, Multi-material design which manufactures a structural member using not only CFRP but also metal or a plastic is required.

Our research group aims to develop the manufacturing process and advanced joining process of continuous carbon fiber reinforced thermoplastics (CFRTP). Specifically, Auto Tape Laying (ATL) and continuous laminate molding process for the flat plate and elongated pipe using various heating sources have been studied. In addition, our group have been developed a new pultrusion machine using unidirectional carbon fiber reinforced thermoplastic tapes for grid structure and mechanical fastening application.

The joining methods of thermoplastic composites can be divided into several methods such as mechanical fastening, adhesive bonding and welding. However, the mechanical fastening method using metallic rivet and metallic bolt has some disadvantages such as stress concentrations, gain of weight, galvanic corrosion and so on. Adhesive bonding method is also difficult to bond chemically between thermoplastic polymers. In our research group, a lightweight rivet fastener is proposed to manufacture using unidirectional CFRTP rod as a substitute for metallic rivet fastener, and several welding methods for CFRTP such as ultrasonic welding, resistance welding and induction welding have also been studied. The purpose of this study is to introduce on our work.

Approaches to damage modeling for advanced composite materials and structures based on peridynamics

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Abstract

We introduce and review our numerical approaches based on peridynamcis to the damage modeling for advanced composite materials and structures. Peridynamics is a physical approach to modeling the damage in solid materials proposed by Dr. Silling. The deformation and fracture of the materials can be addressed through the motions of many particles and the breakage of the bonds between the particles. Peridynamics can deal with the damage at an arbitrary path in composites, similarly to particle-based simulation methods. In addition, the main advantage of the peridynamics is that it can consider the energy-based criterion based on the fracture mechanics approach, and that it defines the constitutive law of the bonds, which is similar to cohesive zone modeling. Our previous study discussed the effectiveness of applying the peridynamics model to the damage in composites with curvilinear fiber reinforcement. Then we also applied to multi-ply laminated composites, and discussed the effectiveness of the peridynamics simulation to reproduce the multiple-type, multiple-site damage in composite laminates with arbitrary fiber orientations. Finally, we attempted to deal with the relation between the processing and properties of the composites by combination with the process simulation considering the manufacturing process. The approach was based on an integrated framework combining a damage simulation and a preforming simulation to predict the manufactured fiber orientations. Here the peridynamics were applied to modeling the impact-induced damage of AP-PLY (Advanced Placed Ply) composites, also called as Pseudo Woven Laminate, and enabled by the latest layup automation techniques (Automated Fiber Placement, AFP). We demonstrated that the peridynamics approach is effective for modeling arbitrary fiber orientations and complicated damage patterns in composites, considering the manufactured fiber orientations.

Anisogrid composite lattice structures for aerospace applications

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Abstract

The presentation is an overview of CRISM experience in development and application of Anisogrid (Anisotropic Grid) composite lattice structures. Anisogrid structures have the form of cylindrical (in general, not circular) or conical shells and consist of a dense system of unidirectional composite helical, hoop and axial ribs made by automatic continuous wet filament winding. Anisogrid structures are characterized by high weight and cost efficiency provided by high specific strength and stiffness of unidirectional composite ribs which are the basic load-carrying elements of the structure and by automatic winding process resulting in low-cost integral structures. Anisogrid structures proposed about forty years ago are under serial production in CRISM which developes and fabricates lattice interstages for space launchers, payload attach fittings (adapters) and space platforms for Russian space programs. Anisogrid structures provide promising design concept for commercial airplanes fuselage and wing structures. The following particular problems are discussed in the presentation in application to Anisogrid structures:

- the basic design idea and the history of lattice structures,
- fabrication processes,
- design and analysis method,
- test methods and mechanical properties,
- application to interstage structures and adapters,
- application to spacecraft structures,
- application to aircraft structures.

The presentation is illustrated with numerous pictures demonstrating real full-scale Anisogrid composite lattice structures.

Challenges to the Improvements of Mechanical Capabilities of Lattice Structures

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Abstract

Lattice- or grid- structures for aerospace applications are well suited to be made of unidirectional fiber composites, the combination of which will fully utilize the advantages of both the structure and the material. In this overviewing paper, the attempts to improve the mechanical performances of the conventional lattice structure carried out by the authors' group are presented.

The main focus is to strengthen the cylindrical structure against the compressive buckling behavior. One of the challenges is to eliminate the circumferential ribs from the conventional lattice configuration, reducing the total number of rib intersections. To replace the function of circumferential ribs, thin skin is added to the structure. This idea is based on the findings through the group's preliminary study indicating that the rib intersections are the critical points from load carrying as well as manufacturing aspects. Further attempts are sought to completely remove these intersections by introducing the bonded type lattice-like configuration. The results from analytical and experimental investigations show that these challenges are well effective.

Another major approach of improving the mechanical capabilities is to alter the overall shape from the cylinder to the bulged- or hourglass-type modified cylinders. Though the existing studies indicated that the hourglass modification improved the buckling strength of the homogeneous shell cylinders, adopting the bulged shape combined with the bonded-type lattice exhibited the superior results through analyses.

The combinations of the improvements described here may be the candidate ways of enhancing the mechanical performance of lattice structures.

Infrared thermographic nondestructive testing of composites: Short history, state-of-the-art and trends

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Abstract

Our industrial world has experienced a revolution in material science in aerospace and other hi-tech industries for several years. Metal structures, which were subject to corrosion and fatigue damage are now being made of composites and ceramics. The importance of Infrared Thermographic Nondestructive Testing (IRTNDT) greatly increased in the last decade due to its effectiveness in the inspection of composite and ceramic materials. Two challenging research fields for IR thermography are the detection of structural defects in composite materials and the characterization of the thermal properties of novel anisotropic materials. The goal of this talk is to provide a short review of IR technologies and NDT of composite materials including the modeling of heat conduction in solids with subsurface defects, as well as defect characterization on the basis of inverse heat conduction problems. Novel techniques of material thermal stimulation are also presented along with practical applications of IRTNDT in the hi-tech industries.

Applications of polymer composite materials in MC-21-300 project

Anatoly Gaydanskiy
General Director of JSC "AeroComposit"

Abstract

The main points of the presentation:

1. Automatic layup of dry carbon tape: difficult issues of in-production implementation. Methods and solutions of the manufacturing task.

2. Technology of manufacturing long-size highly integral structures.

3. Hot forming of stringers with complex geometry.

Rubber-cord modeling: Moment Properties, Moderately Large Strains and Energy Loss

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Keywords: rubber-cord ply, moment properties, large strains, Mooney-Rivlin potential, 3D tire model, heat generation, generalized Maxwell's viscoelasticity model, FE method, self-made computer code.

Abstract

Viscoelastic property may be disregarded for shock / slow tire loadings. Two models of rubber-cord ply were elaborated by the author in terms of elasticity. The models were developed during collaboration with French tire maker Michelin.

Moment Properties and Moderately Large Strains

First model is designed for modeling large deformation of the tire as shown in the figure below

Figure: Tire deformation in breaking test.

This model exploits linear moment elasticity theory. It is developed in the framework of the asymptotic averaging method discussed in first lecture. Strains are assumed to be small so the model suits for breaker ply of the passenger tire. In simple words the need of such a model is due to the fact that rubber cord ply bending rigidity is not strictly equal to conventional bending rigidity Eh^3/12/(1-nu^2), where E stands for average Young modulus.

The second model is developed in the framework of geometrically and physically nonlinear conventional elasticity for large strain region. As the matter of the fact, moderately large strains occurs in some zone in tire. Effective material model is based on equivalent homogeneous anisotropic hyper elastic material. The potential is function of Invariants related to the type of the material anisotropy. Several models of effective anisotropic hyper elastic material for transversal isotropy and orthotropy have been proposed for modeling the averaged (homogenized) rubber-cord ply with regard to finite strains. Also a set of computational tests has been proposed to determine the parameters of each suggested potential.

It is well known that the potential is a function of three invariants of the Lagrange – Green strain tensor in the case of isotropy. Furthermore, there are five independent invariants in transversal isotropy. Sets of independent invariants can be chosen in many ways. For example, the first three invariants can be chosen the same as in the isotropic case. The potential of the transversely isotropic material is formulated by adding the terms corresponding to the longitudinal shear and the longitudinal tension or compression. Some sets of these invariants are compared between each other.

An orthotropic effective layer model is more reasonable, if cord concentration is high, for example, about 50%. There are six Independent invariants in the orthotropy. Two sets of invariants are studied. One set consists of six independent pure orthotropy invariants, the other one is obtained by adding orthotropy invariants to the three isotropy invariants. For all sets of invariants, a system of numerical experiments has been elaborated to calculate parameters of the potentials.

Strictly speaking, the classical definition of the Representative Volume Element (RVE) is not applicable to the ply in 3D. Therefore, the definition was modified for 3D heterogeneous layer.

The developed models were implemented using finite element method in the form of a self-made computer code for simulations severe deformation of the passenger tire. The whole tire model is geometrically and physically nonlinear.

Energy loss in the Rubber-cord Ply (in co-authorship with P.V. Chistyakov)

Next issue concerns modeling the energy loss in tire rolling. For this purpose, generalized Maxwell model of the Viscoelasticity is used.

The tire rolling is considered as the imposition of small fluctuations on the stress/strain of the inflated tire. Static and oscillation experiments were conducted at the Lomonosov Moscow State University Research Institute for Mechanics. As a result the elastic and viscous properties of both filled rubber and rubber-cord plies were determined. Samples of rubber and samples of rubber cord with different cord angles were provided by Michelin.

Static experiments were performed on samples with a cord angle from 10 to 90 degrees. A large number of experiments on the study of relaxation on samples of rubber and rubber cord. The test time, the initial strain, the velocity at the initial loading part varied. Oscillation experiments were conducted using samples with angles of 90, 60, 45 degrees and samples of filled rubber. Cyclic frequency varied from 40 to 140 rad/s.

Measurement of all relaxation functions for rubber-cord is not easy for orthotropic material. Therefore, the averaging of the viscoelastic properties of the rubber-cord ply was proposed. The procedure is suggested for the case of metal cord with elastic properties. It is based on elastic - viscoelastic analogy.

Multiscale damage analysis of thin-ply composite laminates

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Abstract

Recently, the spread-tow thin-ply technology and the automated fiber placement technology have been improving freedom in the design of CFRP laminate in terms of local fiber orientation and ply thickness. On the other hand, the transverse performance of CFRP ply in the laminate significantly varies with ply thickness, volume fraction, and so on. In other words, these effects must be taken into account for the optimum design of laminated CFRP structure in the near future.

This study develops the multiscale damage analysis strategy for thin-ply composite laminates. The developed scheme consists of the micro (fiber/matrix) scale simulation and the meso (lamina) scale simulation. In the micro-scale simulation, the representative volume element (RVE) modeling the whole thickness of lamina was simulated to predict the thickness-dependent damage behaviors. On the basis of the stiffness reduction behavior due to microcracking in the micro-scale simulation, the parameters in the mesoscopic constitutive law using continuum damage mechanics were determined.

The validity of the proposed scheme was tested against the unidirectional tensile test of cross-ply laminates with various ply thicknesses. In all ply thickness, crack initiation and propagation behaviors were in good agreement. Therefore, it was concluded that the obtained stiffness degradation behavior is reasonable and that the proposed multiscale scheme has great potential to aid the design of the composite structure with various ply thickness.

Effects of molecular weight of matrix resin on tensile and fiber/resin interfacial properties of continuous fiber reinforced composites with in-situ polymerized phenoxy resin

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Abstract

Carbon fiber reinforced thermoplastics (CFRTPs) are expected as lightweight materials because their specific strength and stiffness are superior to those of metals, and they have great formability and recyclability. However, impregnation condition of the CFRTPs requires high temperature and pressure since the thermoplastic resin is characterized to have high viscosity. In-situ polymerized thermoplastic resin is of interest due to its effective fabrication process. In this research, effects of molecular weight on the tensile and fiber/resin interfacial properties of CFRTP laminates with in-situ polymerized phenoxy resin were evaluated. First, from the experimental results of the static tensile test and the molecular weight measurement of the matrix resin, it was cleared that the tensile properties of the 90° unidirectional laminates can be improved with the molecular weight of matrix resin. Next, it was suggested that the fiber/resin interfacial properties tended to be improved with the molecular weight of matrix resin from the results of single fiber pull-out test. Also, finite element analysis of the pull-out test was performed to evaluate the fiber/resin interfacial properties. As a result, it was confirmed that the thermal residual stress occurred in the cooling process of fabricating pull-out specimen, and that the carbon fiber is pulled out by forming plasticity zone over the fiber/matrix interface. Finally, the static tensile test of matrix was conducted and the results revealed that the tensile properties of matrix resin can be improved with molecular weight. From the above, it was shown that the increasing of the molecular weight affects the tensile properties, the fiber/resin interfacial properties and the mechanical properties of CFRTP laminates.

The effect of nano-structured surface of aluminum alloy directly bonded to CFRTP on fatigue delamination growth

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Abstract

In the near future, it is pointed out that EV vehicles equipped with fuel cells that use hydrogen as a fossil fuel alternative energy will evolve dramatically. Under such circumstances, weight-reduction technologies of the car body are studied as an urgent issue, and a multi-materialization concept using CFRTPs is required to realize these. However, the body of transport equipment cannot be all made by CFRTPs, and therefore techniques to bond alloys and CFRTPs are needed. In addition, investigation of the fatigue characteristics of bonding surface is also needed because the main failure accidents of the mechanical parts is due to fatigue. In this study, the fatigue delamination growth properties are evaluated by using a double cantilever beam testing. The specimens were joined by three methods; adhesive (adhesive), direct bonding with silane coupling treatment (Si-AR), direct bonding with silane coupling treatment after fabricating nano-structure by anodizing and etching the surface of the aluminum alloys (Si-NS). The fatigue delamination growth properties were evaluated by comparing graphs of relationships between cycles and crack length, and Paris diagrams, and then, the fracture surface of Si-AR and Si-NS were observed. The graphs of the relationships between cycles and crack length showed that the crack growth of Si-NS was significantly less than other two cases after same cycles of fatigue loading. The Paris diagram indicated that Si-NS experimented substantially improved fatigue delamination properties comparing to the other two cases. By supervising the fracture surfaces of the Si-AR and Si-NS, hair-like elongation of the resin was seen on the Si-NS surfaces. Thus, the improved properties

of the Si-NS were assumed to be a result of the higher extent of plastic deformation on the surface of Si-NS.

Simulation of porous two-phase media

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Abstract

The physical processes of fluid flow through porous solid media are widespread in the oil and gas industry, filtration facilities, agriculture. Building models of heterogeneous environments requires a mathematical description their mechanical properties, motion and phase transitions, types of external loads, conditions for internal interactions.

In the development of well-known models of porous saturated media a new model was proposed, which takes into account interphase interactions, various modes of movement (slow and fast) of the liquid and deformations (small and finite) of the skeleton.

The most important concept of this model is the concept of interactive forces. Interactive forces are understood as volume forces of mutual resistance of the fluid and the frame when the flow of fluid through deformed skeleton.

The report deals with the problem of one-dimensional stationary flow of compressible fluid through a flat deformable porous layer of finite thickness of incompressible material in the case of finite deformations, taking into account the Darcy force and the force of frontal pressure.

Also, this work presents additions to the model of interactive forces, taking into account changes in the porosity of the framework, and generalizes the concept of interactive forces from previous works of author.

Ply curving termination: suppressing delamination in composite ply drop-off

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Abstract

In a lightweight aircraft composite structure, it is desirable to decrease the plate thickness in low load areas by terminating unnecessary plies (i.e., ply drop-off). It is possible to significantly save the structural weight by steeply changing the thickness in response to the local load distribution. However, tapered sections with steep taper angles act as initiation points of delamination. It is known that stress concentrates at the edge of the terminated 0° plies that have the fiber direction in parallel to the loading direction. As a result, current aircraft composite structures use quite gradual taper angles and have unnecessary thick parts in the low-load areas. Structural modification that can suppress the stress concentration at the edge of the terminated 0° plies is necessary to realize further-optimized lightweight structures with steeper taper angles. The authors recently devised a new approach called "ply curving termination (PCT)" in which local fiber orientation is changed at the edge of the terminated 0° plies. The curved area has significantly low stiffness and thus the stress concentration at the ply edge is suppressed. This presentation reports the numerical analysis and experiment to validate the effectiveness of this new concept. In addition, suppression of edge delamination by PCT is also demonstrated.

Multiscale modeling of viscous flow in a porous medium

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Abstract

Voids in composite materials strongly affect the physical and mechanical properties. At the same time, modeling and simulation of resin flow require substantial computational resources of current commercial and research computational fluid dynamics tools because of the presence of a vast range of physical scales that need to be resolved: fibers with 10 μm in diameter, bundles of fibers (tows) with 1 mm, composites with sizes more than 10 cm, and bubbles with a wide range of diameters. To study the mechanisms of porosity formation, a computational program has been developed for dual-scale textiles in liquid composite molding. The physical process of impregnation is described by the incompressible Stokes equations for multiphase flow in a porous medium considering the effects of surface tension. If the data compression is sufficiently large to compensate the extra computational cost, then Adaptive Multiresolution refinement techniques become efficient. They have a rigorous and more precise regularity analysis and an error estimator criterion in comparison with Adaptive Mesh Refinement approaches used in most commercial software. The model is implemented on the parallel open source BASILISK software with adaptive mesh generation, which uses tree-based grids and thresholding of the wavelet coefficients.

Numerical results are obtained for saturated and unsaturated liquid flow with bubbles through a porous medium for different wettability: non-wetting and perfect wetting fibers.

Determination of parameters values in the models of microstructure evolution under superplastic deformation conditions

T.A. Beliakova, I.A. Goncharov

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Abstract

Superplasticity is a regime of materials deformation, in which the huge values of strain can be achieved in absence of microstructural defects. The properties of superplastic flow strongly depend on microstructural state of the material. During the deformation, several microstructure mechanisms are working together, which leads to both grain growth and grain refinement as a result of newly appeared grain boundaries. Experimental data commonly used in superplasticity can be described by phenomenological constitutive equations of different types, such as creep, viscoplasticity, etc.

Determination of parameters values in the systems of constitutive equations is usually done by means of the special algorithm for the particular system. The authors of the present work suggest more universal algorithm of parameters values determination suitable for some class of superplastic constitutive equations. The approach to check the stability of the approximation to the random errors in the experimental data is described. The model of grain refinement, which is based on the concept of partial refinement of the grains groups, is also suggested.

Extended experimental data with grain sizes distributions is than used to build a model describing the specific features of microstructure evolution during the superplastic deformation. Applicability of the developed model is shown on the example of blowing the sphere by pressure.

Determination of the averaged characteristics of periodic elastic frames

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Abstract

Flat periodic frames are considered consisting of thin weightless elastic rods rigidly interconnected by nondeformable massive nodes. The problem of deforming such frameworks contains two small parameters. These are ratios of the thickness of the rod to its length and the length to the size of the frame. This fact makes it difficult to solve this problem numerically.

The method for determining the averaged characteristics of the framework is proposed. It consists of the following steps:

- the formulas known from the strength of materials are used, which relate the displacements and angles of rotation of the rod ends on the one hand and the forces and moments that occur in the rods on the other hand;
- equilibrium conditions of an arbitrary node are written;
- three continuous functions are introduced that coincide at the intersection points of the rods with displacements and angles of rotation of the nodes;
- it is assumed that the functions introduced satisfy the equations that coincide at the nodal points with the equilibrium equations of the nodes;
- the functions included in the system of equations are expanded into a Taylor series up to the second order terms with respect to a small parameter (the ratio of the thickness of the rod to the length);
- the equations obtained describe the equilibrium of the averaged medium, the elastic moduli of which are the coefficients of the equations.

The method is applied to several types of frameworks: with square, rectangular, triangular and rhombic periodicity cells.

Dilatancy Effect in Solid Mechanics

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Abstract

Dilatancy plays the key role in deformation of brittle material with grain structure. It takes place in deformation of rock masses, ice, graphite and others. When inelastic deformation occurs in grain materials, the microcracking processes provide the shear and bulk strains simultaneously.

The incremental theory of strain-stress relation for dilatant hardening material was formulated by Rice (1975) and defines the cohesion and dilatancy as the components of one physical model. In this model the active (plastic) and passive (elastic) processes could be estimated in terms of efficient stresses.

We develop this incremental theory in such ways:

- The interpretation of cohesion as a property of “stress-strain” curves for shear test under different value of lateral compression;
- Modeling hardening effect for material loading under constraint;
- Establishing an important property of dilatant material: coefficient of internal friction is not greater then dilatancy ratio;
- Using the “wing-crack” mechanism (M.Kachanov, 1982) for initiating both shear and bulk irreversible deformations. This microstructure mechanism was used for modeling the dilatancy as the incremental process where the voids located in vicinity of grain boundaries are growing. The most interesting result is calculation the dilatancy ratio as a function of Poisson ratio and coefficient of friction.

All these features are under consideration in presentation.

Effect of Cellulose Nano Fiber Addition on Fatigue Properties of Carbon Fiber Reinforced Plastics

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Abstract

The purpose of this study is to investigate the influence of the condition of the length of added CNFs on the fatigue life of CFRP. Four types of CNFs of which the length were different (about 6, 22, 68 and 126 μm), respectively, while the diameter of those were almost same, were prepared in order to investigate the effect of the fiber length on fatigue lives of the specimens of the CFRPs reinforced by plain-woven carbon fabrics under tension-tension cyclic fatigue loading. The interfacial shear strengths between modified matrix and single carbon fiber or two carbon fibers were also evaluated. Changes of energy release rates for crack propagation around the interface between carbon fiber and epoxy resin were also simulated by using FEM. The experimental results showed that the fatigue life of CFRP was not improved by adding comparatively short CNF compared to that of original specimen. In contrast, when comparatively long CNFs were added into the matrix, fatigue lives of CFRPs were improved. The fractured surface observation suggested that interfacial adhesion strength between carbon fiber and epoxy resin was improved by adding comparatively long CNFs, due to the mechanical fiber bridging between carbon fibers by added CNFs were formed. Interfacial shear strength between single carbon fiber and matrix was not improved. In contrast, that between two carbon fibers and matrix was significantly improved when the well mechanical fiber bridging of CNFs occurred. The calculation results showed that energy release rate should be reduced by the increase of the chance of cross-links of the carbon fibers by the fiber bridging with added CNF over the initiated internal crack when the comparatively long CNF was applied for the modification of the matrix.

Estimation of R-curve for mode II interlaminar fracture toughness from tensile strength of CFRP laminates with fiber discontinuities

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Abstract

The CFRP laminates with fibre discontinuities show tensile failure at much lower stress due to crack originated from the discontinuities. Previous studies have shown that the stress at which crack propagation from fibre discontinuity occurs can be predicted by using mode II interlaminar fracture toughness G_{II}. The present study aims to reverse this methodology in order to estimate the R-curve of mode II interlaminar fracture toughness G_{II} from tensile test of CFRP laminates with fibre discontinuity. In the technique we suggest here there is no need to perform stabilized ENF tests that require a variety of controls.

Tensile tests for unidirectional CFRP laminates that contain three spots of fibre discontinuities dispersed at an arbitrary interval are carried out. Relations between the interval and the obtained shear strength, which is the fracture load divided by surface area created by interlaminar crack originated from fibre discontinuities, has revealed that the fracture of the laminates is dominated by interlaminar fracture toughness of this material. Energy release rates at crack tips from different spots of fibre discontinuities are qualitatively evaluated by finite element analysis with virtual crack closure technique. A crack from thicker fibre discontinuous spot has been found to exhibit higher energy release rate at its tip. The experimentally obtained fracture stresses are converted into critical energy release rates (CERR) in mode II by applying an analytical model that calculates changes in strain energy before and after crack growth from the fibre discontinuity. As a result, relations between the fracture stress and the interval are converted into that between CERR in mode II and crack extension. The trend of CERR plots agrees well with the R-curve obtained by ENF tests.

Development of Tsunami shelter structure using green composites

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Abstract

The goal of present study is the development of dome structure using green composites for Tsunami shelter. For the design of Tsunami shelter, the crash-proof, specific strength, modulus and reasonable cost of materials and manufacturing were required. Green composites have the high fracture toughness depend on the high failure strain of natural fibers, the high specific modulus comparative to GFRP, the friendly-environment property, abundance resource and low cost in manufacturing. In this study a novel dome structure consist of the green composite crossbeams using a unidirectional tape was proposed. Because this dome crossbeam structure was built by 15 beams in a regular pattern, the beam geometries was easily designed from the viewpoint of CAE. The regular pattern of crossbeams has also the superior handling in manufacturing. At first, the off-axis contact analyses of the dome structure based on finite element method were conducted in order to investigate the deformation behaviour of crossbeams and design the beam thickness and width to sustain the out-plane loading. Additionally, the prototypes of the flax/PP composite dome with various tape in width were manufactured in lab-scale, the handling of molding in oven was then confirmed.

Anisoprinting - Design and Manufacturing of New Generation Composite Structures

Aleksey Khaziev
Anisoprint

Abstract

Continuous fiber 3D printing enables to produce polymer composite parts of new generation. This technology provides high flexible fiber steering and utilizes maximum potential of continuous fibers in composites. That gives great opportunities for structural and topological optimization of lightweight and strong composite parts. The structural optimization technique is supposed to find the optimal fiber laying under given constrains and loading conditions while topology optimization provides the optimal shape of the composite part.

The presentation focuses on the features of the technology, technology capabilities and limitations that should be considered in parts design. The materials used in the technology are also considered. Description of Anisoprint software for the manufacturing of composite parts by three-dimensional printing is given. Possible ways of design and analysis of 3D printed composite structural elements are suggested. In particular, approaches based on topology optimization of parts and structural optimization are considered.

Structural and Topology Optimization of 3D Printed Composite Parts

Tatiana Latysheva
Anisoprint

Abstract

Continuous fiber 3D printing enables to produce polymer composite parts of new generation. This technology provides high flexible fiber steering and utilizes maximum potential of continuous fibers in composites. That gives great opportunities for structural and topological optimization of lightweight and strong composite parts. The structural optimization technique is supposed to find the optimal fiber laying under given constrains and loading conditions while topology optimization provides the optimal shape of the composite part.

This research is dedicated to the development of a tool for structural and topology optimization of continuous fiber 3D printed parts. Minimum compliance and minimum weight are considered as optimum criteria. Mass and strength constraints are taken into account. For optimization of composite printing parts with minimum compliance, continuous Fiber Angle Optimization (CFAO) Technique developed by Hoglund was used as a method of optimization problem statement. In order to solve this problem the following optimization algorithms were applied: Augmented Lagrangian Particle Swarm Optimization (ALPSO), Optimality Criteria (OC) Method, Safonov method, Method of Moving Asymptotes (MMA), Globally Convergent Method of Moving Asymptotes (GCMMA). The test problem of cantilever plate with applied concentrated force was solved by this tool and the solutions of different algorithms were compared. Some approaches to structural and topology optimization of continuous fiber 3D printing parts with minimum weight are considered as well.

Characterizations and Applications of Nanocarbon Materials for Electromagnetic Shielding

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Abstract

Electromagnetic interference (EMI) shielding refers to the reflection and/or adsorption of electromagnetic radiation by a material, which thereby acts as a shield against the penetration of the radiation through it. Polymer composites are extensively employed in EMI shielding due to their superior molding, more dependable lightweight and respected adsorption property of EMI wave. In this presentation, the nanocarbon materials developed for electromagnetic shielding are introduced. Their fabrication process, characterization and applications were discussed. The continuous carbon fiber reinforced composites (CFRP) is also discussed as an important EMI material for its high conductivity and excellent mechanical property. The EMI anisotropic behavior is investigated and a new nondestructive evaluation (NDE) based on EMI SE characteristics is proposed.

Twist measurements under tensile loading for anti-symmetric CFRP laminates

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Abstract

The deformation behaviors of various CFRP laminates are explained by classical lamination theory based on plate theory. An antisymmetric angle-ply laminate has laminae oriented at $+\alpha$ degrees to the laminate coordinate axes on one side of the middle surface and corresponding equal-thickness laminae oriented at - α degrees on the other side at the same distance from the middle surface. It is known from this theory that whenever B in not zero, the laminate is coupled: for in-plane stress resultant it will exhibit also curvatures, while for a pure bending state, the middle plane will have not zero strains. Additionally, it is found that an extensional force results in not only extensional deformations, but bending and/or twisting of the laminate. The purpose was to measure accurately these tension-twist coupling properties by experimental method. The balanced and antisymmetric laminates consisting of 0°, 90°, 45° and -45° plies which number of each ply of 2 were used in this study. All kinds of laminates in present study are 12.

At first, the relationship between the value of B_{16}, which is the coupling stiffness component of the stiffness matrix, and the twist angle calculated by FE analyses was confirmed. As a result, it is found that the correlation of B_{16} and twist angles was large compared with those of D_{11}, D_{12}, D_{22} and D_{66} in bending stiffness D. Next, the tensile test method for measuring the twist angle of anti-symmetric CFRP laminates was carried out. In order to measure the twist angle under tensile loading, a novel tensile jig combined with the conversion apparatus from tensile direction to compressive direction and a thrust block were proposed. Consequently, the experimental results were compared with numerical results to evaluate the validity of proposed experimental method.

Selection of synthesis conditions for improving mechanical properties of untwisted CNT yarn

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Abstract

Carbon nanotubes (CNTs) are recognized to be a candidate of the next generations structural materials with low density and high strength. However, tensile strengths of the CNT yarns fabricated from the CNT arrays are much lower than that of multi-walled carbon nanotube (MWCNT). In order to achieve the high strength CNT yarn, it is well known that to synthesize the MWCNTs with the small diameters as well as the few wall is essential. In this research, CNTs are synthesized under various conditions using the CVD method to obtain small diameter, few wall and drawable CNTs. By comparing the synthesis conditions and mechanical properties of MWCNTs and the CNT yarns, it was tried to identify the method to obtain the CNT yarns which has high mechanical properties. First, by appropriately selecting the thickness of the catalyst layer of the substrate used for synthesis, it was confirmed that MWCNTs which have small diameter and thin walls can be obtained because of the change of the size of catalyst nanoparticles. And by controlling total gas flow rate used for synthesis, it was found that drawable CNT array can be obtained. Next, it was found that the smaller the diameter of MWCNTs, the higher the strength. And also for untwisted CNT yarns, it was confirmed that those made from smaller diameter and thinner wall MWCNTs have higher strength.

Experimental evaluation of formability in preforming process using CFRTP preforms

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Abstract

A high production rate leads to increase the usage of carbon fiber reinforced plastics (CFRP). The press molding using carbon fiber reinforced thermoplastics (CFRTP) is one method for reducing production time. In this method, draping ability can be improved by preforming at the temperature which is higher than the glass transition temperature. However, in this preforming process, some defects such as gaps, tape slippage or wrinkles are generated, and they become factors that reduce the mechanical properties of the final products. Reduction of defects can be achieved by optimizing the geometrical and constraint conditions of preforming process.

The present paper examined formability of CFRTP preforms by preforming experiments. As a specimen, AP-PLY was made by thin prepreg tapes with a width of 10 mm and a thickness of 0.04 mm. AP-PLY combines through-the-thickness reinforcements with an automated fiber placement process. The prepreg consisted of TR50S and DIAMIRON C, and they were uni-directional carbon fibers, and polyamide 6 single-layer films, respectively. A mold was designed by CAD, and had a curved surface. In the preforming experiments, the mold was pressed against the specimen at the temperature which is higher than the glass transition temperature of polyamide 6. After that, fiber orientation and generation of defects were observed, and the effects of a curved surface were discussed.