出國報告（出國類別：開會）

參加「**2023**年第**13**屆國際疲勞力學代表大會（**International Fatigue Congress**）」出國報告

服務機關：國家運輸安全調查委員會

姓名職務：副研究員／林意程

派赴國家／地區：日本廣島市

出國期間：民國112年11月5日至11月11日

報告日期：民國113年2月1日

公務出國報告提要　　系統識別號*******************

出國報告名稱：參加「2023 年第 13 屆國際疲勞力學代表大會 （International Fatigue Congress）」出國報告

頁數：26 頁　　含附件：否

出國計畫主辦機關：國家運輸安全調查委員會
聯絡人：郭芷桉
電話：（02）8912-7388

出國人員姓名：林意程
服務機關：國家運輸安全調查委員會
單位：運輸工程組
職稱：副研究員
電話：（02）8912-6325

出國類別：□考察 □進修 □研究 □實習 □視察 □訪問 ■開會 □談判 □其他 _____

出國期間：民國 112 年 11 月 5 日至 11 月 11 日

出國地區：日本廣島市

報告日期：民國 113 年 2 月 1 日
分類號/目
關鍵詞：疲勞分析、International Fatigue Congress
內容摘要：

2023 年第 13 屆國際疲勞力學代表大會（International Fatigue Congress）於日本廣島舉辦，針對工程疲勞分析的各式議題，由學界與業界提出學理與實務探討。另法國 BEA 及澳洲 ATSB 等事故調查單位建議 AIM 年會成員國參加該會議，除強化本會調查工程能量，另針對法、澳兩國調查人員於 IMIG 論壇上所關注之 Fiber Composites 複合材料等相關議題，於 2024 年材料事故調查員年會（AIM），提報本次參與該會議之心得並進行討論，藉以增加國際交流，深化夥伴關係。

目次

一、目的

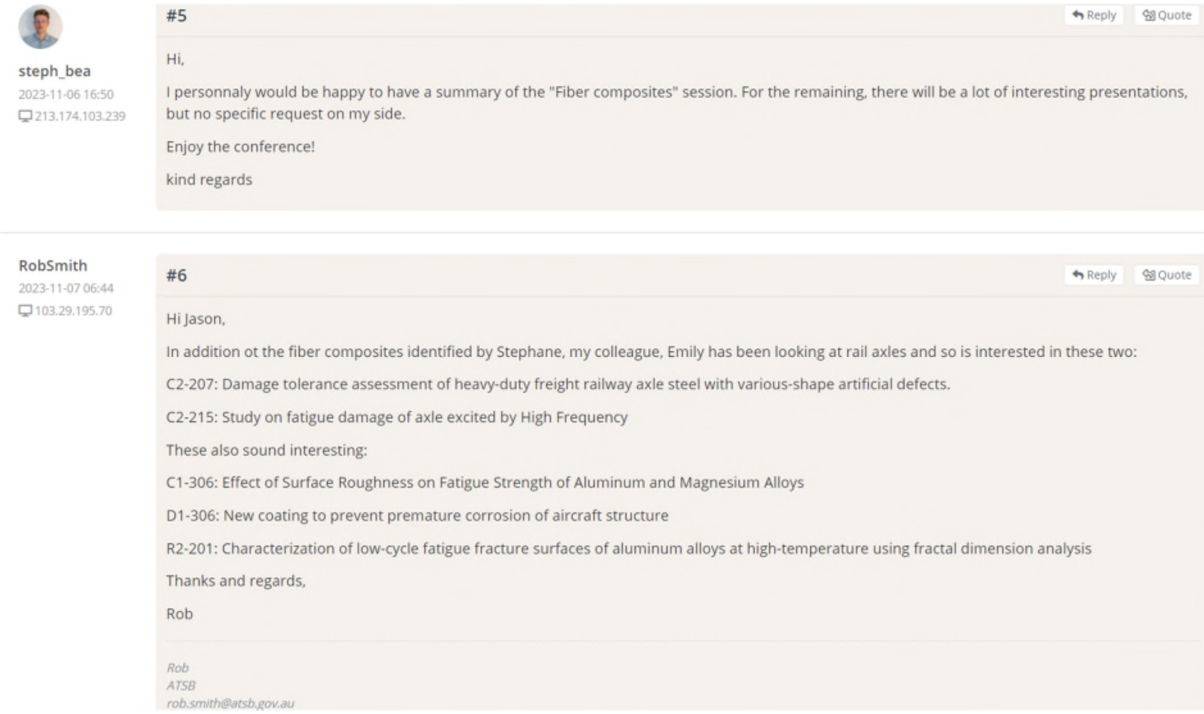
國際疲勞力學大會（International Fatigue Congress, IFC）是專門針對疲勞議題的國際會議，由瑞典 A.F. Blom 教授於 1981 年倡議成立。第一屆大會在斯德哥爾摩舉行，此後每三年在不同城市舉辦一次，直至 2002 年再次回到斯德哥爾摩舉辦。該會議與國際材料機械性質會議（ICM）和國際破壞力學會議（ICF）皆是探討材料強度和固體力學的會議，為錯開前開個別會議期間，本會議自 2002 年起每四年舉辦一次，2006 年在美國亞特蘭大舉行，此後一直如此。上次會議係於 2018 年在法國普瓦捷舉行，本次會議原訂於 2022 年於日本廣島舉行（圖 1.1，1.2），嗣因疫情之故，延後一年舉辦，本次會議進行了近 400 場演講，相關論文擬由該領域權威期刊 Fatigue & Fracture of Engineering Materials & Structures （FFEMS）以專刊方式發行。

本會職司重大運輸事故安全調查，無論從材料機械性質或破壞力學觀之，金屬疲勞或是其他材質的疲勞現象是常見的破壞樣態。本會早期調查的華航 CI-611 空中解體事故案，以及近期調查之台鐵隆田站電聯車馬達脫落案，皆屬金屬疲勞導致失效之範疇。本次會議係針對工程疲勞分析的各式議題，由學界與業界提出學理與實務探討，包含巨觀與微觀觀測疲勞現象、不同表面加工技術對疲勞壽命的影響、運用新科技模擬預測疲勞壽命、日本福島核災後重新修正之金屬疲勞曲線、纖維增強複合材料（Fiber Composites）的疲勞性質等議題，對於強化本會調查工程能量極具助益。

此外，由法國運輸事故調查單位 BEA 發起，本會負責建置與維護之資深材料分析調查員交流平台（International Material Investigator Group, IMIG），參與者多數來自歐美地區的資深材料分析調查員，在平台上分享各國材料分析的調查實務經驗，並研討最新的材料分析調查技術。2023 年 9 月法國 BEA 及澳洲 ATSB 等事故調查單位於 IMIG 論壇上，建議材料分析調查員會議（Accident Investigator Materials, AIM meeting）成員國參加本次會議，並分享該會議相關議題。爰本會擬派員參加，除強化本會調查工程能量，另針對法、澳兩國調查人員於 IMIG 論壇上所關注之纖維增強複合材料（Fiber Composites） 等相關議題（圖 1.3），擬於 2024 年 AIM 年會提報參與本次會議之心得並進行討論，藉以增加國際交流，深化夥伴關係。

圖 1.1 會議舉辦地-日本廣島市

圖 1.2 本屆會議場地位於廣島和平紀念公園的廣島國際會議中心



steph_bea
2023-11-06 16:50
213.174.103.239

#5 Reply Quote

Hi,

I personnaly would be happy to have a summary of the "Fiber composites" session. For the remaining, there will be a lot of interesting presentations, but no specific request on my side.

Enjoy the conference!

kind regards

RobSmith
2023-11-07 06:44
103.29.195.70

#6 Reply Quote

Hi Jason,

In addition ot the fiber composites identified by Stephane, my colleague, Emily has been looking at rail axles and so is interested in these two:

C2-207: Damage tolerance assessment of heavy-duty freight railway axle steel with various-shape artificial defects.

C2-215: Study on fatigue damage of axle excited by High Frequency

These also sound interesting:

C1-306: Effect of Surface Roughness on Fatigue Strength of Aluminum and Magnesium Alloys

D1-306: New coating to prevent premature corrosion of aircraft structure

R2-201: Characterization of low-cycle fatigue fracture surfaces of aluminum alloys at high-temperature using fractal dimension analysis

Thanks and regards,

Rob

Rob
ATSB
rob.smith@atsb.gov.au

圖 1.3 法、澳兩國調查人員於 IMIG 論壇上所關注之相關議題

二、過程

2.1 行程

日 期		起 訖 地 點	詳 細 任 務
月	日		
11	5	台北~岡山	啟程
11	6	廣島	會議
11	7	廣島	會議
11	8	廣島	會議
11	9	廣島	會議
11	10	廣島	會議
11	11	福岡~台北	返程

2.2 參與人員

本次會議由近五百位學界與實務界專家參與，包含來自歐、美、日機械工程與材料科學學界專家，及空中巴士、日本鋼鐵、三菱重機、馬自達汽車、豐田汽車、關西電力等重工業實務界人士，針對工程疲勞分析的各式議題提出學理與實務探討。

2.3 議程

FINAL PROGRAM

Tuesday, 7 November [Day 2]

Phoenix

10:30-12:30 — New materials

Chair : Benjamin Guennec(Toyama Prefectural Univ) & Takayuki Shiraiwa(The University of Tokyo)

P-201	Assessment of the four-point bending fatigue properties of zirconia-reinforced Ti6Al-4V nanocomposite processed by laser powder bed fusion	Benjamin Guennec(Toyama Prefectural University)
P-202	Effect of Volume Fraction of Network Structure Composed of High-Entropy CrMnFeCoNi Alloy on Fatigue Crack Propagation in 304L Stainless Steel Compact	Arisa Ito(Shizuoka University)
P-203	Fatigue damage evaluation of coarse and fine grains in notched austenitic stainless steel with harmonic structure	Keisuke Fujita(Shizuoka University)
P-204	Retarded Crack Growth and Self Sensing Ability of Metal-Matrix Composites produced by High-Pressure Torsion	Valeria Lemkova(Saarland University)
P-205	Fatigue crack propagation of nano particles reinforced Al matrix composite	Qingqing Pu(Shanghai Jiao Tong University)
P-206	Fatigue behavior of accumulative roll bonded Cu/Nb laminate materials	Takayuki Shiraiwa(The University of Tokyo)

14:00-16:00 — Japanese Activity for New Fatigue Curves and Fatigue Analysis 1

Chair : Masahiro Takanashi (IHI Corporation) & Akihiko Hirano (Hitachi-GE Nuclear Energy Ltd) & Masao Itatani (Toshiba Energy Systems & Solutions Corporation)

P-207	Overview of Japanese Activity for New Fatigue Curves and Fatigue Analysis	Takeshi Ogawa(Aoyama Gakuin University)
P-208	Development of Best Fit Curves	Masanori TOYODA(Mitsubishi Heavy Industries, Ltd.)
P-209	Definition of Fatigue Life in Best Fit Curves and Large Components	Chihiro Narazaki(Toshiba Energy Systems & Solutions Corporation)
P-210	Mean Stress Correction Method for Fatigue Analysis	Takuya OGAWA(Toshiba Energy Systems & Solutions Corporation)
P-211	Investigation of Mean Stress Effect for Local Strain Behavior at Notch Root of Large-Scale Plate Specimen	Daiki Takagoshi(Mitsubishi Heavy Industries, Ltd.)
P-212	Verification of SWT Method for Notched Components	Yuichiro NOMURA(Mitsubishi Heavy Industries, Ltd.)

16:30-18:30/18:50 — Japanese Activity for New Fatigue Curves and Fatigue Analysis 2

Chair : Motoki Nakane (Hitachi-GE Nuclear Energy Ltd) & Seiko Toshiyuki (Toshiba Energy Systems & Solutions Corporation)

P-213	Effect of Machined Surface Finish on Fatigue Life of Carbon Steel	Yun Wang(Hitachi Ltd.)
P-214	Fatigue crack initiation and growth behavior of specimen with machined surface layer under low cycle fatigue regime	Shota Hasunuma(Aoyama Gakuin University)
P-215	QA Sheet for Variability Factors in Fatigue Life of S-N Curve –Introduction of Activity for Development of "Fatigue Knowledge Platform" in JWES (1)–	Nao Fujimura(Hokkaido University)
P-216	QA Sheet for Fatigue Analysis of Weld Joint –Introduction of Activity for Development of "Fatigue Knowledge Platform" in JWES (2)–	Hideaki Nishikawa(National Institute for Materials Science)
P-217	QA Sheet for Difference between Post Construction Code for Pressure Vessel and Damage Tolerance Design of Aircraft –Introduction of Activity for Development of "Fatigue Knowledge Platform" in JWES (3)–	Yuka Miyata(Hitachi-GE Nuclear Energy Ltd)
P-218	Status of Codification for New Fatigue Curves and Fatigue Analysis	Seiji Asada(Mitsubishi Heavy Industries, Ltd.)

Dahlia1

10:30-12:30 — Biomaterials

Chair : Tohikazu Akahori(Meijo Univ) & Ligua Zhao(Nanjing Univ of Aeronautics and Astronautics)

D1-201	Change in mechanical properties and surface morphology of alpha+beta type titanium alloy subjected to gas nitriding duplex treatment	Tohikazu Akahori (Meijo university)
D1-202	Fatigue property evaluation of Ti-Ta Alloy Rods Using Spiral Fixation Model	Akane YANAGAWA(Sophia University)
D1-203	Evaluation of Corrosion, Wear and Tribocorrosion Properties of Ti-Ta Alloys	Shota YAMAMURO(Sophia University)
D1-204	Effect of Angioplasty on Fatigue Resistance of Nitinol Stent in Femoropopliteal Artery	Ligua Zhao(Nanjing University of Aeronautics and Astronautics)

14:00-16:00 — Growth of short and long cracks 1

Chair : Tilmann Beck(RPTU Kaiserslautern-Landau) & Takayuki Yonezawa(Nippon Steel Corporation)

D1-207	Experimental and numerical investigations of the influence of grain orientation on the fatigue behavior of coarse-grained nickel-based superalloys	Tilmann Beck(RPTU Kaiserslautern-Landau)
D1-208	Fatigue Crack Extension Mode for 18Ni Martensitic Steel and its Effect on Fatigue Limit	Shun KINO(Kyushu University)
D1-209	Carbon content effect on fatigue crack extension behavior and extension mode in 18%Ni martensitic steels	Fengxu REN(Kyushu university)
D1-210	Fatigue crack propagation behavior of Ferritic steels with different cyclic softening properties	Takayuki Yonezawa(Nippon Steel Corporation)

16:30-18:30/18:50 — Growth of short and long cracks 2

Chair : Yi SHI(Shanghai Jiao Tong University) & Shigeru HAMADA(Kyushu University)

D1-213	Investigation of defect induced crack and fatigue crack growth behavior of a P/M nickel based superalloy and corresponding life prediction	Yi SHI(Shanghai Jiao Tong University)
D1-214	In-situ Observation of Fatigue Crack Propagation in Soda-Lime Glass with Vickers Indentation-induced Initial Crack under Four-Point Bending	Hibiki KOMINE(Shizuoka University)
D1-215	Intrinsic fatigue resistance and the influence of material defects	Mirco Chapetti(National University of Mar del Plata)
D1-216	Investigation of the influence of physical notch parameters on fatigue life and fatigue life scatter in EN AW-2015A	Jan Radners(Fraunhofer Institute for Mechanics of Materials IWM)
D1-217	Fatigue short crack propagation in a Ni alloy manufactured by Laser powder bed fusion	Li Jianghua(Institute of Mechanics, Chinese Academy of Sciences)
D1-218	Fatigue Crack Extension by Damage Accumulation	Shigeru HAMADA(Kyushu University)

Dahlia2

10:30-12:30 — Additive Manufacturing 1

chair : Bo Li(East China University of Science and Technology) & Yajing Li(East China University of Science and Technology)

D2-201	High cycle fatigue behavior of CoCrFeNi high entropy alloy manufactured with laser powder bed fusion	Bo Li(East China University of Science and Technology)
D2-202	Fatigue Properties of WAAM-manufactured components	Moritz Hupka(Clausthal University of Technology)
D2-203	Inferior fatigue resistance of additively-manufactured Ni-based superalloy 718 and its dominating factor	Sangcheol PARK(Kyushu University)
D2-204	Combined effect of surface integrity parameters on the fatigue strength of Laser Powder Bed Fusion (L-PBF) 316L stainless steel	Marion Aufray(Ecole Nationale Supérieure d'Arts et Métiers)
D2-205	Effect of Post-Processing on Fatigue Performance of SLM Ti6Al4V Alloy	LITTON BHANDARI(Indian Institute of Technology Roorkee)
D2-206	Low Cycle Fatigue Behavior of Wire Arc Additive Manufactured and Solution Annealed 308 L Stainless Steel	Yajing Li(East China University of Science and Technology)

14:00-16:00 — Additive Manufacturing 2

Chair : Aditya Pandey(Indian Institute of Technology Roorkee) & Atsuhiro KOYAMA(Nagasaki University)

D2-207	A study on fatigue properties of wire-arc additively manufactured Inconel 718 alloy	Aditya Pandey(Indian Institute of Technology Roorkee)
D2-208	A study on different heat-treatment cycles for additively manufactured Ni-based alloy and its fatigue properties	SUMIT CHOUDHARY (Indian Institute of Technology Roorkee)
D2-209	The effect of surface modification on crack propagation properties and fatigue life on Ti-6Al-4V alloy formed by electron beam lamination	Yaya ARAKI(Sophia University)
D2-210	Applicability of non-ideal powders in powder bed fusion processes - Fatigue life of additively manufactured structures	Julie Richter(University of Kassel)
D2-211	Influence of Heat-treatment on Fatigue Properties of Super Duplex 2507 Stainless Steel produced by Directed Energy Deposition Process	Sébastien BALLESIO(Institut Polytechnique de Paris)
D2-212	Influence of manufacturing history and resulting microstructure on the very high cycle fatigue behavior of additively manufactured samples	Leonhard Stampa(Technical University Dresden)

16:30-18:30/18:50 — Additive Manufacturing 3

Chair : Jakob Blankenhagen(Technical University of Munich) & Koji Takahashi(Yokohama National University)

D2-214	Cyclic plastic material behavior of novel high manganese austenitic stainless steel Printdur? HSA additively manufactured by PBF-LB/M	Jakob Blankenhagen(Technical University of Munich)
D2-215	Effect of Heat Treatment on Fatigue Life of Ti-6Al-4V Alloy with Additively Manufactured Layer and Conventional Wrought Layer	Atsuhiro KOYAMA(Nagasaki University)
D2-216	Process Parameters and Fatigue Crack Initiation in Cold Spray	Hamid Jahed(University of Waterloo)
D2-217	An assessment of the high-temperature fatigue properties of additively manufactured nickel-based alloys	Tomáš Kruml(Institute of Physics of Materials, CAS)
D2-218	Microstructure modification to increase resistance to fatigue crack propagation in titanium alloys made by wire based directed energy deposition process	Xiang Zhang(Coventry University)
D2-219	Combined Effect of Shot and Laser Peening on Fatigue Strength of Additively Manufactured Aluminum Alloy	Koji Takahashi(Yokohama National University)
D2-220	Anisotropic Fatigue Properties of Laser Additive Manufactured (LAMed) Ni-based Superalloys	ZhenanZhao(Zhejiang University)

Cosmos1

10:30-12:30 — Reliability analysis

Chair : Zhiping Xu(Tsinghua University) & Balajee Ananthasayanam(Honda Aero Inc.)

C1-201	A Data Science Approach to Understanding Fatigue	Zhiping Xu(Tsinghua University)
C1-202	Identification of Plastic-Creep Fatigue Damage Rule for Aluminum Alloys Using Particle Swarm Optimization Method	Towa HAYASHIBE(Akita University)
C1-203	Dimensioning a Reference Volume Element for Detecting Fatigue Cracks in Equiaxed Titanium Alloy	Azdine Nait-ali(Institut Polytechnique de Paris)
C1-204	Slow Adoption of Modern Statistical Methods in Industrial Applications for the Development of Fatigue Curves	Balajee Ananthasayanam(Honda Aero Inc.)
C1-205	Development of Fatigue Curve with Multiple Competing Failure Modes	Balajee Ananthasayanam(Honda Aero Inc.)
C1-206	Fatigue Deformation Behavior and Life Prediction in a Newly-Developed Cast Aluminum Alloy	Daolun Chen(Toronto Metropolitan University)

14:00-16:00 — Non-destructive testing 1

Chair : Zhe ZHANG(Tianjin University) & Norihiko Hana(Mitsubishi Electric Corporation)

C1-207	Mechanoresponsive luminogen (MRL)-based real-time and visible detection method for fatigue damage	Zhe ZHANG(Tianjin University)
C1-208	Self-heating and rapid fatigue limit prediction for single-ply thermoplastic composites under tensile fatigue load based on the infrared thermography technology	Aijie Li(Northwest Polytechnical University)
C1-209	Using 3D energy-dispersive Laue diffraction to study fatigue damage evolution in materials showing wavy and planar slip behaviour	Carolin Leidigkeit(University of Siegen)
C1-210	Evaluation of fatigue strength of Cr-Mo steel based on dissipated energy measurement	Taichi Sugimoto(Kobe university)
C1-211	Crack shape identification from surface deformation using inverse analysis	Norihiko Hana(Mitsubishi Electric Corporation)
C1-212	Fatigue Crack Behavior of 304 Stainless Steels using Synchrotron X-ray Tomography and Diffraction: Influence of the Martensite Fraction and Role of Inclusions	Djamel KAOUMI(North Carolina State University, USA)

16:30-18:30/18:50 — Non-destructive testing 2

Chair : Paul DarioTOASA CAIZA(Karlsruhe Institute of Technology) & Stéphanie DESCHANEL (INSA-Lyon)

C1-213	Real time fatigue crack detection on welded specimens by applying inductive Thermography. Simulation and experimental results	Paul DarioTOASA CAIZA(Karlsruhe Institute of Technology)
C1-214	Evaluation of Fatigue Strength by Dissipated Energy of Dissimilar FSW Joints of Aluminum Alloy and Steel sheets	Tenyu Hidaka(Kobe university)
C1-215	POD modeling of a flexible array eddy current NDT method for near-surface cracks in the tenon-groove structure of a turbine disk and its application for damage tolerance assessment	Hongzhuo Liu(Beihang University)
C1-216	Metalayer-based piezoelectric transducer for unidirectional excitation and reception of SH guided wave	Yuehao Du(Southwest Jiaotong University)

Cosmos2

10:30-12:30 — Crack closure and shielding

Chair : Carl Fischer(Fraunhofer Institute for Mechanics of Materials IWM) & Emiel Amsterdam(NLR)

C2-201	Finite element study on the influence of the phase shift on plasticity-induced crack closure and the crack tip opening displacement under thermomechanical fatigue loading	Carl Fischer(Fraunhofer Institute for Mechanics of Materials IWM)
C2-202	Mixed mode crack growth behaviour considering plasticity-induced and roughness-induced closure	Shuancheng Wang(Southwest Jiaotong University)
C2-203	Improved Analytical Tool for Crack Closure Evolution after Overload and Underload	Radek Kubíček(Institute of Physics of Materials, Czech Academy of Sciences)
C2-204	Crack closure effects at negative load ratios	Gilbert HÉNAFF(University of Poitiers)
C2-205	On the strain energy release rate and fatigue crack growth rate in metallic alloys	Emiel Amsterdam(NLR)

14:00-16:00 — Damage evaluation and fatigue design 1

Chair : Jie-WeiGao(Univ of Electronic Science and Technology of China) & Fabien Lefebvre(CETIM)

C2-207	Damage tolerance assessment of heavy-duty freight railway axle steel with various-shape artificial defects	Jie-WeiGao(University of Electronic Science and Technology of China)
C2-208	Fretting fatigue damage of axial interference fit structures subjected to fretting wear	Yikang Shu(Beijing Jiaotong University)
C2-209	Research on fatigue assessment method of high-speed train axle based on axle box acceleration	Ruiguo Yan(Beijing Jiaotong University)
C2-210	An entropy-based approach to low cycle fatigue damage evolution for GH4169 at intermediate and elevated temperature	Shuyang Xia(Beihang University)
C2-211	Proposition and Development of the General Relation between Tensile and Fatigue Strengths of Metallic Materials	Jianchao Pang(Institute of Metal Research, Chinese Academy of Sciences)
C2-212	Effect of internal defects of G20Mn5 cast steel on the fatigue strength	Fabien Lefebvre(CETIM)

16:30-18:30/18:50 — Damage evaluation and fatigue design 2

Chair : Bastian Blinn(RPTU Kaiserslautern) & Masayuki Kamaya(Institute of Nuclear Safety System, Inc.)

C2-213	Analysis of the defect tolerance of bainitic 100Cr6 with high retained austenite content	Bastian Blinn(RPTU Kaiserslautern)
C2-214	Cyclic indentation - A new method to estimate the fatigue strength by considering the cyclic deformation behavior	Bastian Blinn(RPTU Kaiserslautern)
C2-215	Study on fatigue damage of axle excited by High Frequency	Ziyo Dong(Beijing Jiaotong University)
C2-216	A Study of Rate Process Analysis on the Rotating Bending Fatigue Limit of Carbon Steel	Mai FUKAMI(University of Toyama)
C2-217	Mean stress sensitivity for carbide-rich PM tool steels	Lennart Mirko Scholl(RWTH Aachen University)
C2-218	Influence of Pre-strain on the Fatigue Strength of Stainless Steel	Masayuki Kamaya(Institute of Nuclear Safety System, Inc.)

Ran1

10:30-12:30 — Cyclic deformation and crack initiation 1

Chair : Aariel Leonard(The Ohio State Univ) & Ulrich Krupp(RWTH Aachen Univ)

R1-201	Fatigue strength evaluation of 1180MPa class recycled steel	Nobuo NAGASHIMA(National Institute for Materials Science)
R1-202	Influence of Dislocation Interactions on Fatigue Crack Initiation in Additively Manufactured Nickel-Aluminum-Bronze Alloys	Aariel Leonard(The Ohio State University)
R1-203	Notched High Cycle Fatigue and Macrozones in Ti-6Al-4V	Yan Gao(Imperial College London)
R1-204	In situ observation and crystal plasticity simulation of internal fatigue crack initiation and propagation behavior around synthetic hard alpha inclusions embedded in Ti-6Al-4V	Hongzhuo Liu(Beihang University)
R1-205	A novel micromechanism-based fatigue model for FCC single crystal combining crystal plasticity with CDM	Ao Li(Beihang University)
R1-206	Initiation and Growth of Short Fatigue Cracks in Tempered Martensitic and Bainitic Steels	Ulrich Krupp(RWTH Aachen University)

14:00-16:00 — Cyclic deformation and crack initiation 2

Chair : Yabin Yan(East China University of Science and Technology) & Ankur Chauhan(Indian Institute of Science)

R1-207	In situ SEM experimental study on the fatigue failure of micro-single-crystal copper	Yabin Yan(East China University of Science and Technology)
R1-208	Dislocation networks in the (111) cell boundaries in fatigued near-[-111] copper single crystals	Bohan Wang(Tokyo Institute of Technology)
R1-209	Improvement of stress corrosion cracking resistance by low cycle fatigue of a CrNiMoV steel	Fang-Xin Yang(East China University of Science and Technology)
R1-210	Cryoforged nanotwinned CoCrNi medium-entropy alloy with exceptional fatigue resistance at cryogenic temperature	Yu Xie(East China University of Science and Technology)
R1-211	Elucidation of small fatigue crack initiation behavior on polycrystal Ti-22V-4Al	Koki Hirazumi(Okayama University)
R1-212	Low-cycle fatigue response of an equiatomic CrFeNi multi-principal element alloy	Ankur Chauhan(Indian Institute of Science)

16:30-18:30/18:50 — Cyclic deformation and crack initiation 3

Chair : Jean-Bernard VOGT(University de Lille) & Lihe Qian(Yanshan University)

R1-213	Low cycle fatigue of a fully pearlitic steel	Jean-Bernard VOGT(University de Lille)
R1-214	Cyclic plasticity of a 9Ni steel	Jean-Bernard VOGT(University de Lille)
R1-215	Secondary orientation effects on the low-cycle fatigue behaviors of rectangular-sectional Ni-based single crystal superalloys at medium and high temperatures	Shao-Shi RUI(Institute of Mechanics, CAS)
R1-216	Improved fatigue resistance of heterogeneous materials suppress strain localization and damage accumulation	Lei Lu(Institute of Metal Research, CAS)
R1-217	Nanostructure; 316L stainless steel; Low-cycle fatigue life; Ductility; Cumulative plastic strain	Nairong Tao(Institute of Metal Research, Chinese Academy of Sciences)
R1-218	Effect of Al on the Low-Cycle Fatigue Properties of Fe-Mn-C TWIP Steel	Lihe Qian(Yanshan University)

Ran2

10:30-12:30 — Creep 1

Chair : Kohei FUKUCHI(Akita University) & Oliver Jordan(RPTU Kaiserslautern-Landau)

R2-201	Characterization of low-cycle fatigue fracture surfaces of aluminum alloys at high-temperature using fractal dimension analysis	Kohei FUKUCHI(Akita University)
R2-202	Acceleration of Creep-Fatigue Damage in Ni-Base Superalloy due to Viscoelasticity at Elevated Temperature by Considering Local Stress	Le XU(Tohoku University)
R2-203	Cold dwell fatigue response of aero-engine component titanium alloys: Influence of hold time and peak stress	Jianke QIU(Institute of Metal Research, Chinese Academy of Sciences)
R2-204	Molecular Dynamics Analysis of the Acceleration Mechanism of the Degradation of Grain Boundary Strength in Alloy GH4169 Caused by δ-Phase Precipitation	Takuto Kudo(Tohoku University)
R2-205	Modified Kitagawa-Takahashi Approach for Improved Lifetime Prediction under Creep-Fatigue Loading of Polycrystalline Gas Turbine Components	Oliver Jordan(RPTU Kaiserslautern-Landau)
R2-206	Probabilistic Modelling of creep-fatigue interaction in polycrystalline Nickel-base alloy based on the Kitagawa-Takahashi diagram	Tuan Duc Nguyen(Siemens Energy)

14:00-16:00

FATIGUE2026 presentation

16:30-18:30/18:50 — Creep 2

Chair : Shiyu Suzuki(JAXA) & Tuan Duc Nguyen(Siemens Energy)

R2-213	Transition from crack retardation to acceleration under high temperature dwell-fatigue loading in a wrought Ni-base superalloy	Shiyu Suzuki(JAXA)
R2-214	Evaluation of fatigue and creep-fatigue damage levels on the basis of engineering damage mechanics approach	Li Sun(East China University of Science and Technology)
R2-215	Acceleration Mechanism of Intergranular Cracking of Stainless Steel SUS316LN at Elevated Temperature Caused by Local Strain Energy Around Grain Boundaries	Ayane Yasumura(Tohoku University)
R2-216	Cyclic deformation behaviors and damage mechanisms in P92 steel under creep-fatigue: Effects of hold condition and oxidation	Kang-Kang Wang(East China University of Science and Technology)
R2-217	Numerical Analysis of P91 notched specimen by damage-coupled inelastic constitutive model	Daisuke Kashiwagi(Tokyo University of Science, JAPAN)

FINAL PROGRAM

Wednesday, 8 November [Day 3]

Phoenix

10:30-12:30 — Japanese Activity of Fatigue design and Evaluation Committee in Society of Automotive engineers of Japan

Chair : Toshiaki Nakamura(Nissan Motor Co., LTD) & Hiroaki Kawamura(Toyota motor corporation)

P-301	Activities of Fatigue design and Evaluation Committee in Society of Automotive engineers of Japan	Toshiaki Nakamura(Nissan Motor Co., LTD)
P-302	Evaluation of Fatigue Characteristics of CFRP Bonding Materials by Urethane Adhesive	Masayuki Osada(Hiroshima University)
P-303	Investigation of the Effects of Adherend Materials and Epoxy Adhesive Properties on the Fatigue Strength	Hiroaki Kawamura(Toyota motor corporation)
P-304	Investigation of the effects of adhesive edge shape and Adherend stiffness on fatigue strength of adhesive bonded specimens	Masashi Inoue(Toyota Industries Corporation)

14:00-16:00 /16:20 — Growth of short and long cracks 3

Chair : Yali Yang (Shanghai University of Engineering Science) & Committee

P-307	The Cyclic R-Curve for Predicting Growth and Arrest of Short Cracks	Keisuke Tanaka(Nagoya University)
P-308	Study on fatigue propagation shape of surface crack	Yali Yang (Shanghai University of Engineering Science)
P-309	Influence of exposure to moist air on the fatigue striation formation in a 7175 7351 alloy	Gilbert HENAFF(University of Poitiers)
P-310	A physically small crack growth model based on CTOD	Lu Han(Beihang University)

16:30-18:30/18:50 — Growth of short and long cracks 4

Chair : Motoki Sakaguchi(Tokyo Institute of Technology) & Xiaoguang Yang(Beihang University)

P-313	Fatigue crack propagation in a single crystal and a few-dimensional polycrystalline Ni-base superalloys	Motoki Sakaguchi(Tokyo Institute of Technology)
P-314	Quantitative analysis of fatigue damage of Inconel 718 after creep-fatigue fracture based on micro-pillar tests	Ji Wang(East China University of Science and Technology)
P-315	A Study on Fatigue Crack Propagation in Steel Rail Weld Zones Based on Damage Mechanics and Cohesive Zone Model	Chenhao Ji(Beihang University)
P-316	Effect of sustained load on fatigue crack growth behavior of FGH96 at elevated temperature	Zhitong WANG(Beihang University)
P-317	Consideration on short crack propagation resistance in SM490 steels with different ΔKth	Yoshihiro HYODO(JFE Steel Corporation)
P-318	Small Crack Growth Behaviors and Its Interaction with Microstructures in A Ni-Based P/M Superalloy At High Temperature	Xiaoguang Yang(Beihang University)

Dahlia1

Experimental techniques, corrosion

Chair : Catherine MABRU(University de Toulouse) & Damien DESGACHES(AIRBUS Atlantic)

D1-301	Contribution of the self-heating method in the characterization of the fatigue damage of materials with defects resulting from additive manufacturing	Catherine MABRU(University de Toulouse)
D1-302	Study on Mechanical Properties of Anode Material for Lithium Ion Batteries in Water	Shen Tagai(Tokyo City University)
D1-303	Effect of cyclic hardening on stress corrosion cracking behavior of NiCrMoV steel welded joints	Yuhui Huang(East China University of Science and Technology)
D1-304	Investigation of Fatigue Crack Growth Behavior in Fine Particle Peened 7075 Aluminum Alloy using Digital Image Correlation	Yuichi ONO(Tottori University)
D1-305	Effect of Corrosive Environment on Fatigue Strength Characteristic of Magnesium Alloy Ultrafine Wire	Yuta Sakamoto(The University of Electro-Communications)
D1-306	New coating to prevent premature corrosion of aircraft structure	Damien DESGACHES(AIRBUS Atlantic)

Additive Manufacturing 4

Chair : Lea Strauss(University of the Bundeswehr Munich) & Fabien Szmytka(Institut Polytechnique de Paris)

D1-307	Fatigue Life Prediction of PBF-LB AlSi10Mg based on Roughness and Residual Stress	Lea Strauss(University of the Bundeswehr Munich)
D1-308	Defects tolerance and fatigue limit prediction in additive manufactured titanium alloy Ti6Al4V	Abdul KhaderSyed(Coventry University)
D1-309	Structure Integrity Analysis of Additive Manufactured Cabin Door: Design-Manufacture-Fatigue behavior	Yu'e MA(Northwestern Polytechnical University)
D1-310	Fatigue damage evolution and tolerance in additive manufactured metals	Alexander Koch(TU Dortmund University)
D1-311	Microstructurally Small Fatigue Crack Initiation and Growth Behaviors of Additively-Manufactured Alloy 718	Hideaki Nishikawa(National Institute for Materials Science)
D1-312	High-cycle and Low-cycle Fatigue of a Laser-Powder Direct Energy Deposition manufactured Inconel 625	Fabien Szmytka(Institut Polytechnique de Paris)

Additive Manufacturing 5

Chair : Rui Fu(Harbin Institute of Technology) & Boris Tejman(Institut Polytechnique de Paris)

D1-313	High-Cycle and Very-High-Cycle Fatigue Behavior and Life Prediction of Ti-6Al-4V Fabricated by Laser Powder Bed Fusion	Rui Fu(Harbin Institute of Technology)
D1-314	Low-cycle fatigue of conventional and additively manufactured IN939 superalloy	Tomáš BABINSKY(Institute of Physics of Materials, Czech Academy of Sciences)
D1-315	Coupling effects of microstructure and defects on fatigue properties of 3D-printed Ti-6Al-4V	Zhenjun Zhang(Institute of Metal Research, Chinese Academy of Sciences)
D1-316	Cyclic Strain Localization in Fatigued 316L Stainless Steel Manufactured Additively using Selective Laser Melting (SLM)	Jiří MAN(Institute of Physics of Materials, Czech Academy of Sciences)
D1-317	Influence of the defect tolerance on the fatigue strength of additively manufactured AlSi10Mg	Bastian Blinn(RPTU Kaiserslautern)
D1-318	Assessment of cyclic resistance on stainless steel 316L based cylindrical structures repaired by metal additive manufacturing methods	Boris Tejman(Institut Polytechnique de Paris)
D1-319	Enhancing the Fatigue Performance of Additively Manufactured AlSi10Mg Alloy Using A Novel Chemo-mechanical Surface Treatment	Jidong Kang(CanmetMATERIALS)

Dahlia2

Hydrogen embrittlement

Chair : Aman Arora (Kyushu University) & Daniel Osorio(University of Stuttgart)

D2-301	Development of an experimentally informed model for fatigue crack initiation in metals due to hydrogen	Aman Arora (Kyushu University)
D2-302	Influence of the interaction hydrogen/microstructure on low-cycle fatigue behavior and fatigue crack growth in a precipitation-hardened nickel-based superalloy.	Achraf Radi(University of Technology of Compiègne)
D2-303	Some impact of hydrogen concentration and distribution on low cycle fatigue behavior of an alpha titanium alloy	Larissa Caroline Martins Moreira(La Rochelle University)
D2-304	Review of the antagonistic processes of hydrogen on physical mechanisms of plasticity and their consequences on fatigue behavior of fcc metals	Xavier FEAUGAS (La Rochelle University)
D2-305	Experimental investigation of hydrogen embrittlement on the tensile and low-cycle fatigue properties of an X52 steel	Carl Fischer(Fraunhofer Institute for Mechanics of Materials IWM)

Joint

Chair : Han ShenHe(Zhengzhou University) & Yoshihiko UEMATSU(Gifu University)

D2-307	Effects of tightening torque on vibration fatigue performance of single-lap joints: modal parameter analyses	Hain ShenHe(Zhengzhou University)
D2-308	Evaluation of Fatigue Properties of Adhesive Bond joint with Laser Patterning Surface Treatment	Ryuta Yotsutani(Hiroshima University)
D2-309	Effect of Plate Thickness Ratio on the Fatigue Strength Properties of Friction Stir Spot Welds of Aluminum Alloy	Yuki NOSE(Hiroshima University)
D2-310	Influencing Factors on Fatigue Strength of SPR joint in Magnesium Alloy	Yukio MIYASHITA(Nagaoka University of Technology)
D2-311	Fatigue Strength of Linear Friction Welded Joints for SS400 Steel Plates	Noboru KONDA(Kyushu University)
D2-312	Fatigue Behavior of Al-steel Dissimilar Friction Stir Welds and the Effect of Die Press Working	Yoshihiko UEMATSU(Gifu University)
D2-313	Fatigue performance of A356/6082 dissimilar aluminum alloys butt joint	Mei ZHANG(Shanghai University)

Case studies and industrial applications

Chair : Marcel Krochmal(University of Kassel) & Taizo MAKINO(Nippon Steel Corporation)

D2-314	On the fatigue properties of a S590MC+100Cr6 cladded steel in different fatigue regimes	Marcel Krochmal(University of Kassel)
D2-315	Fatigue behavior of an Off-highway axle subjected to a variable amplitude strain-based load spectrum derived from field tests	Jacopo Pelizzari(University of Padua)
D2-316	Evaluation of Fatigue Strength of Full-scale Induction-hardened Axles for Railway Vehicles and Its Estimation under Very-High-Cycle Regime	Taizo MAKINO(Nippon Steel Corporation)
D2-317	Double-sided ultrasonic surface rolling process for improving the surface integrity and vibration fatigue resistance of titanium welded blade-like samples	Zhang Kaiming(East China University of Science and Technology)
D2-318	Study of impact-sliding composite fretting corrosion of heat exchanger tubes in different concentrations of NaCl solution	Guorui Zhu(Tianjin University)

Cosmos1

Surface engineering 1

Chair : Shirin FALAKBOLAND(RPTU Kaiserslautern) & Koichiro NAMBU(Osaka Sangyo University)

C1-301	Influence of organically modified sol-gel SiO2 coating on the VHCF behavior of austenitic stainless steel AISI 904L	Shirin FALAKBOLAND(RPTU Kaiserslautern)
C1-302	Improvement in Fatigue Strength by Ball Burnishing of Aluminum Alloy with a Surface Defect	Kohei Wakamatsu(Yokohama National University)
C1-303	Effect of Residual Stress on Internal Crack Initiation and Propagation of Induction Heated and Quenched AISI4140 Steel with Different Hardened Layer Depths	Tomofumi Aoki(Keio University)
C1-304	Controlling Factors of Scanning Cyclic Press on the Surface Modification of Magnesium Alloy	Nao Fujimura(Hokkaido University)
C1-305	Fatigue behavior of metastable and stable austenitic stainless steels with different surface morphologies	Tong Zhu(RPTU Kaiserslautern-Landau)
C1-306	Effect of Surface Roughness on Fatigue Strength of Aluminum and Magnesium Alloys	Koichiro NAMBU(Osaka Sangyo University)

Surface engineering 2

Chair : Yang Liu(Northeastern University) & Kiyotaka MASAKI(Saitama Institute of Technology)

C1-307	High Temperature Stability Mechanism of Fatigue Resistance of Warm Laser Shock Peened IN718 Superalloy	Yang Liu(Northeastern University)
C1-308	Effect of Multifunction Cavitation on Rotating Bending Fatigue Properties of Low Alloy Steel Rods	Kazuma Ono(Shizuoka University)
C1-309	Evaluation of the effect of stress ratio and compressive residual stress on the fatigue properties of shot-peened AISI4140 specimens, considering residual stress relaxation	Motoki Hayama(Keio university)
C1-310	Effect of Gas Carburizing on Axial Fatigue Strength of SCM420H Steel	Takayuki Kameoka(The University of Electro-Communications)
C1-311	Residual stress relaxation in Inconel718 cold expanded hole under loading at elevated temperature	Moeri FATMI(University of Technology of Troyes)
C1-312	Surface Crack Propagation Behaviour of Peening Treated A2024 Alloy	Kiyotaka MASAKI(Saitama Institute of Technology)

Surface engineering 3

Chair : Verônica VELLOSO(Sao Paulo State University) & Cheng Ye(Zhengzhou University)

C1-313	Study of the Ti-6Al-4V fatigue behavior superficially treated by plasma immersion ion implantation (PIII) combined with shot peening as pre and post treatment	Verônica VELLOSO(Sao Paulo State University)
C1-314	Low-cycle fatigue investigation of CrCoN multilayer coated Ti-6Al-4V alloy with equiaxed microstructure	Martins Ferreira Fernandes(Sao Paulo State University)
C1-315	Effect of Nitrided-Fine Particle Peening on Formation of Nitrided Layer and Fatigue Properties of Titanium Alloys	Ryuichi Tachigaya(Shizuoka University)
C1-316	Effect of Fine Iron-Sulfide Particle Peening on Rotating Bending Fatigue Properties of Low Alloy Steel	Shotaro NOGUCHI(Shizuoka University)
C1-317	Effect of Oxide Films on Fatigue Properties of Anodically Oxidized Aluminum Alloys	Takeshi ANDO(Hiroshima University)
C1-318	Improving the fatigue performance of Ti64 using electropulsing-assisted ultrasonic peening	Cheng Ye(Zhengzhou University)

Cosmos2

Fatigue modelling and simulation 1

Chair : Thomas Ebbert(Endurica LLC) & Mauro Madia(Bundesanstalt für Materialforschung und -prüfung)

C2-301	Life Prediction and Virtual Qualification of an Elastomeric Engine Mount	Thomas Ebbert(Endurica LLC)
C2-302	Vibration fatigue life prediction of 60Si2Mn fastener clips based on CDM theory and ML model	Wei Dong(Beihang University)
C2-304	Deep Learning-enabled Cyclic Deformation Modeling of Single Crystal Ni-based Superalloy Considering the Effect of Microstructure State	Long TAN(Beihang University)
C2-305	Determination of the Kitagawa-Takahashi diagram for the EA4T railway axle steel by means of the cyclic R-curve method	Mauro Madia(Bundesanstalt für Materialforschung und -prüfung)
C2-306	Microstructure-induced cracking and life prediction of Inconel 713C superalloy for very high cycle fatigue at elevated temperatures	Xiaolong LI (East China University of Science and Technology)

Fatigue modelling and simulation 2

Chair : Pascale KANOUTE(ONERA) & Wenyi Yan(Monash University)

C2-307	Multiaxial Fatigue Criteria for the Fatigue Life Assessment of Metallic Assemblies	Pascale KANOUTE(ONERA)
C2-308	Crack Closure and Fatigue Crack Growth under Variable Amplitude Loading	Andrei Kotousov(The University of Adelaide)
C2-309	A mesoscopic damage model for the low-cycle fatigue of an extruded magnesium alloy	Ziyi Wang(Southwest Jiaotong University)
C2-310	A Simple and Accurate Fatigue Life Prediction Method under Variable Loading	Shoma Ueda(Tokyo City University)
C2-311	Modelling the influence of clustered defects on HCF properties of Ni-based superalloys	Arjun Kalkur MATPADI RAGHAVENDRA(Centre des Matériaux)
C2-312	Numerical Study on Rolling Contact Fatigue Cracks in Curved Railway Tracks	Wenyi Yan(Monash University)

Fatigue modelling and simulation 3

Chair : Antti Forsström(VTT Technical Research Center of Finland) & Huang Yuan(Tsinghua University)

C2-313	Fatigue modelling of martensitic steel for engine components	Antti Forsström(VTT Technical Research Center of Finland)
C2-314	A fast Neuber-type Finite Element simulator to calibrate a multi-mechanism HCF model of alloys with process-induced pores	Abhishek Palchoudhary(Mines Paris PSL University)
C2-315	FFT-based Crystal Plasticity Simulation of Cyclic Loading of SLM AlSi10Mg	Manoj Singh Bisht(Indian Institute of Technology Roorkee)
C2-316	Creep Rate of Anode Material for Lithium-ion Batteries under High Temperature Environment	Kairi Shiraishi(Tokyo City University)
C2-317	Investigation of Simple Mechanical Model for Fatigue Life Prediction of Anode Material for Lithium-ion Batteries	Masaya Ueda(Tokyo City University)
C2-318	Microstructure-based fatigue life assessment of additively manufactured nickel-based superalloy	Huang Yuan(Tsinghua University)

Iris1

Cyclic deformation and crack initiation 4

Chair : Viet Duc LE(Arts et Métiers Institute of Technology) & Zhefeng Zhang(Institute of Metal Research Chinese Academy of Sciences)

R1-301	Investigation of the torsional fatigue crack initiation mechanisms in the cast AlSi7Mg0.3 aluminum alloy using combined 3D X-ray CT and diffraction contrast tomography in a synchrotron beamline	Viet Duc LE(Arts et Métiers Institute of Technology)
R1-302	Fatigue damage and temperature evolution under anisotropic cyclic deformation in a single crystal Ni-base superalloy using notched specimens	Pull Tiansakul(Tokyo Institute of Technology)
R1-303	Phase-field simulation on the martensitic transformation/reorientation toughening behaviors of single crystal NiTi shape memory alloy	Junyuan Xiong(Southwest Jiaotong University)
R1-304	Analysis and modeling of the strain distribution and evolution during a fatigue test in LLCF and LCF, Application on a friction stir welded specimen from steel and aluminum	Paul Dario TOASA CAIZA(Karlsruhe Institute of Technology)
R1-305	A review on the fatigue cracking of twin boundaries: crystallographic orientation and stacking fault energy	Zhefeng Zhang(Institute of Metal Research, Chinese Academy of Sciences)
R1-306	Low-cycle fatigue of CrCoNi medium-entropy alloy with different grain sizes	Linlin Li(Institute of Metal Research, Chinese Academy of Sciences)

Cyclic deformation and crack initiation 5

Chair : Constanze Backes(RPTU Kaiserslautern) & Lei Xu(Institute of Metal Research, Chinese Academy of Sciences)

R1-307	Influence of mechanical fatigue on magnetic properties of electrical steels	Constanze Backes(RPTU Kaiserslautern)
R1-308	Influence of different temperatures on the fatigue behavior of fully ferritic high chromium steel	Patrick Lehner(RPTU Kaiserslautern)
R1-309	Cyclic Simple Shear Properties of Single- and Poly-crystalline Fe and Fe?3wt%Si alloys	Mamoru HAYAKAWA(Nippon Steel Corporation)
R1-310	Effect of Lüders strain localization on notch fatigue of medium manganese steels	Xiangtao Hu(Hunan university)
R1-311	Evaluation of Fatigue Properties of CFRP and Experimental Elucidation of Damage Growth Mechanism	Yuta Koga(Waseda University)
R1-312	Achieving superior fatigue strength in a powder-metallurgy titanium alloy via in-situ globularization during hot isostatic pressing	Lei Xu(Institute of Metal Research, Chinese Academy of Sciences)

Cyclic deformation and crack initiation 6

Chair : Shuxin Chang(Southwest Jiaotong University) & Committee

R1-314	Experimental investigation of early strain localizations on ferrite-pearlite steel under cyclic loading.	Nagesh Narasimha Prasad(Univ. Lille)
R1-315	Multi-mechanism constitutive model for uniaxial ratchetting of extruded AZ31 magnesium alloy at room temperature	Yu Lei(Southwest Jiaotong University)
R1-316	Cyclic responses and damage evolution of ultra-high strength steel under low-cycle fatigue	Feihong Gao(Beijing Institute of Technology)
R1-317	Mechanism-based assessment of profiles made from directly recycled hot extruded EN AW-6060 aluminum chips	Alexander Koch(TU Dortmund University)
R1-318	Phase transformation and ratcheting behavior of medium manganese steel under asymmetrical cyclic stressing: experiments, phase-field simulations and meso-mechanical constitutive model	Shuxin Chang(Southwest Jiaotong University)

Iris2

Very high cycle fatigue 1

Chair : Luis Reis(IDMEC) & Bernd M. SCHÖNBAUER(University of Natural Resources and Life Sciences)

R2-301	Different Axial/Shear Stress Ratios under Tension/Torsion UFT	Luis Reis(IDMEC)
R2-302	Effects of microstructure refinement and metallic adhesion on the sub-surface fatigue crack propagation process in Ti6Al4V alloy	Hiroyuki OGUMA(National Institute for Materials Science)
R2-303	20 kHz cantilever fatigue testing of high strength precision strip steels in different load conditions	Mohamed Sadek(Karlstad University)
R2-304	Fatigue assessment in the HCF and VHCF regimes of PM-HIPed Inconel 625	Faezeh Javadzadeh Kalahroudi(Karlstad University)
R2-305	High and very high cycle fatigue properties of pearlitic rail steel R350HT	Bernd M. SCHÖNBAUER(University of Natural Resources and Life Sciences)
R2-306	Crack Initiation and Propagation of Cruciform Specimens in Ultrasonic Fatigue Testing	Luis Reis(IDMEC)

Very high cycle fatigue 2

Chair : Yoshinobu Shimamura(Shizuoka University) & Tao Wu(Nanjing University of Aeronautics and Astronautics)

R2-307	Effect of Mean Torsional Stress on Torsional Fatigue Strength in the Very High Cycle Regime for Spring and Bearing Steels	Yoshinobu Shimamura(Shizuoka University)
R2-308	Study and modeling of Fatigue Properties at Very Large Cycles from Self-heating Tests under Cyclic Loads	Théo SEVEDE(IRDL)
R2-309	A naturally initiated internal fatigue crack growth process in beta titanium alloy using in situ synchrotron radiation multiscale computed tomography	Gaoge Xue(Hokkaido University)
R2-310	Physics-informed neural networks for very high cycle fatigue	Mingliang Zhu(East China University of Science and Technology)
R2-311	Interior microstructure induced cracking of a NiCr20TiAl alloy at elevated temperature	Gang Zhu(East China University of Science and Technology)
R2-312	A VHCF Life Prediction Method Based on Surface Crack Density for FRP	Tao Wu(Nanjing University of Aeronautics and Astronautics)

Journals' Meeting

FINAL PROGRAM

Friday, 10 November [Day 5]

Dahlia1

8:00-10:00 — Thermo-mechanical fatigue 1

Chair : Vincent Maurel(Mines Paris, PSL University) & Xu Chen(Tianjin University)

D1-501	Anisotropic thermomechanical fatigue assessment of nickel-base single crystal alloys	Jiawei Xu(Tsinghua University)
D1-502	Role of temperature gradient in thermo-mechanical fatigue analyzed through micro-cracks growth	Vincent Maurel(Mines Paris, PSL University)
D1-503	Crack Growth Behavior of 316LN Stainless Steel under Thermomechanical and Isothermal Fatigue Loading	Yiming Zheng(Tianjin University)
D1-504	Material characterization of pearlitic railway steels exposed to simultaneous thermal and mechanical cycling	Erika Steyn(Chalmers University of Technology)
D1-505	Thermomechanical fatigue behavior of 316LN stainless Steel	Xu Chen(Tianjin University)

10:30-12:30 — Thermo-mechanical fatigue 2

Chair : Mi Wang(Beihang University) & Lu ZHANG(Nanjing University of Aeronautics and Astronautics)

D1-507	A CTOD-based fatigue crack growth model under high temperature and dwell time	Mi Wang(Beihang University)
D1-508	A comparison of the thermomechanical fatigue behavior of electron-beam-melted and conventional Inconel 718	Stefan Guth(Karlsruhe Institute of Technology)
D1-509	Development of a thermal fatigue characterization protocol for metal alloys, adapted to characterize the strength of repaired structures	Nicolas Thurieau(Institut Polytechnique de Paris)
D1-510	Cyclic deformation and fracture mechanisms of powder-metallurgy nickel-based superalloy under thermo-mechanical fatigue	Lu ZHANG(Nanjing University of Aeronautics and Astronautics)
D1-511	Constitutive Modelling of alloys under high temperature low-cycle and thermal- mechanical fatigue: a key issue in component design	Luc REMY(Mines Paris, PSL University)

14:00-16:00 — Crack growth thresholds

Chair : Hisao Matsunaga(Kyushu University) & Salim ÇALIŞKAN(Turkish Aerospace)

D1-513	Quantitative Evaluation of the Sliding-mode Crack-closure Affecting the Shear-mode Fatigue Crack-growth Threshold in Ni-based Superalloy 718	Hisao Matsunaga(Kyushu University)
D1-514	Fatigue crack propagation behavior of Inconel 718 superalloy aged with different temperature/stress coupled fields	Lu WANG(Northeastern University)
D1-515	In-situ scanning electron microscopy observation of crack closure of non-propagating fatigue crack in Fe alloy	Atsushi Takayama(Nippon Steel Corporation)
D1-516	Fatigue Limit Evaluation of Ni-based Superalloy 718, Considering the Competition between Opening- and Shear-mode Fatigue Crack-growth	Yuya Tanaka(Fukuoka University)
D1-517	Investigation of failure analysis for AISI 4340 steels on near threshold region	Salim ÇALIŞKAN(Turkish Aerospace)

Dahlia2

8:00-10:00 — Life prediction methodology, software development 1

Chair : Marcos Pereira(Pontifical Catholic University of Rio de Janeiro) & Marion Bartsch(German Aerospace C

D2-501	Investigation on Fatigue Life Estimation of GH4169 Superalloy at Elevated Temperature Based on Thermodynamic Entropy Generation	Langfeng ZUO(Beihang University)
D2-502	Modelling the effect of a superficial defect over the fatigue-life structural steels: a modified version of the S-N curve	Marcos Pereira(Pontifical Catholic University of Rio de Janeiro)
D2-503	Multiscale Modeling Strategy for Accurately Predicting Fatigue Life of Steels	YOO CHAN(Korea University)
D2-504	A Physics-informed Neural Network for Probabilistic Fatigue Life Prediction under Constant Amplitude Loading with Overloads	Shan Jiang(Minzu University of China)
D2-505	Probabilistic estimation of the Woehler and Goodman-Haigh curves by considering the stress ratio effect	Paul Dario TOASA CAIZA(Karlsruhe Institute of Technology)
D2-506	High Temperature Fatigue Tests on Small-scale Specimens Extracted from High Pressure Turbine Blades for Calibrating an Efficient Lifetime Model	Marion Bartsch(German Aerospace Center)

10:30-12:30 — Life prediction methodology, software development 2

Chair : Tiago Castro(Pontifical Catholic University of Rio de Janeiro) & Yongzhen ZHANG(Institute of Corrosion Science and Technology)

D2-507	On the influence of mean stresses on the predictive capability of the elliptical curve method	Tiago Castro(Pontifical Catholic University of Rio de Janeiro)
D2-508	Machine learning-based fatigue life prediction of metal materials: Perspectives of physics-informed and data-driven hybrid methods	Haijie Wang(East China University of Science and Technology)
D2-509	Prediction of fatigue crack growth life under complex environmental loads via cycle-by-cycle algorithm and XFEM	Zhiying Chen(Tsinghua University)
D2-510	On the integration of domain knowledge and branching neural network for fatigue life prediction with small samples	Lei GAN(Harbin Institute of Technology)
D2-511	Methodology for pore detection and classification with regard to fatigue of PBF-LB/M-manufactured 316L using μCT and machine learning algorithms	Johannes Diller(Technical University of Munich)
D2-512	Prediction of Corrosion Fatigue Crack Growth Rate in Alloys Based on Quantitative Expression of Data Nonlinear Correlation	Yongzhen ZHANG(Institute of Corrosion Science and Technology)

14:00-16:00 — Effective factors

Chair : Masatoshi Kuroda(Kumamoto University) & Wandong Wang(School of Aeronautics, Northwestern Polytechnical University)

D2-513	Separate Effects of Surface Roughness and Residual Stress on Fatigue Limit of Austenitic Stainless Steels	Masatoshi Kuroda(Kumamoto University)
D2-514	Influence of manufacturing process, heat treatment and microstructure on fatigue properties of carbide-rich high-speed steels	Lennart Mirko Scholl(RWTH Aachen University)
D2-515	Bidirectional Transformation: A Novel Approach to Enhance Fatigue Durability of Steel	Fumiyoshi Yoshinaka(National Institute for Materials Science)
D2-516	Fatigue crack growth behavior of metallic plates reinforced with bonded and prestressed retarders	Wandong Wang(School of Aeronautics, Northwestern Polytechnical University)
D2-517	An analytical approach to evaluate fatigue behaviour of notched specimens in VHCF: challenges, accomplishments and limitations	Abílio Jesus (University of Porto)
D2-518	Influence of Metallurgical Variables on Corrosion Fatigue Strength of Structural Steels	Ryuichiro Ebara (Fukuoka University)

Cosmos1

8:00-10:00 — Very high cycle fatigue 3

Chair : Anja Weidner(TU Bergakademie Freiberg) & Chong Wang(Sichuan University)

C1-501	Very high cycle fatigue at RT and elevated temperatures on additively manufactured materials	Anja Weidner(TU Bergakademie Freiberg)
C1-502	Contribution of self-heating measurements under cyclic loading to the study of VHCF properties at high temperature of nickel-based superalloys	Alexis MION(Institut Polytechnique de Paris)
C1-503	Nanograin formation mechanism under fatigue loadings in additively manufactured Ti-6Al-4V alloy	Weiqian Chi(Beijing Jiaotong University)
C1-504	Very high cycle fatigue properties of bearing steels at elevated temperature	Suraj More(University of Natural Resources and Life Sciences)
C1-505	Factors in ODA-like Morphology on the Fracture Surface in Beta Titanium Alloys	Rajshree Awasthi(Hokkaido University)
C1-506	Thermodynamic investigation on the Crack Growth Behavior at Very High Cycle Fatigue Regime	Chong Wang(Sichuan University)

10:30-12:30 — Very high cycle fatigue 4

Chair : Yuki Nakamura(National Institute of Technology, Toyota College) & Yoshiyuki Furuya(National Institute for Materials Science)

C1-507	Construction of Probabilistic Model on Interior Crack Nucleation and Propagation in Very High Cycle Fatigue of High Strength Steels	Yuki Nakamura(National Institute of Technology, Toyota College)
C1-508	Fatigue Mechanism for an Additively Manufactured Aluminum Alloy up to Very-High-Cycle Regime	Xiangnan PAN(Institute of Mechanics, Chinese Academy of Sciences)
C1-509	Localized oxidation assisting microcrack initiation in a LPSO-reinforced Mg-RE alloy up to very-high-cycle-fatigue regime	Yao Chen(Kyushu University)
C1-510	Characterising the very high cycle fatigue behavior of CF-PEKK material under ultrasonic cyclic bending loads	Arvind Premanand(University of Freiburg)
C1-511	New fatigue limits in gigacycle fatigue of high-strength steels	Yoshiyuki Furuya(National Institute for Materials Science)
D2-213	Very High Cycle Fatigue of Laser Additively Manufactured Titanium and Nickel Alloys	Yao CHEN (Sichuan University)

14:00-16:00 — Very high cycle fatigue 5

Chair : Elen Ragitz(RPTU Kaiserslautern) & Yevgen GORASH(University of Strathclyde)

C1-513	Microstructural changes during fatigue loading in the very high cycle regime of the metastable austenitic steel AISI 347 at 573 K	Elen Ragitz(RPTU Kaiserslautern)
C1-514	Mechanism of nanograin formation and crack initiation for very high cycle fatigue of titanium alloys	Chengqi Sun(Institute of Mechanics, Chinese Academy of Sciences)
C1-516	Effects of Induction hardening and Press-Fitting on Very High Cycle Fatigue Properties of Railway Axle Steel	Makoto AKAMA(Osaka Sangyo University)

Cosmos2

8:00-10:00 — Fatigue modelling and simulation 4

Chair : Franck MOREL(Arts et Metiers Institute of Technology) &Daiyang Gao(Nanjing University of Science and

C2-501	Modelling Cyclic Deformation and Fatigue Crack Growth through Coupling of Phase Field and Viscoplasticity	Liguo Zhao(Nanjing University of Aeronautics and Astronautics)
C2-502	Process-performance-prediction integration oriented to fatigue life improvement: Implementation in high-temperature structures based on dual-scale modeling approach	Kai-Shang Li(East China University of Science and Technology)
C2-503	Physics-based modelling of HCF variability in carburized steels	Franck MOREL(Arts et Metiers Institute of Technology)
C2-504	Phase-Field and Crystal Plasticity Coupling Model Investigation of Grain Growth under Fatigue Loading	Wei Peng(East China University of Science and Technology)
C2-505	Molecular Dynamics Analysis of the Effect of Strain Rate on the Acceleration of the Degradation of the Crystallinity of a Grain Boundary under Creep-Fatigue Loads at Elevated Temperature	TakumaYamawaki(Tohoku University)
C2-506	Spectral method for fatigue life estimation of notched metallic structures under broad-band random vibration loadings	Daiyang Gao(Nanjing University of Science and Technology)

10:30-12:30 — Fatigue modelling and simulation 5

Chair : Kazuki Shibanuma(The University of Tokyo) & Larissa Duarte(Bundesanstalt für Materialforschung und -prüfung)

C2-507	Multiscale Modeling Strategy for Accurately Predicting Fatigue Life of Steels	Kazuki Shibanuma(The University of Tokyo)
C2-508	A Bridging Strategy between Microscopic and Macroscopic Crack Growth Simulations for Predicting Fatigue Strength of Steels	Hongchang ZHOU(The University of Tokyo)
C2-509	An elastoplastic constitutive model for effect of loading history on ratcheting and cyclic hardening behavior	Jiawei Bai(School of Aerospace Science and Technology)
C2-510	Fatigue behavior and cyclic slip irreversibility of AlCoCrFeNi high entropy alloys: A molecular dynamics simulation study	Dongxing Pan(Hunan university)
C2-511	A Bridging Strategy between Microscopic and Macroscopic Crack Growth Simulations for Predicting Fatigue Strength of Steels	Yun-Jae Kim(Korea University)
C2-512	Fatigue assessment procedure based on effective crack propagation data and cyclic R-curve	Larissa Duarte(Bundesanstalt für Materialforschung und -prüfung)

14:00-16:00 — Fatigue modelling and simulation 6

Chair : Abel Santos (University of Porto) & Yongtao Bai(Chongqing University)

C2-513	A unified approach for the fatigue categorization of cold-formed mild steel details	Abel Santos (University of Porto)
C2-514	A continuum damage mechanics-based machine learning approach for thermal fatigue life prediction of aluminum alloy	Zhen Zhan(Beihang University)
C2-515	Studying the Fatigue Strength in the VHCF Regime of an Epoxy used for Fiber-Reinforced Polymers	Malo Rosemeier(Fraunhofer Institute for Wind Energy Systems IWES)
C2-516	Comprehensive Comparison between two different fatigue modeling methods for welded hollow spherical joints	Yongtao Bai(Chongqing University)
C2-517	Incorporation of Notch Size Effect Correction Factors into the Correlation Parameter between Fatigue Strength Diagrams of Smooth and Notched Specimens and Induction of Master Diagrams as Base Data for Estimation of Fatigue Strength of Machine Parts and Structural Elements	Hiroshi MATSUNO(Sojo University)

Ran1

8:00-10:00 — Fiber composites

Chair : Sylvie Castagnet(University of Poitiers) & Andreas Baumann(Leibniz-Institut für Verbundwerkstoffe Gmb

R1-501	Fatigue Properties of Short Fiber Reinforced Polyamides exposed to acid environment	Sylvie Castagnet(University of Poitiers)
R1-502	Evaluation of Fatigue Properties of Injection Molded Plates of Short Glass Fiber Reinforced Composites Based on Matrix Phase Stress	Kenichi Shimizu(Meijo University)
R1-503	Fatigue crack evolution of thermoplastic-based fiber metal laminates under application-related temperatures	Selim Mrzljak(TU Dortmund University)
R1-504	Fatigue damage evolution and damage tolerance of composite structures	Selim Mrzljak(TU Dortmund University)
R1-505	Correlating composite fatigue to its matrix properties	Andreas Baumann(Leibniz-Institut für Verbundwerkstoffe GmbH)
R1-506		

10:30-12:30 — Cyclic deformation and crack initiation 7

Chair : Zhengguan Lu(Institute of Metal Research, Chinese Academy of Sciences) & Marek Smaga(RPTU Kaiserslautern)

R1-507	Effect of thermal induced porosity on high-cycle fatigue and very high-cycle fatigue behaviors of hot-isostatic-pressed Ti-6Al-4V powder components	Zhengguan Lu(Institute of Metal Research, Chinese Academy of Sciences)
R1-508	Effect of powder size on fatigue properties of Ti-6Al-4V powder compact using hot isostatic pressing	Jie Wu(Institute of Metal Research, Chinese Academy of Sciences)
R1-509	Creep-fatigue crack initiation criterion for crystallographic evolutions based on damage mechanics descriptions	Run-Zi Wang(Tohoku University)
R1-510	Dynamic Evolution and Crystal Plasticity Study of GCr15 Bearing Steel Damage under Cyclic Loading	Liu Tengyuan(Institute of Metal Research, Chinese Academy of Sciences)
R1-511	Non-uniform cyclic temperature field induced deformation behavior of IN718 in thermal gradient mechanical fatigue	Shaochen BAO(Beihang University)
R1-512	Fatigue behavior of metastable Fe-based austenites	Marek Smaga(RPTU Kaiserslautern)

14:00-16:00 — Cyclic deformation and crack initiation 8

Chair :Wei Li(Beijing Institute of Technology) & Zhenlei Li(Beihang University)

R1-514	In-site Mesoscopic Tension and Fatigue Properties of Proton Exchange Membrane for Fuel Cell	Wei Li(Beijing Institute of Technology)
R1-515	Study on the effects of inclusions on the fatigue properties of bearing steels	Peng Zhang(Institute of Metal Research, Chinese Academy of Sciences)
R1-516	Crystallographic mechanism of fatigue failure of zirconium alloys	Conghui Zhang(Xi'an University of Architecture and Technology)
R1-517	High Frequency High Cycle Bending Fatigue Failure Mechanism of Blade-like Specimen at High Stress Ratio under Biaxial Tension-bending Load	Zhenlei Li(Beihang University)
R1-518	Improving the fatigue defect tolerance of steels by Cu precipitates	Dietmar Eifler (RPTU Kaiserslautern)

Ran2

8:00-10:00 — Variable amplitude loads, multiaxial and mixed mode fatigue 1

chair : Matus Margetin(Slovak University of Technology in Bratislava) & Michael Marx(Saarland University)

R2-501	Application of energy-based damage accumulation rule for fatigue monitoring of structure under variable amplitude loading	Matus Margetin(Slovak University of Technology in Bratislava)
R2-502	Micromechanical study of low-cycle fatigue behavior of additively manufactured Inconel 718 superalloy at ambient and elevated temperatures	Xin Zhang(Harbin Institute of Technology)
R2-503	Strain distribution of a fir-tree tenon/mortise structure under combined high and low cycle fatigue loads	Han Yan Dr.(Beihang University)
R2-504	An in-situ SEM investigation on fatigue crack growth mechanism under single overload	Lindong Chai(Beihang University)
R2-505	Fatigue of metallic glasses after an overload as a first step to fatigue under variable amplitude loading	Michael Marx(Saarland University)
R2-506	An iso-damage model based on residual S-N curves to consider fatigue damage accumulation under HCF-VHCF loads	Tao Liang(Beihang University)

10:30-12:30 — Variable amplitude loads, multiaxial and mixed mode fatigue 2

chair : Christian Kontermann(TU Darmstadt) & Peter Haefele(University of Applied Sciences Esslingen)

R2-507	Crack Initiation and Relaxation Behavior of a 1Cr-Cast Steel under Multiaxial High Temperature Loading	Christian Kontermann(TU Darmstadt)
R2-508	Fatigue behaviors and life evaluation of AISI 304 under multiaxial non-proportional random loading	Yu-Chen WANG(Ritsumeikan University)
R2-509	Fatigue Life Estimation Method Using Equivalent Stress Amplitude by Smith-Watson-Topper Method for SCM440	Naoki Hashimoto(Hiroshima University)
R2-510	Investigation of the test evaluation for the determination of multiaxial material properties	Alexander Linn(Clausthal University of Technology)
R2-511	Influence of cut edge and notch on electric steel strip under constant and variable amplitude loading	Peter Haefele(University of Applied Sciences Esslingen)

三、會議重點摘要

1842 年 5 月 8 日民眾在法王路易-菲利普一世於凡爾賽宮慶典結束後，搭乘列車返回巴黎。途中車頭輪軸脫落出軌，而煤車翻覆導致嚴重大火圖（3.1），這場法國第一起的鐵路事故，也是全球首例的鐵路大災難，約有 52 至 200 名乘客死亡。當時金屬冶煉的品質較差，因而導致輪軸脫落，此起事故也開啟人們對金屬疲勞進行有系統的研究。當局也提出兩項改善建議：取消把乘客鎖在車廂內的規定、輪軸使用到一定程度後需進行更換，以保障鐵路安全。

圖 3.1 凡爾賽鐵道事故

「疲勞」是一個材料領域的專門術語，描述重複載荷下的變形，這種現像在 19 世紀工業革命期間開始出現，並成為廣泛研究的主題。最初大多數研究都是使用工程方法進行的，透過根據應力標準掌握疲勞壽命來防止失效。隨後開展了基於塑性應變的壽命評估方法和實際工作載荷下的疲勞壽命估算方法的研究。此外，隨著光學顯微鏡、透射及掃描電子顯微鏡、同步輻射等觀察儀器的發展，人們進行了廣泛的研究，重點是基於顯微觀察來了解疲勞裂紋產生機制，及疲勞裂紋擴展的機制，以解決材料疲勞的問題，避免材料因疲勞失效造成重大損害。

早期研究對象僅限於金屬材料，通常稱為金屬疲勞，但隨著工程陶瓷、樹脂材料和複合材料的出現，以及根據金屬疲勞理論開發的新型先進材料，疲勞的研究範圍也逐漸擴大。國際疲勞力學大會匯集了從事疲勞斷裂機制實驗、理論和表徵研究的學者和工程師，為相關領域的發現、想法和經驗提供交流的環境。

IFC 會議因疫情因素而延期兩年後再次舉辦，本會係初次參加，在此謹將對本會具參考價值之主題與內容摘要如下：

3.1 專題演講（Keynote Speak）

<u>以超音波疲勞測試來看疲勞近臨界值裂紋生長的微觀結構影響的特徵</u>

開場的專題演講是德國德勒斯登大學材料系教授 Martina Zimmermann（圖 3.1.1），現為德國材料科學學會（DGM）主席，同時也是德國工程學院院士。講題是以超音波疲勞測試來看疲勞近臨界值裂紋生長的微觀結構影響的特徵。自 1973 年開始學者即開始以超音波作為疲勞裂縫生長的檢驗工具（圖 3.1.2），迄今新型客機如空中巴士 A350 的維修檢驗亦如是，是實務界常見可告的檢測方式。

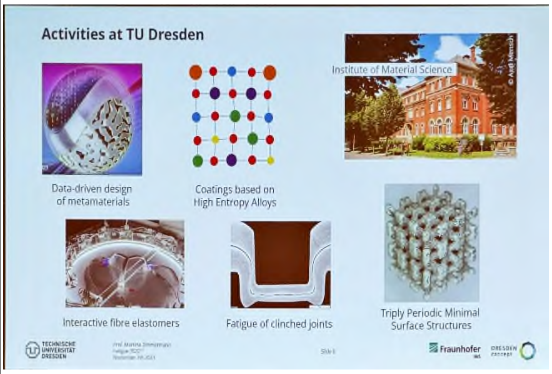


圖 3.1.1 Martina Zimmermann 研究範圍

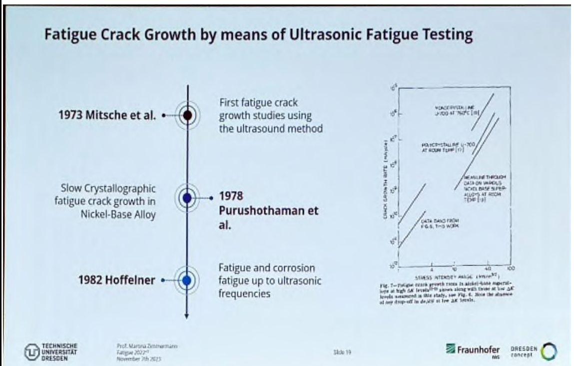


圖 3.1.2 超音波作為疲勞裂縫檢驗工具

金屬材料的超高週期疲勞（VHCF）的研究，通常集中在總使用壽命以及使用壽命與裂紋產生之間的關係。此研究以鋁合金作為實驗材料，觀察鋁合金於低週期時初期產生裂紋（圖 3.1.3），即第一階段的疲勞，裂紋成長再依 Paris'Law 的調整 ΔK^m 至臨界值，即第二階段的疲勞（圖 3.1.4、3.1.5），以超音波疲勞測試來看疲勞近臨界值裂紋生長的微觀結構，證實載重循環次數導致裂紋初期產生的重要性明顯高於裂紋成

長階段的載重循環次數（圖 3.1.6）。然而，對破損過程的完整描述當然必須包括裂紋成長階段。當零組件從一開始就已經破裂或有瑕疵時，疲勞裂紋成長行為就變得特別重要。

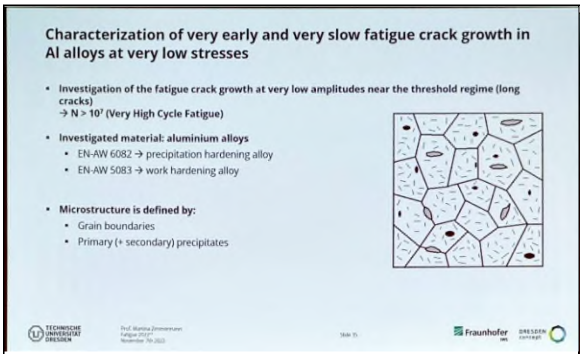


圖 3.1.3 第一階段的疲勞

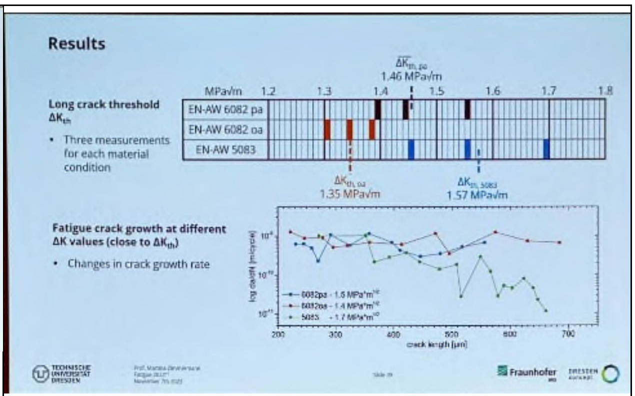


圖 3.1.4 第二階段的疲勞

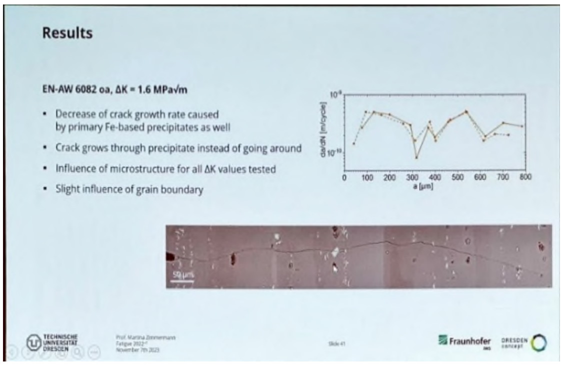


圖 3.1.5 第二階段的疲勞

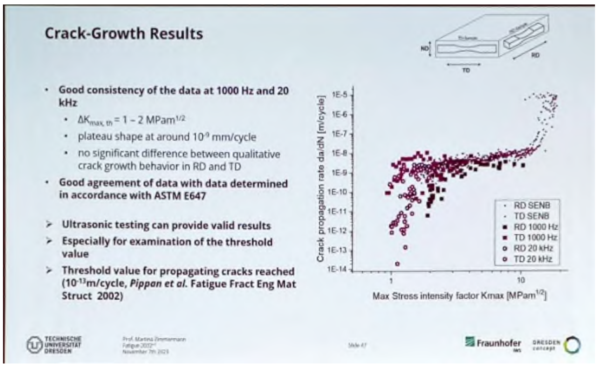


圖 3.1.6 第一階段與第二階段比較

同步輻射於金屬疲勞非破壞性檢測之運用

另外一場的專題演講是日本九州大學機械與航太工程系教授 Takashi Nakamura 主講關於同步輻射於金屬疲勞非破壞性檢測之運用。

在過去的四分之一個世紀中，極高循環週期疲勞（VHCF）現像已被認識並進行了廣泛研究。 VHCF 最奇特和最顯著的特徵之一是在超過 10^6-10^7 個週期的長壽命狀態下，裂痕的起始點從材料表面到內部的轉變。特別是在高強度金屬中，微小的部位都可能成為內部疲勞裂紋的起點，例如高強度鋼中幾微米至幾十微米的非金屬雜質（inclusion）和鈦合金中數十微米的晶粒（crystal grain）。

然而傳統的非破壞檢測方法（例如工業 X 光電腦斷層掃描 CT 或超音波 CT）皆很難檢測到如此微小的裂縫。有鑑於此，該研究嘗試使用日本 SPring-8 （圖 3.1.7、3.1.8）提供的同步輻射多尺度 X 光 CT。 該系統包括約為 1 μm 的投影 CT 和解析度約為 200 nm 或更高 CT 成像。該研究介紹使用多尺度 X 射線 CT 和原位疲勞測試來說明內部疲勞裂紋行為的實驗方法。以 VHCF 為探討方向，使用（α+β）型 Ti-6Al-4V、β型 Ti-22V-4Al、17-4 析出硬化的麻田散鐵系不鏽鋼三種材料進行試驗。描述了多尺度 X 射線 CT 的概要和主要性能，並討論了上述材料內部疲勞裂紋的產生和成長行為（圖 3.1.9、3.1.10），以深入了解 VHCF 現象。

圖 3.1.7 日本兵庫縣同步輻射中心

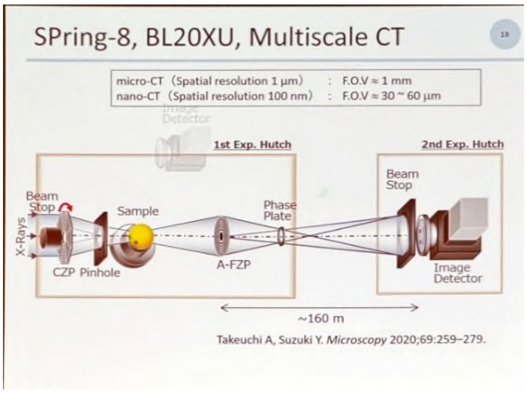


圖 3.1.8 日本 SPring-8

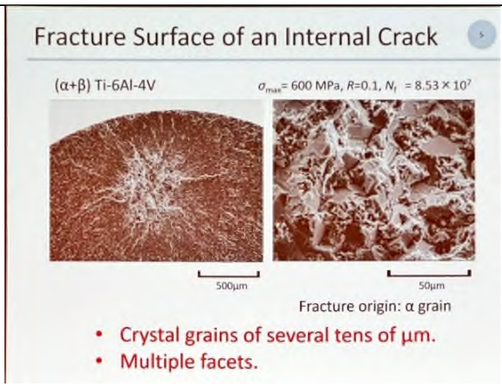


圖 3.1.9 斷裂面內部疲勞裂紋

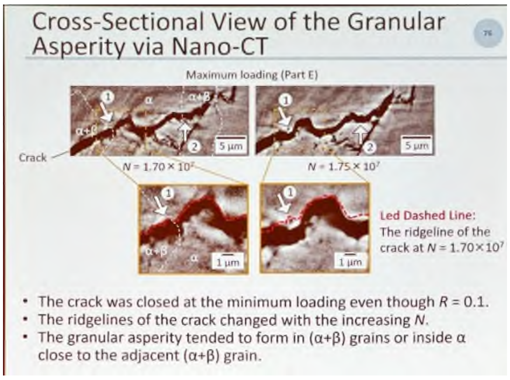


圖 3.1.10 以奈米級電腦斷層看晶界截面

3.2 日本福島核災後 疲勞曲線修正

西元 2011 年日本大地震，福島核核能電廠所造成的災害，怵目驚心。雖然流體運輸管線災害非本會執掌項目，惟部分國家的已將運輸管線列入調查範圍，例如美國國家運輸安全委員會（NTSB）即屬之。本次由日本主辦的會議選擇在核爆的廣島和平國際會議中心舉辦（圖 3.2.1），並以福島核災十幾年後，耗費許多研究資源所修正的疲勞曲線，除了體現對待核能的審慎態度，也別具意義。

圖 3.2.1 本屆會議場地-廣島原爆後興建的和平公園

定義新疲勞曲線和分析會議係由日本銲接工程學會（JWES）負責，在本次會議中詳細介紹的主題，包括最佳擬合曲線的開發、平均應力修正法、基於 SWT 的平均應力修正、表面處理的影響、銲縫疲勞分析以及透過大規模測試驗證尺寸效應。

為了開發新的設計疲勞曲線和設計疲勞評估方法，日本銲接工程學會（JWES）原子能研究委員會內成立了設計疲勞曲線（DFC）第 1 至第 4 階段小組委員會，成員由日本學界與諸多重工業的實務界人士組成（圖 3.2.2）。

圖 3.2.2 日本新疲勞曲線參與公司

疲勞曲線通常係由曲線擬合 （Curve fitting）建構而成，該委員會先收集了日本國內外小型試片在常溫下的疲勞數據，建構了綜合疲勞資料庫。基於此疲勞資料庫之數據，以拉伸強度為參數並參酌設計因子，建構出碳鋼、低合金鋼和沃斯田鐵不鏽鋼的最佳擬合曲線。 此外，日本公用事業合作計畫使用沃斯田鐵不鏽鋼管路和低合金鋼平板進行了大規模疲勞試驗，使用小試片進行了疲勞試驗。這些試驗不僅要獲得基礎數據，還要取得平均應力效應、表面處理效應和尺寸效應的疲勞數據。委員會藉由這些測試結果，開發了新的設計疲勞曲線和疲勞評估方法（圖 3.2.3）。

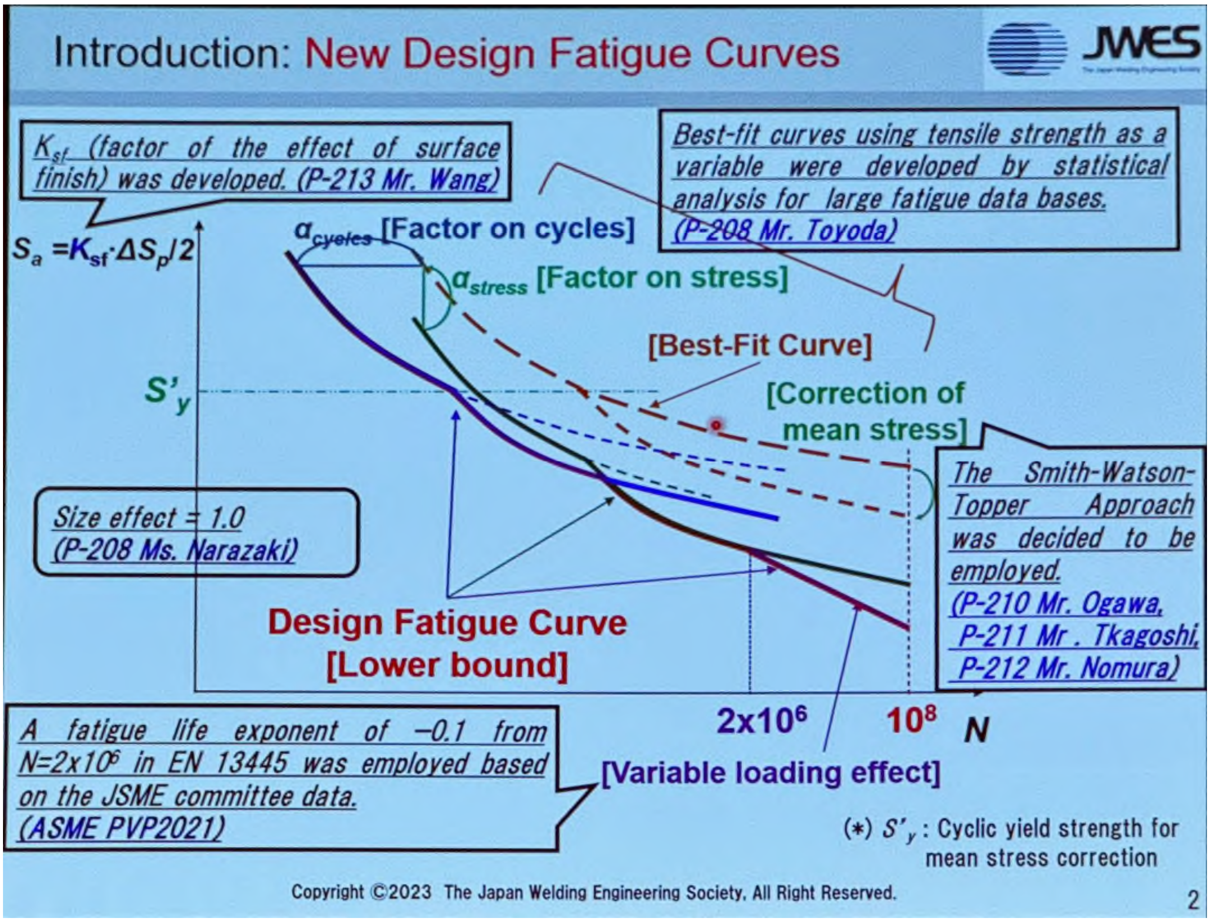


圖 3.2.3 新疲勞曲線

設計疲勞曲線是基於使用小試片進行疲勞試驗所獲得的最佳擬合疲勞曲線（BFC，Best Curve fitting）。根據美國核管會（NRC）NUREG/CR-6909 Rev.1，BFC（由 25% 應力降循環定義）相當於小圓棒樣品中裂縫深度約 3 mm 時的疲勞壽命。對肥粒鐵型鋼片和沃斯田鐵不鏽鋼管道進行了大型疲勞試驗，並與小試片的最佳擬合疲勞曲線進行了比較。研究發現在大尺寸試片所觀察到裂紋成長行為，與小試片的最佳擬合疲勞曲線於裂紋深度約為 3 mm 相當。因為大尺寸試件的應力梯度平緩，並且在距表面 3 mm 處幾乎平坦。如果裂紋表面上的應力等於小試片的應力，則最佳擬合疲勞曲線 的尺寸效應可以忽略不計，證實了基於小試件的設計疲勞曲線的適用性。

一般來說，平均拉伸應力會導致疲勞強度降低，而平均應力校正則藉由普遍使用的改進古德曼方法（Modified Goodman approach），JSME 和 ASME 設計規範中的設計疲勞曲線皆使用 Modified Goodman 方法。 而日本銲接工程學會（JWES）成立的設計疲勞曲線（DFC）小組委員會對新的設計疲勞分析方法和曲線進行了研究，經由

大量測試數據對幾種平均應力校正方法進行了研究和比較後，發現 SWT（Smith-Watson-Topper）方法比改進的 Modified Goodman approach 提供了更精確的校正。因此，採用了 SWT 方法，並將其納入 JSME 規範《核電廠環境疲勞評估方法》2022 年版中。

另外，在對缺口（Notch）試片進行平均應力（應力比，R>-1）的負載控制疲勞試驗中，當循環塑性變形僅發生在缺口根部附近時，缺口根部的平均應力應該會隨著疲勞循環次數的增加而減小。通常局部應力在測試中無法測量，故以有限元素分析（FEA）來估計局部應力-應變行為。 然而，在小缺口試片的疲勞試驗中，由於應變片空間太小，無法測量缺口根部的局部應變。 因此，FEA 的結果無法得到驗證。為了驗證缺口試件的有限元素分析，該研究採用大型缺口板試件進行了循環加載試驗。在試驗過程中，透過有限元素分析對缺口根部附近的局部應變進行了測量和分析。結果，試驗測量與有線元素分析的局部應變幾乎相同。這表明小缺口試片的局部應變可以透過有限元素分析來估計。此外，也進行了小尺寸缺口試件的疲勞試驗，有限元素法估算的疲勞壽命與缺口根部應變之間的關係與圓棒試體所獲得的最佳擬合曲線吻合良好。

三菱重工採用碳鋼 STPT370 和低合金鋼 SQV2A，以不同應力因子濃度（Kt=1.5 和 1.8）的圓形缺口棒材型試體施加平均應力進行疲勞測試。 此外也進行了模擬試片的彈塑性有限元素分析，以檢驗當缺口引起的應力集中和平均應力同時作用時 SWT 方法的適用性。 結果，透過設定 FEM 分析獲得的缺口底部的應力和應變值，確認可以透過 SWT 方法對維護側進行評估。

此外，日立、東芝、關西電力等公司，透過比較光滑和缺口圓棒的拋光和機械加工樣品，探討 STPT370 碳鋼 的機械加工表面處理對疲勞壽命的影響。 透過砂紙拋光和機械加工，製造不同粗糙度等級的試片。 在疲勞試驗前，研究了光滑試樣的材料性質，包括表面層厚度、殘餘應力、粗糙度和硬度。 根據疲勞試驗結果，比較這些材料性能參數對疲勞壽命變化。 即使在相同的粗糙度水準下，在高應力振幅下，缺口試樣的表面光潔度影響因子 Ksf 往往大於光滑試樣。但在低應力振幅下，這種趨勢並不明顯。 根據微觀觀察，不同的趨勢被認為與表面輪廓相關的裂紋合併的不同行為有關。經委員會審查後，此一結果被認為是小樣本的獨特現象，在實際部件中可能不會出現，

結論是 JSME Ksf 方程式可以評估缺口部分銕面光潔度的影響。

研究中，對具有機械加工表面層的試樣進行了鋼的低週疲勞試驗，以揭示疲勞裂紋的產生和成長行為。本研究使用 STS410 碳鋼和 SUS316L 沃斯田鐵不銹鋼進行疲勞測試。 為了改變加工表面層，透過不同的車削條件對圓棒試片進行加工。當旋轉速度或進給速度較慢時，由於積屑瘤而產生長刮痕。然後對不同條件下加工的試片進行疲勞試驗。疲勞測試結果顯示刮痕會縮短疲勞壽命。如果試樣表面有刮痕，則許多裂縫從刮痕谷處連續產生。裂紋迅速合併成半圓形裂紋，幾乎與疲勞壽命早期的刮痕一樣大。這些行為會縮短疲勞壽命。但是，有一些小刮痕的試片的疲勞壽命與去除刮痕的樣品的疲勞壽命相似。 STS410 和 SUS316L 都可以觀察到這些疲勞壽命趨勢。

由於循環載荷而發生的疲勞斷裂是一種與時間相關的斷裂，以 S-N 曲線表示，該曲線顯示了應力與疲勞壽命之間的關係。斷裂過程由裂紋產生和長兩個過程組成，疲勞壽命是這些壽命的總和。疲勞壽命變異主要是由裂紋產生引起的。一般來說，斷裂是由缺陷（材料微觀結構的薄弱點）引起的。疲勞裂紋始於表面的薄弱點，例如沿滑移方向取向的粗晶粒中的滑移帶或夾雜物。這些弱點與結構敏感特性有關。結構敏感特性對裂紋產生的影響因應力程度而異，這會導致疲勞壽命的變化。 另一方面，由於弱點是平均的，因此裂紋擴展的結構敏感性較弱，因此裂紋成長壽命的變化小於裂紋發生的變化。

日本銲接工程學會原子能委員會開發了疲勞知識平台「疲勞知識平台」涵蓋不同工業領域和科學理解的交叉描述，通常的文章都是分別解釋各領域的疲勞分析方法。在此次會議中，該平以壓力容器施工後規範與飛機損壞容忍度概念之間的差異作為一個範例圖（3.2.4）。

根據建造規範，壓力容器的設計和製造具有適當的疲勞壽命裕度，不允許損壞。此外，施工後規範還提供了（1）透過計畫檢查來檢測損壞的方法，（2）對檢測到的損壞進行評估和預測，以及（3）維修/更換方法。因此，當設備在運作過程中發生損壞時，應用施工後規範可以延長設備的使用壽命。

另一方面，飛機的損壞容忍度與建造後規範類似，透過計畫檢查來預測損傷。然

而，它與壓力容器設計的不同之處在於，採用基於將進行更換的假設的作為故障安全架構。

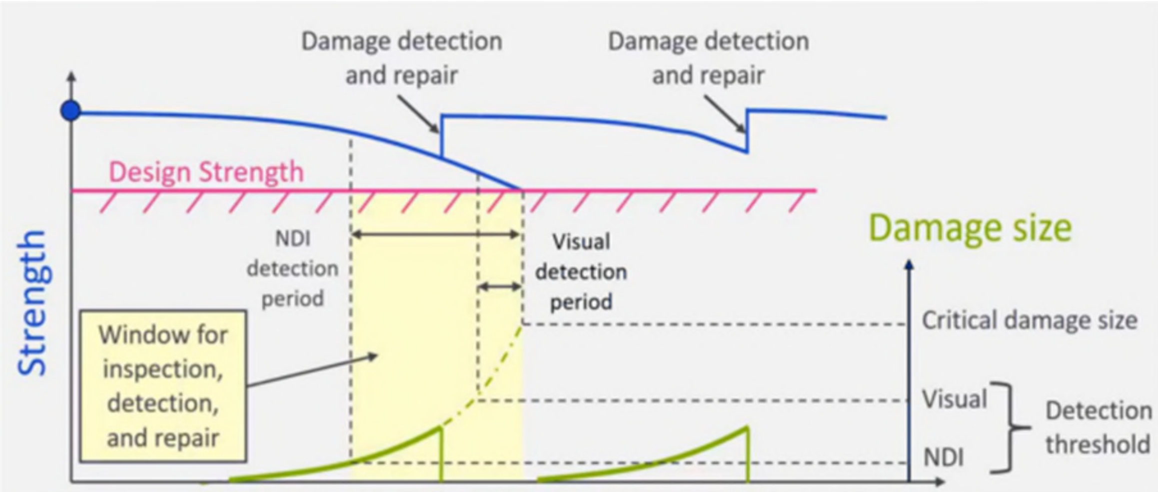


圖 3.2.3 飛機損壞容忍度概念

日本銲接工程學會 （JWES） 原子能研究委員會的 DFC 小組委員會開發了新的疲勞曲線和疲勞分析方法，並將結果提交給 JSME 發電設施規範委員會。規範委員會批准將新的疲勞分析方法納入 JSME 環境疲勞評估方法 2022 版。此外，新的疲勞分析方法正在作為規範案例提交給 ASME BPV 規範委員會（BPV III 疲勞強度工作小組）。

3.3 IMIG 會員關注的複合材料議題

無論是空中巴士公司或波音公司所生產的新型客機，為了輕量化與耐用，皆大量採用複合材料，今年 1 月 2 日日航 JAL516 於日本羽田機場跑道起火的客機，即是使用大量複合材料的空中巴士 A350 機型。惟複合材料的結構複雜多樣，與金屬的材料性質迥異。2023 年 9 月法國 BEA 及澳洲 ATSB 等事故調查單位，於 IMIG 資深材料分析調查員交流平台，特別關注纖維增強複合材料（Fiber Composites）等相關議題，本會擬於 2024 年 AIM 年會提報本次參與旨揭會議之心得並進行討論。關於本次大會關於複合材料的議題分述如下：

短纖維增強熱塑性塑料（SFRP）在酸性環境下的疲勞壽命的影響

該研究採用兩種汽車部件（PA6 和 PA66），含有 35%重量比的 SFRP 短玻璃纖維的聚醯胺，在 pH= 2.5 和 T=60°C 環境下，將其中一個預先老化 1000 小時，再與另一

個未老化的試片進行比較。

透過掃描電子顯微鏡和差示掃描量熱法先達成預時效的效果。單一負載試驗顯示，老化後的材料有輕微脆化，但沒有硬化，這與水解導致的分子鏈斷裂以及不受影響的結晶度一致，但 200μm 外層纖維則與基體脫膠。

在恆定振幅、頻率（1Hz）和負載比（R=0.1）下對短纖維的三個主要方向（0°、45°和 90°）進行應力疲勞試驗。為確保疲勞測試過程中應變測量與酸性溶液的穩定性和均勻性，特別開發了一種設備，用於測試浸入酸性溶液中的試片。老化的試片在酸性環境下，疲勞壽命略有下降，特別是當纖維主要與拉伸方向成 0°時；而在水中老化的測試樣品中未觀察到疲勞壽命下降（圖 3.3.1）。

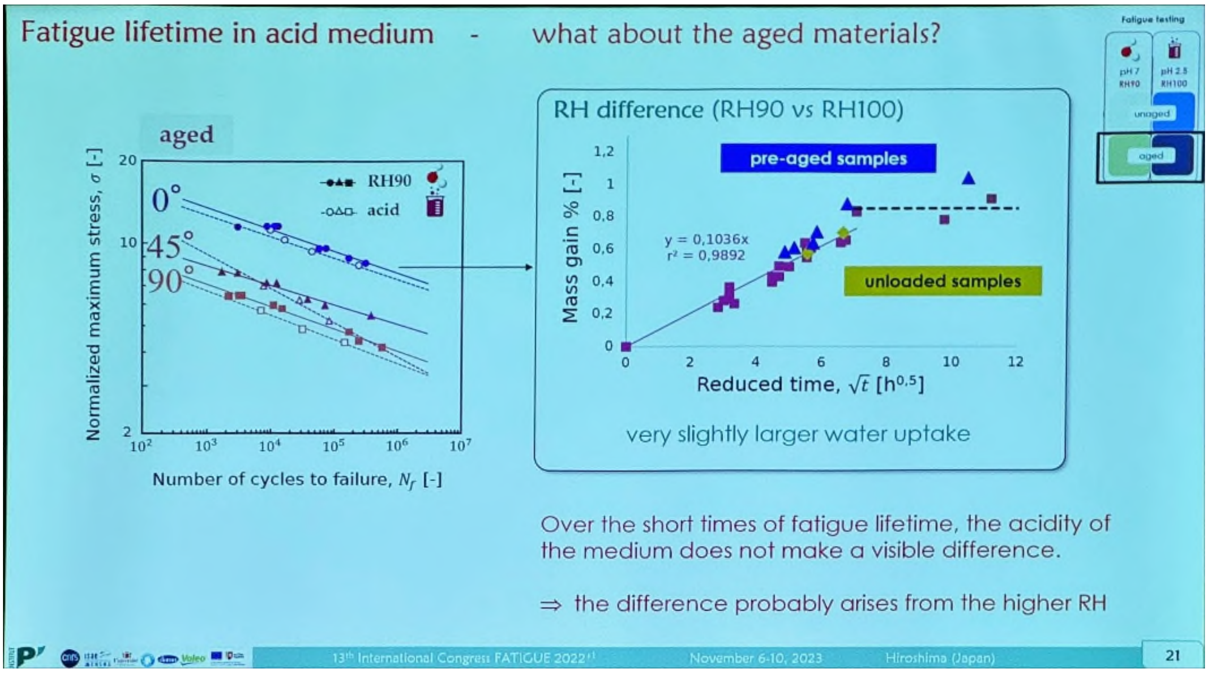


圖 3.3.1 酸性環境與正常環境之疲勞壽命比較

<u>基於基體相應力的短玻纖增強複合材料 short-fiber GFRP （SGFRP）射出成型板之疲勞性能評估</u>

該研究進行疲勞測試是為了評估由填充短玻璃纖維（稱為短纖維 GFRP（SGFRP））的 PPS 樹脂射出成型板的使用壽命（圖 3.3.2）。準備了三種類型的樣品來研究纖維取向的影響：平行於注射方向切割的成型方向（MD）樣品、垂直於注射方向切割的橫向（TD）樣品以及不含纖維的 PPS 樣品。與不含纖維的 PPS 樣本相比，MD 樣本的疲勞強度有所增加，而 TD 樣本則沒有任何改善（圖 3.3.3）。短纖維取向

的 X 射線 CT 同步輻射分析顯示，SGFRP 射出成型板具有三層結構，表層纖維沿成型方向，芯層纖維沿橫向。依纖維方向，利用微觀力學計算各層的楊氏係數（圖 3.3.4），並利用有限元素法分析 PPS 相的應力。基於 PPS 相應力的建構 S-N 圖，觀察到 MD 和 TD 樣本與 PPS 樣本的行為非常相似（圖 3.3.5）。這顯示 SGFRP 的疲勞破壞主要受 PPS 相應力的影響。

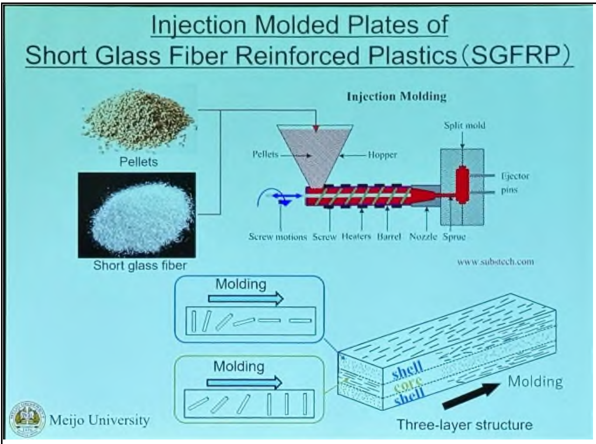


圖 3.3.2short-fiber GFRP 射出成型板

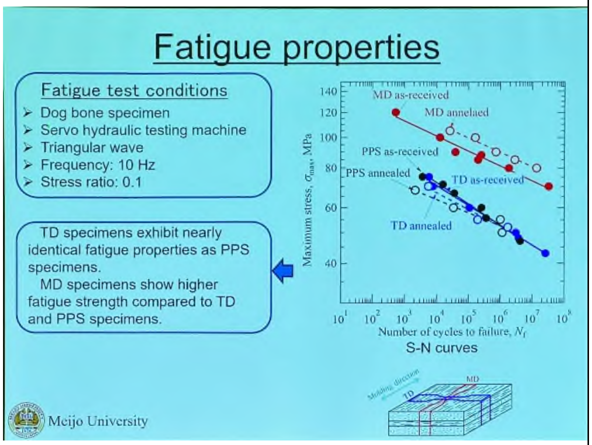


圖 3.3.3 疲勞性質

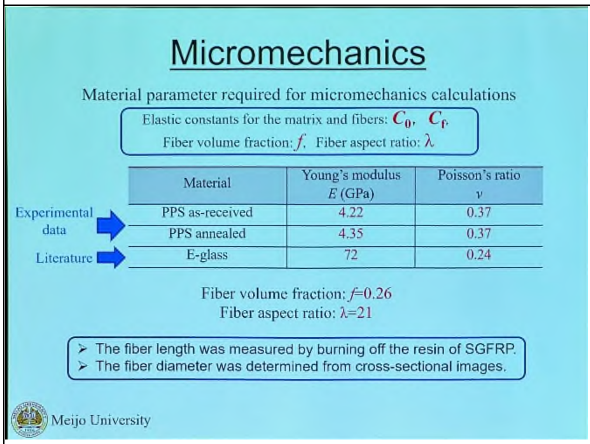


圖 3.3.4 微觀力學計算各層楊氏係數

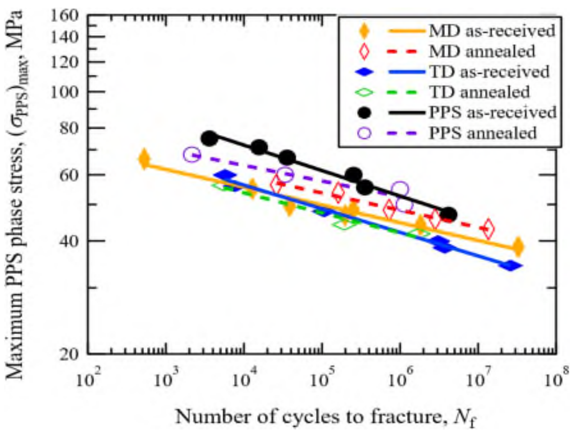


圖 3.3.5 最大 PPS 相應力與斷裂循環次數之間的關係

德國 TU Dortmund University 提出了兩篇報告，熱塑性纖維金屬層壓板在特定溫度下的疲勞裂紋演變，及複合材料結構的疲勞損傷演化與損傷容忍限度

複合材料結構的疲勞損傷演化與損壞容忍度

現代複合材料結構因其輕量化和高性能等良好特性（圖 3.3.6），而廣泛應用於當今航太等各種工業結構中（圖 3.3.7）。複合材料結構的設計依賴可靠的壽命估計，點出了疲勞行為和相關損壞容忍度的的需求。現今材料的特殊技術和製造程序，滿足高性能應用和可持續適用性的需求。其中包括經典的以天然纖維增強聚合物、纖維素基複合材料和混合結構，例如熱塑性纖維金屬層壓板（圖 3.3.8a）。所使用的表徵技術著重於使用計量學研究實驗室規模下的損壞機制，例如數位影像相關和熱成像。由於此類複合材料的複雜性，需要使用人工氣候室對關鍵環境條件（包括溫度和濕度條件）進行研究，以全面了解其材料機械性質和結構性能。為了收集有關損傷產生和演變的重要信息，真實損傷狀態表徵的技術（圖 3.3.8b），以散射電子顯微鏡和電腦斷層掃描分析期間的原位測試，並與間歇性疲勞測試一起使用。目的為使複合材料就可以滿足汽車、航空航太和建築業的各種應用。

圖 3.3.6 現代複合材料

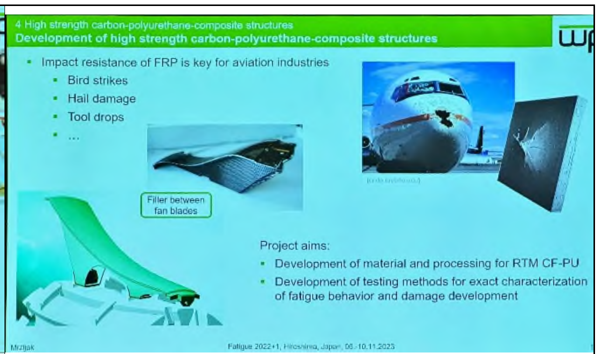


圖 3.3.7 航太複合材料

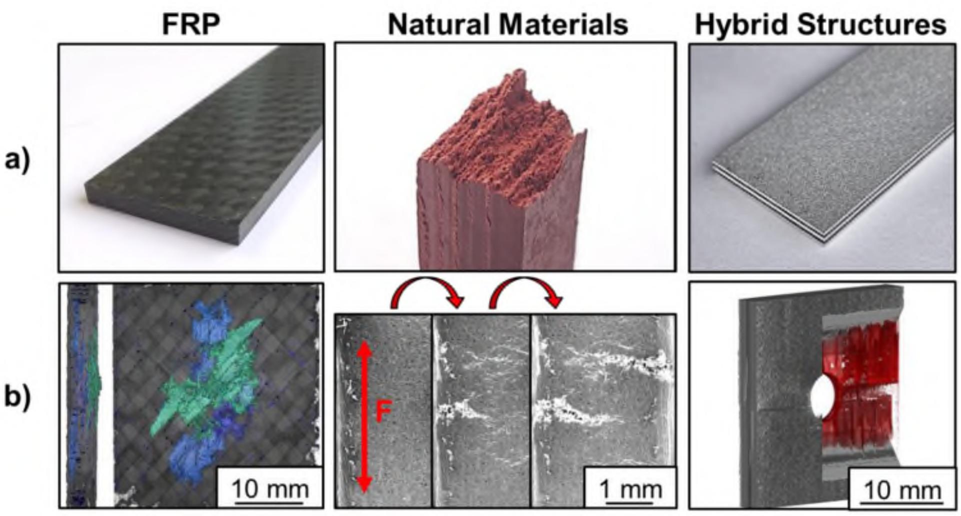


圖 3.3.8 a） 複合材料 b） 相關觀察損害特徵技術

熱塑性纖維金屬層壓板在特定溫度下的疲勞裂紋演變

該研究目的係為探討複合材料運用於飛機與汽車零件（圖 3.3.9），受彎矩與扭矩的的疲勞演變。與單純金屬（如航太工業的鋁）相比，導入金屬層壓板（FML，Fiber metal laminates）可減緩材料裂縫發展並延長疲勞壽命（圖 3.3.10）。此類材料不僅具備良好的機械材料性質，更重要的是符合永續性（包括可回收性和長期使用）的需求。因此，與熱固性 FML 相比，引入了基於熱塑性塑膠的 FML，可提高成型性並縮短生產時間。然而，有關此種材料的機械性質，特別是疲勞方面的資訊尚未充分，這對於疲勞壽命估計和零件設計是不可缺少的。該研究中係由單向玻璃和碳纖維 polyamide 6 和 AA6082 鋁合金板組成的熱塑性 FML，測試在各種溫度環境（-35 至 80 ˚C 範圍內）下的疲勞性能。

使用 3D 數位影像進行裂縫和變形測量，並監測電阻變化，在 VHCF 範圍的拉伸-拉伸負載下研究疲勞引起的裂紋演變（圖 3.3.11）。結果顯示，熱塑性 FML 的疲勞壽命很大程度上取決於環境溫度，材質層界面的強度隨著溫度的升高而降低，並導致鋁板中裂縫的產生和加速成長。

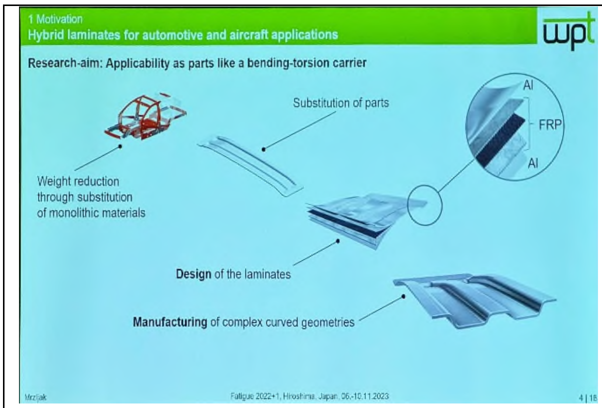


圖 3.3.9 複合材料運用於飛機與汽車零件

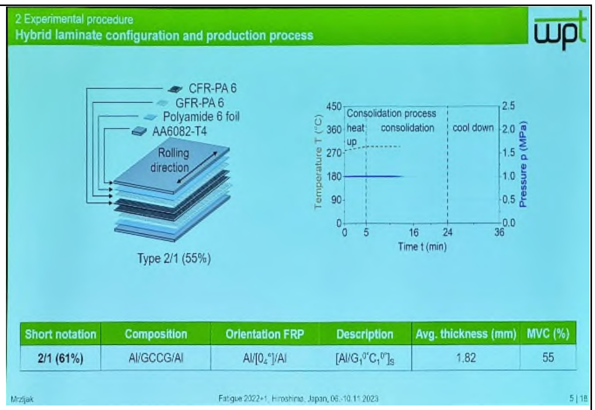


圖 3.3.10 導入金屬層壓板複合材料

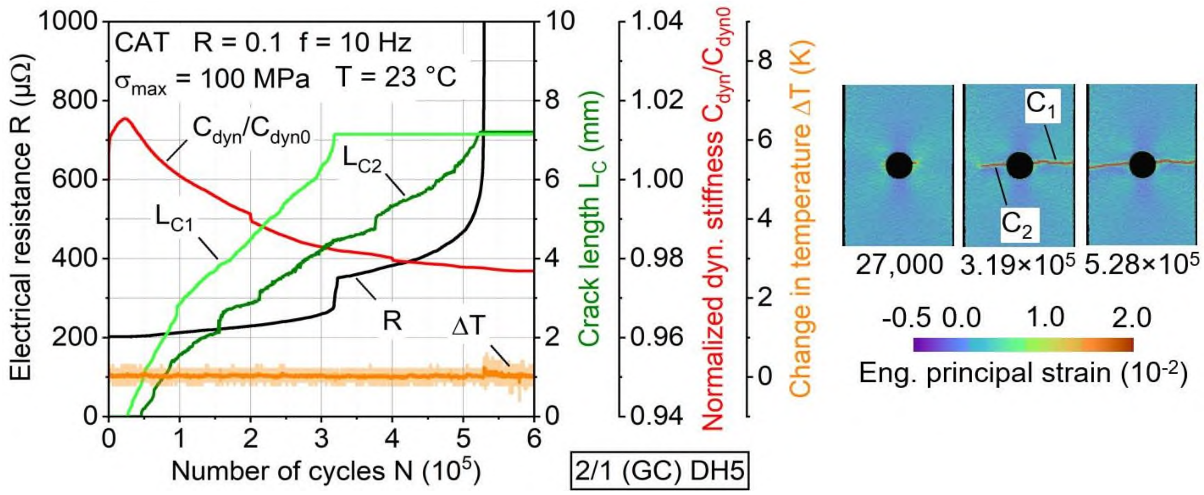


圖 3.3.11 熱塑性 FML 的恆幅測試：裂紋長度和電阻演變、循環負載的變形

空中巴士：可防止飛機結構過早腐蝕的新塗層材料

金屬零件的腐蝕是影響飛機結構壽命的重要問題。飛機腐蝕損壞的發生取決於幾個參數：1. 製造/組裝過程中的腐蝕防護程度。2. 使用壽命期間執行的維護程度（預防）3.飛機運作的環境條件。

機艙的樓板結構是前期受過腐蝕影響最嚴重的區域之一，主要集中在潮濕區域，如廁所、備餐室、大門入口。樓板結構僅由鋁合金零件組裝而成時，現行的表面處理方法是硫酸陽極氧化。但這種保護並非非常有效。使用些區域時易損壞鋁材質表面保護層，使地板產生多孔洞並導致液體殘留。這既誘發了自我腐蝕，也誘發了電偶腐蝕，即兩種不同的金屬相互接觸而同時處於電解質中所產生的電化學腐蝕。

目前的解決方案是使用鈦零件取代鋁零件。另一個防腐蝕結構的解決方案是在潮濕區域的外露部分採用防腐蝕材料，使鈦合金確保了良好的性能。但這個解決方案會不斷增加維護成本，同時也增加地板結構的重量。

該研究提出的新塗層料，目的是對地板結構進行修改，顯著減少腐蝕狀況，以拉長檢查時間間隔，減少維護的工作量。這種新塗層必須符合歐盟關於化學品的 REACH 環保標準，因此不含鉻酸鹽，且仍以減少飛機重量和維護成本為目標。

這種新塗層目前已經完成生命週期評估。接下來主要挑戰是驗證這種新塗層在防

止結構腐蝕方面的摩擦、磨損和潤滑等三個方面可行性。

表面粗糙度對鋁鎂合金疲勞強度的影響

噴丸處理（Shot Peening），是一種冷加工工法，要用足以產生塑性變形的力來擊打金屬表面，藉以壓縮殘餘應力層並改變金屬和復合材料的機械材料性能。惟對於鎂合金來說效果欠佳，造成這種情況的原因之一是鋁鎂合金極易出現缺口，但具體細節尚未明確。為了評估缺口敏感度的影響，該研究製備了不同表面粗糙度的試片，評估表面粗糙度對鎂合金疲勞強度性能的影響。也將表面粗糙度對鎂合金疲勞強度性能的影響與鋁合金進行了比較。製作三種不同表面粗糙度的樣品：機械加工、拋光和金剛砂拋光。然後將試片進行退火處理，每種材料的表面粗糙度不同。疲勞試驗結果顯示，疲勞強度隨著表面粗糙度的增加而降低，但與這些材料之間的缺口敏感性沒有差異。鋁合金和鎂合金的比較同時顯示，疲勞強度下降幅度幾乎相同。

3.4 疲勞案例研析

鐵道車輛全尺寸感應淬火車軸疲勞強度評估及極高週次數下的估算

日本鋼鐵多年來已經在鐵道車輛的輪軸，依不同的表面加工方式做出許多研究成果（圖 3.4.2），本次則是以感應淬火 Induction Hardening）加工方法與疲勞強度的評估，由首席科學家 Tazio Makino 提出報告。

為了研究疲勞損壞評估在設計過程中的應用，對全尺寸感應淬火車軸進行了 10^7 個循環的疲勞測試，提出 S-N 曲線和疲勞極限（圖 3.4.2）。大多數車軸的失效根源是軸體硬化層與基體之間的內部邊界，該研究嘗試透過局部疲勞強度方法預測疲勞極限，比較試驗軸不同徑向位置的局部疲勞極限和應力分佈。使用疲勞測試車軸中的殘餘應力分佈以及平均應力和硬度對從全尺寸車軸內部區域切割的小樣本的疲勞極限的依賴性來估計疲勞極限。此外，在疲勞試驗條件下，使用有限元素法進行局部應力分析，將預測的疲勞極限與實驗值相對應，並且以小試件進行了 10^9 次循環的疲勞試驗，在 10^7 至 10^9 次循環之間沒有出現任何失效，這表明全尺寸車軸的疲勞極限並不存在，即在極高週運轉下，即全尺寸車軸的實驗疲勞極限 10^7 強度對應於極高週疲勞極限 10^9

強度狀態下，疲勞狀態未改變（圖 3.4.4）。

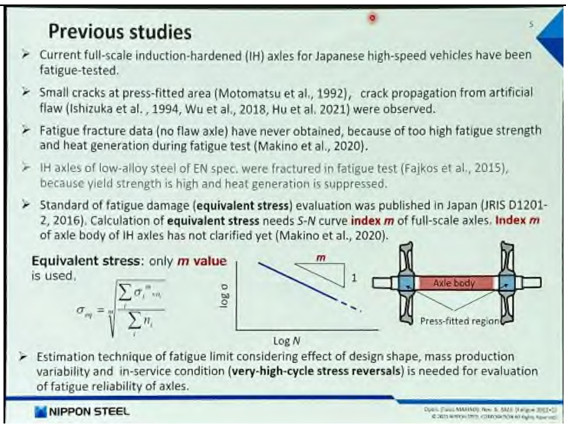


圖 3.4.1 導入金屬層壓板複合材料圖

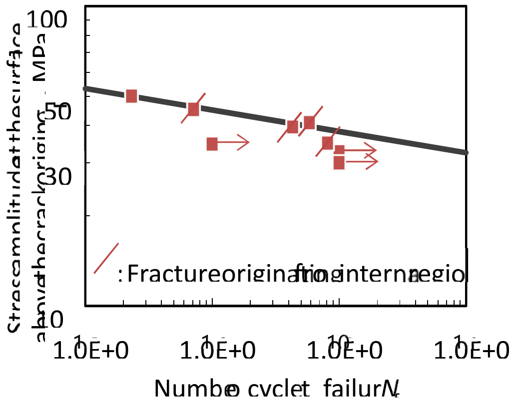


圖 3.4.2 導入金屬層壓板複合材料

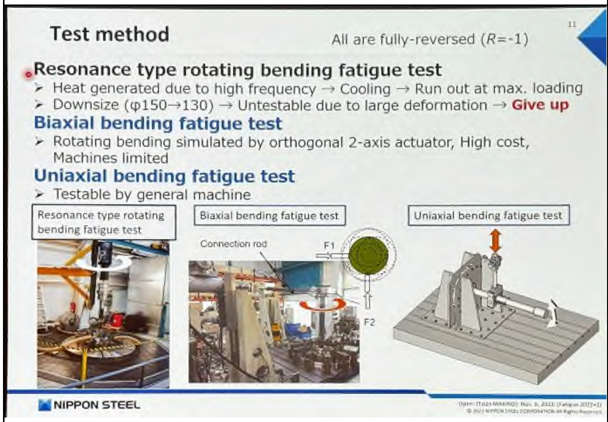


圖 3.4.3 導入金屬層壓板複合材料圖

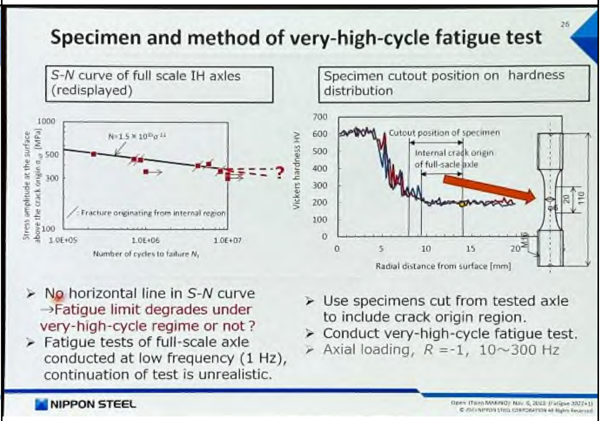
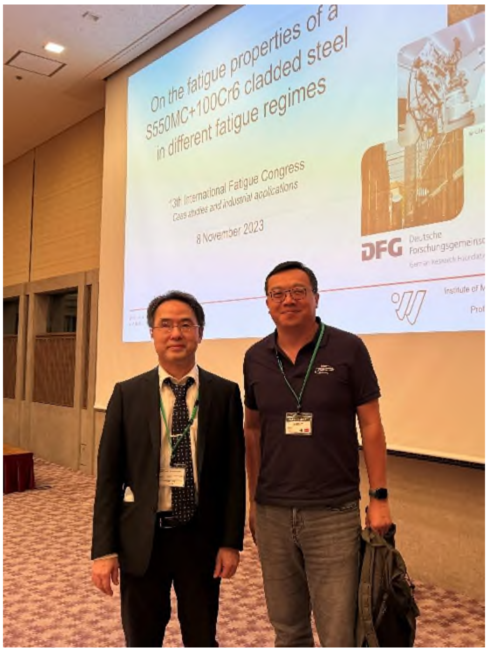


圖 3.4.4 導入金屬層壓板複合材料圖

四、心得與建議

<u>心得</u>

1. IFC 今年於日本廣島舉辦，針對工程疲勞分析的各式議題，由學界與業界提出學理與實務探討。與會中與不同領域專家進行討論，其中首場專題演講的德國德國材料科學學會（DGM）主席暨德國工程學院院士 Dr. Martina Zimmerman 及日本鋼鐵首席科學家 Dr. Tazio Makino 皆對與本會交流表示興趣，希望未來有更多的交流。



2. 傳統的非破壞檢測方法（例如工業 X 光電腦斷層掃描 CT 或超音波 CT）皆很難檢測到如此微小的裂縫，本次會議日本學者提報之同步輻射方法，卻能解決微小的裂縫的觀察，我國原能會核分所亦曾與本會提過嘗試此種針對細微瑕疵檢測方法的構想。
3. 日本福島核災的疲勞曲線修正，採取的實驗方法與本會科技計畫碰撞測試相同，即先使用有限元素分析，與實際碰撞測試比對，建構可靠有限元素模型，後續對座椅不同鎖固方式進行應力分析，僅需透過模擬方式即可取得可靠結果。

4. 本會應積極參與國際技術交流，於研討會中發表本會調查案例以及工程技術能量。由於疫情之故，本會知悉該會議時已逾投稿期限，致台鐵隆田站電聯車馬達脫落失效案未能投稿，讓與會成員看到台灣的調查能力，實為美中不足。
5. 身為 Accident Investigator Materials, AIM meeting 成員國，針對法、澳兩國調查人員於 IMIG 論壇上所關注本會議關於纖維增強複合材料（Fiber Composites） 等相關議題，希冀於 2024 年 AIM 年會提報參與本次會議之心得並進行討論，藉以增加國際交流，深化夥伴關係。

<u>建議</u>

1. 本會囿於經費，僅派一位調查員參加，由於該會議係由七個會議場地同時進行，若要發表論文還要與其他各界專家交流，相當辛苦，建議在經費許可下，多派員參加此破損分析相關研討會，吸取經驗與技術交流。
2. 國際材料機械性質會議（ICM）和國際破壞力學會議（ICF）皆是處理材料強度和固體力學系統的會議，本會應積極參與國際事故調查技術交流，於研討會中分享本會事故調查案例以及工程技術能量。

參加 2023 年第 13 屆國際疲勞力學代表大會出國報告

服 務 機 關：國家運輸安全調查委員會

出國人職稱：副研究員

姓　　　名：林意程

出 國 地 區 ：日本廣島市

出 國 期 間 ：民國 112 年 11 月 5 日至 11 月 11 日

報 告 日 期 ：民國 113 年 2 月 1 日

建議事項：

	建議項目	處理
1	本會囿於經費，僅派一位調查員參加，由於該會議係由七個會議場地同時進行，若要發表論文還要與其他各界專家交流，相當辛苦，建議在經費許可下，多派員參加此破損分析相關研討會，吸取經驗與技術交流。	□ 已採行 √ 研議中 □ 未採行
2	國際材料機械性質會議（ICM）和國際破壞力學會議（ICF）皆是處理材料強度和固體力學系統的會議，本會應積極參與國際事故調查技術交流，於研討會中分享本會事故調查案例以及工程技術能量。	□ 已採行 √ 研議中 □ 未採行