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June 2 (Sun) – 6 (Thu), 2013 / ICC Jeju, Korea

APVC 2013

The 15th Asia Pacific Vibration Conference

KSME

KSNVE

Conference at a Glance

	2 (Sun)	3 (Mon)	4 (Tue)	5 (Wed)	6 (Thu)
10:00 - 10:30			IOC Meeting 10:30-11:30 [300]		Technical Tour 08:20 - 14:30
11:00 - 11:30		REGISTRATION 11:00 - 22:00; Chair Session (Luncheon) 11:00 - 12:10 [OCEAN VIEW(5F)]	REGISTRATION 11:00 - 18:00; IOC Luncheon 11:30-12:30 [DELIZIA 406 (3F)]	REGISTRATION 11:00 - 18:30	
12:00 - 12:30					
12:30 - 13:00		Opening Ceremony 12:30 - 12:50 [HALLA B Hall (3F)]			
13:00 - 13:30		Keynote Lecture 1 13:00 - 13:30 [HALLA B Hall (3F)]	Keynote Lecture 4 13:00 - 13:30 [HALLA B Hall (3F)]	Keynote Lecture 5 13:00 - 13:30 [HALLA B Hall (3F)]	
13:30 - 14:00		M1 13:40 - 15:10 [301A, 301B, 302, 303A, 303B, 304]	T1 13:40 - 15:10 [301A, 301B, 302, 303A, 303B, 304]	Keynote Lecture 6 13:35 - 14:05 [HALLA B Hall (3F)]	
14:00 - 14:30				W1 14:15 - 15:45 [301A, 301B, 302, 303A, 303B, 304]	
14:30 - 15:00					
15:00 - 15:30		Coffee Break 15:10 - 15:30 [Hall 3F)]	Coffee Break 15:10 - 15:30 [Hall 3F)]		
15:30 - 16:00		M2 15:30 - 17:30 [301A, 301B, 302, 303A, 303B, 304]	T2 15:30 - 17:30 [301A, 301B, 302, 303A, 303B, 304]	Coffee Break 15:45 - 16:00 [Hall 3F)]	
16:00 - 16:30				W2 16:00 - 17:45 [301A, 301B, 302, 303A, 303B, 304]	
16:30 - 17:00					
17:00 - 17:30					
17:30 - 18:00		Dinner 17:30 - 19:00 [DELIZIA (3F)]			
18:00 - 18:30			Banquet 18:00 - 20:30 [TAMNA B Hall (5F)]	Closing Ceremony 18:00 - 18:15 [HALLA B Hall (3F)]	
18:30 - 19:00					
19:00 - 19:30	REGISTRATION 19:00 - 21:30	Keynote Lecture 2 19:00 - 19:30 [HALLA B Hall (3F)]			
19:30 - 20:00	Welcome Reception 19:30 – 21:00 [OCEAN VIEW(5F)]	Keynote Lecture 3 19:35 - 20:05 [HALLA B Hall (3F)]			
20:00 - 21:00		M3 20:15 - 21:45 [301A, 301B, 302, 303A, 303B, 304]			
21:00 - 22:00					

Technical Program

June 3 [Mon.]

* OS: Organized Session

Room / Time	301A	301B	302	303A	303B	304
11:00-	Registration [3F Hall]					
11:00-12:10	Chair Luncheon [OCEAN VIEW (5F)]					
12:30-12:50	Opening Ceremony [HALLA B Hall (3F)]					
13:00-13:30	**Keynote Lecture 1 [HALLA B Hall (3F)] : Prof. Mitsuo Kawatani** **Low Frequency Sound due to Traffic-induced Vibration of Bridges /27** Chaired by Prof. Marco Torbol					
13:30-13:40	Break					
M1 **13:40 – 15:10**	**M1_301A** **General Acoustics**	**M1_301B** **Nonlinear Vibration**	**M1_302** **OS: Research Review of Center for Noise and Vibration Control, KAIST (Dedicated to Prof. Emeritus, Chong-Won Lee)**	**M1_303A** **OS: System Identification for Civil Structures**	**M1_303B** **Vibration Suppression**	**M1_304** **SHM of Infrastructure**
Chaired by	Dr. Dung-An Wang Prof. Junhong Park	Prof. T. Nakamura Prof. Soo Il Lee	Prof. Youngjin Park	Prof. Sung-Han Sim	Prof. Y. Narita Prof. O. Furuya	Prof. S. Fang Prof. Wen Li
13:40-13:55	***M1_301A_1*** **Sweet Spot Analysis of Sound Field Reproduced by Ear-level Linear Arrays of Loudspeakers using Inter-aural Time Difference Cue */33*** Hunmin Yang, Youngjin Park, Youn-sik Park	***M1_301B_1*** **Response of a Non-linearly Supported Cylinder in an Array Subjected Cross-flow */36*** Tomomichi Nakamura, Njuki Mureithi	***M1_302_1*** **Development of Active Engine Mount System with Variable Cylinder Management */39*** Youngjin Park, Haemin Lee, Hafiz Farhan Maqbool, Youn-sik Park	***M1_303A_1*** **Optimization of Multi-hop Communication for Structural Vibration Monitoring using Wireless Sensor Networks and its Application to a Suspension Bridge Vibration Measurement */41*** Tomonori Nagayama, Zilong Zou, Yozo Fujino	***M1_303B_1*** **Maximization of Vibration Control Performance for Micro Smart Composites with the Laser Excitation Technique */44*** Kazuki Watanabe, Shinya Honda, Yoshihiro Narita, Itsuro Kajiwara	***M1_304_1*** **Prediction of Unmeasured Modal Data using Statistical Multi-stage ANN For Damage Detection: An Experimental Verification */47*** Lyn Dee Goh, Norhisham Bakhary, Azlan Rahman, Baderul Ahmad
13:55-14:10	***M1_301A_2*** **A Bezier Profiled Horn for Reducing Penetration Force with Applications in Surgery */33*** Dung-An Wang, Hai-Dang Tam Nguyen	***M1_301B_2*** **Averaging Method using Elliptic Functions for Nonlinear Oscillators Having Multi-degree-of-freedom */36*** Kazuki Kourogi, Tadashi OKABE, Takayuki Hamahata	***M1_302_2*** **Semi-active Friction Control of Space Truss Structures for Maximization of Modal Damping */39*** Kwang-joon Kim, Young-min Park	***M1_303A_2*** **Fusion of Multimetric Data for Displacement Estimation */42*** Sung-Han Sim, JongWoong Park, Hyungjo Jung	***M1_303B_2*** **Robust Tuning of S-curve for Motion Control with Less Residual Vibration in Medium Distance Case */45*** Chang-Wan Ha, Keun-Ho Rew, Kyung-Soo Kim, Soohyun Kim	***M1_304_2*** **Stochastic Model Updating based on Response Surface Models and Monte Carlo Simulation */48*** Sheng-En Fang, You-Qin Lin, Zhang-Hua Xia
14:10-14:25	***M1_301A_3*** **Three-dimensional Analysis of Head-Related Impulse Responses based on Principal Components Analysis */34*** Daehyuk Son, Youngjin Park, Yoonsik Park, Sei-jin Jang	***M1_301B_3*** **Nonlinear Dynamic Behavior of a Rotor-bearing System with Rub-impact Fault Based on Finite Element Method */37*** Chaofeng Li, Jie Liu, Bangchun Wen	***M1_302_3*** **Aeroelastic Analysis of a Wind Turbine Blade under Different Inflow Conditions */40*** In Lee, Min-Soo Jeong, Seung-Jae Yoo	***M1_303A_3*** **A Flaw Imaging Technique of Welded Zone of a Plate-like Member based on Point-source Laser Actuation */42*** Seunghee Park, Changgil Lee, Hyun Uk Kim	***M1_303B_3*** **Pure-rotary Periodic Motions of Planar Auto-Balancer Systems by Harmonic Balance Method */45*** Hao-Wei Chen, Chung-Jen Lu	***M1_304_3*** **Video-based Deformation Measurement System for Structural Health Monitoring */48*** Yoon Bong Shin, Yohan Park, Gwanwoo Park, Seung-Hwan Sin, Young-Min Kim, Hwi Kim

14:25-14:40	***M1_301A_4*** **The Analysis of the Dispersion Characteristics of the Infinite Cylindrical Shell in Viscous Fluids */34*** Haosen Chen, Tianyun LI, Xiang Zhu	***M1_301B_4*** **The Analytical Study on a Rattle Evaluation Method considering the Material Degradation */37*** Su Jung Lyu, Jaemin Choi, Yong Jin Kim, Chang Su Woo, Joon Sik Kim, In Ki Jun	***M1_302_4*** **Influence of Rotor Wake on Noise and Vibration of Helicopter */40*** Duck Joo Lee, Se Hwan Park, Ji Sung Jang, Seong Yong Wie	***M1_303A_4*** **Dynamic and Static Responses for Jacket-type Offshore Structure under Severe Tidal Environment */43*** Jin-Hak Yi, Jin-Soon Park, Kwang-Soo Lee, Won-Dae Baek	***M1_303B_4*** **Research and Development of Multiple TMD for Excavators */46*** Keisuke Minagawa, Satoshi Fujita, Satoshi Roppongi, Yasuo Tsuyuki, Daisuke Oono, Kento Sakakibara, Naoto Fujimura, Takashi Nagatsuka	***M1_304_4*** **Meshless and Parametric Modeling of Complex Dynamic Systems */49*** Wen Li, Xuefeng Zhang
14:40-14:55	***M1_301A_5*** **Feasible Design of 2D Acoustic Cloaking Based on Impedance Matched Multi-layered Structure */35*** Choonghee Jo, Il-Kwon Oh	***M1_301B_5*** **Nonlinear Resonance of Carbon Nanotube Cantilever with Tip Attached Mass */38*** Il Kwang Kim, Soo Il Lee	***M1_302_5*** **Zone Control of Sound and Vibrations */41*** Yang-Hann Kim, Jung-Woo Choi	***M1_303A_5*** **Parallel Data Driven Stochastic Subspace Identification for Structural Health Monitoring */43*** Marco Torbol	***M1_303B_5*** **Research and Development of Response Control Element using Oval Type Leaf Spring with Displacement Amplifying Function */46*** Osamu Furuya, Hiroshi Kurabayashi, Eigiro Inamura, Yun Seok Kim	***M1_304_5*** **Susceptibility of the Critical Structural Components of Railway Bridges to the Changes in Train Speed */49*** Mehran Aflatooni, Tommy Chan, David Thambiratnam
14:55-15:10	***M1_301A_6*** **Zero-group Velocity Lamb Modes in an Incompressible Plate */35*** Takasar Hussain, Faiz Ahmad	***M1_301B_6*** **Associated Linear Equations for the Wiener Kind of Volterra Systems */38*** Juan Vazquez Feijoo, Enrique Garcia Aparicio, Vladimir Lerin, Pastor Matadamas Ortiz		***M1_303A_6*** **Mathematical Modelling of Thermal Extension in Tamar Suspension Bridge */44*** Ki Young Koo, James Brownjohn	***M1_303B_6*** **Stabilization of a Railway Wheelset Hunting Motion by Gyroscopic Damper */47*** Shih-Pin Lin, Hayato Yoshino, Daisuke Tomimatsu, Kentaro Nishimura, Hirokazu Okamoto, Hiroshi Yabuno, Yoshihiro Suda	
15:10-15:30	Coffee Break [3F Hall]					
M2 15:30 – 17:30	**M2_301A** **Dynamics of Machines & Structures I**	**M2_301B** **Computational Methods I**	**M2_302** **OS: Noise and Vibration in China**	**M2_303A** **OS: Wind-Induced Vibration in Bridges**	**M2_303B** **Machine Condition Monitoring**	**M2_304** **Measurement Technique & Sensors**
Chaired by	Prof. Takahiro Ryu Prof. Youngshik Kim	Prof. W. Ostachowicz Dr. B. C. Goo	Prof. Xiang Yan	Prof. Ho-Kyung Kim	Prof. Kihong Shin Prof. S. Kaneko	Prof. Junhong Park Prof. Jae-Hung Han
15:30-15:45	***M2_301A_1*** **Fundamental Study on Optimal Design of Vibration Isolating Bed using Magnetic Spring for Ambulance */50*** Kensaku Kawazu, Takashi Nakae, Takahiro Ryu, Kenichirou Matsuzaki, Etsunori Fujita, Hiroki Ohshimo, Takumi Inoue	***M2_301B_1*** **Numerical and Experimental Studies of Temperature and Moisture Influence on Lamb Wave Propagation in Composite Laminates */54*** Wieslaw Ostachowicz, Pawel Kudela	***M2_302_1*** **Acoustic Research on Brain Healthy Speech Vibration */57*** Hui Li, Xiang Yan, Wang Jianghua	***M2_303A_1*** **Estimation of Damping Ratio of a Parallel Cable-stayed Bridge based on Operational Monitoring */61*** Ho-Kyung Kim, Radiance Calmer, Sun-Joong Kim, Deok-Geun Lee, Gyu-Seon Kim	***M2_303B_1*** **Bifurcation Characteristics of Rub-Impact Fault in Rotor Systems */64*** Hui Ma, He Li, Wei Sun, Qibin Wang, Bangchun Wen	***M2_304_1*** **Real-time Attitude Estimation of A Biped Robot with Sensor Fusion of Range Extended Visioin and Gyro */67*** Jinseong Park, Youngjin Park, Youn-Sik Park

15:45-16:00	***M2_301A_2*** **Experimental Study on a Vibration System Automatically following to Excitation Frequency */50*** Takuya Kishida, Takumi Inoue, Yuuki Tokuura, Daisuke Maeda, Kazuhisa Ohmura, Takahiro Ryu	***M2_301B_2*** **Gradual Reliability Analysis of Serial and Parallel System */54*** Hao Lv, Yimin Zhang, Qianqian Wang	***M2_302_2*** **The Research on Human Response of Staying in Extreme Silent Environment for Eight Hours */58*** Jianghua Wang, Hui Li, Xiang Yan, Xuguang Wang	***M2_303A_2*** **Response Characteristics of an Inclined Circular Cylinder in Smooth and Turbulent Flow */62*** Kichiro Kimura, Kusuo Kato, Yoshinobu Kubo	***M2_303B_2*** **Hidden Markov Model based Crack Diagnosis for a Rotating Blade */65*** Chan Kyu Choi, Hong Hee Yoo	***M2_304_2*** **A Survey Research of Vibration Technologies applied on Body Activity Recorder */68*** JoonHo Hyeong, KyungRyul Chung, ChunHo Choi, SaYup Kim, SeongBin Park
16:00-16:15	***M2_301A_3*** **Experimental Study on the Mechanism and Countermeasures of Rifling Mark Generation in BTA Deep Hole Drilling Process */51*** Takaaki Honda, Takahiro Ryu, Kenichiro Matsuzaki, Keizo Tsukamoto, Katsushi Fujii, Yoshikazu Yuge, Atsuo Sueoka	***M2_301B_3*** **Complex Eigenvalue Analysis of the Disc Brake Unit of a High Speed Train */55*** Byeong Choon Goo	***M2_302_3*** **The Acoustic Design of Piano Concert Hall in Central Conservatory of Music, Piano Academic at GuLangYu */58*** ZhanChun Huang, Peng Wang	***M2_303A_3*** **Twin Rotor Damper for Control of Wind-induced Bridge Deck Vibrations */62*** Uwe Starossek, Jorn Scheller	***M2_303B_3*** **Position and Depth Identification of Open Transverse Beam Crack using Model Based Method */65*** Changyou Li, Wenyuan Dai, Xiaochen Kang, Nan Wu, Yimin Zhang	***M2_304_3*** **Measurement of Dynamic Compressive Stiffness and Dynamic Shear Stiffness by Impact Technique */68*** Lu Ean Ooi, Zaidi Mohd Ripin
16:15-16:30	***M2_301A_4*** **Reduction of Primary and Secondary Vibrations of Reciprocating Machine with a Single Slider-Crank Mechanism by Small and Lightweight Balancer */51*** Daichi Goto, Tadashi Okabe, Takayuki Hamahata	***M2_301B_4*** **Analysis of Nonlinear Pressure Wave in Elastic Pipe by Concentrated Mass Model */55*** Satoshi Ishikawa, Takahiro Kondou, Kenichiro Matsuzaki, Shota Nagano	***M2_302_4*** **An Applied Design of Box in Box Structure for Oilfiled Industry Noise Control */59*** Xiwei Wang, Hui Li	***M2_303A_4*** **Buffeting Characteristics of Cable-stayed Bridge with Lower Height Towers */63*** Hiroshi Katsuchi, Hitoshi Yamada, Mayuko Nishio, Keita Ishizeki	***M2_303B_4*** **A New Strategy for Machinery Health Monitoring based on Fictitious Frequency Response Functions */66*** Kihong Shin, Sang-Heon Lee	***M2_304_4*** **15MW Hydro-Turbine Generator Assessment on Noise & Vibration */69*** Seung-Tae Oh, Jin-Woo Choi, Ji-Hyo Ock, Jintai Chung
16:30-16:45	***M2_301A_5*** **Dynamic Behavior Analysis of the 2.5MW Offshore Wind Turbine Considering the Elastic Effect of the Tower */52*** Dae-Guen lim, Xiangqian zhu, Wan-Suk Yoo	***M2_301B_5*** **An Estimation of Lower Extremity Muscle Forces and Modal Analysis while Rising from a Seated Position */56*** Young Nam Jo, Moon Jeong Kang, Hong Hee Yoo	***M2_302_5*** **The Noise Control Design for Shanxi Grand Theatre in China */59*** XiangDong Zhu, Hongbing Su, Bin Jia	***M2_303A_5*** **The Evaluation Methods of Aerodynamic Impulse Response Functions for the Time-domain Aeroelastic Analysis */63*** Hae Sung Lee, Kilje Jung, Jinwook Park	***M2_303B_5*** **Estimation of Seal Strength on Heat Sealing by Ultrasound */66*** Daiki Yanagihara, Takumi Inoue, Takahiro Nakano, Tatsuya Oda, Kazuhisa Omura	***M2_304_5*** **Research on Moment Excitation Device without Additional Weight */69*** Yoshio Tsuji, Akira Sanada, Takuya Yoshimura
16:45-17:00	***M2_301A_6*** **Dynamic Similarity Analysis on Short Thin-walled Cylindrical Shell */52*** Zhong Luo, Ning Sun, Kai Zhang, Qing-Kai Han	***M2_301B_6*** **Nonlinear Dynamics of Rotor connected by Bolted Joints */56*** Zhaoye Qin, Fulei Chu	***M2_302_6*** **Noise Control for a Large Underground Natural Gas Storage in China */60*** XuGuang Wang, Hongbing Su, Xiang Yan, Hailiang Zhang	***M2_303A_6*** **Span-wise Coherence of Buffeting Forces on a Two-separated-deck Bridge */64*** Le-Dong Zhu, Qi Zhou, Pengjie Ren	***M2_303B_6*** **A Method of Sleepiness Estimate by using Bayesian Estimation */67*** Shunpei Miyazaki, Shigehiko Kaneko	***M2_304_6*** **Measurement of Dynamic Support Properties of Railway Track Fastening System for Flexural Vibrations */70*** Jeongwon Park, Hyo-In Koh, Junhong Park

17:00-17:15	***M2_301A_7*** **Comparison of Compliant One-segmented and Two-segmented Leg Dynamics for a Wheel-leg Hybrid Mobile Robot using a Mass-spring Model */53*** Youngshik Kim, Bong-Jo Ryu	***M2_301B_7*** **Lagrangian Finite Element Formulation to Axisymmetric Liquid Sloshing of Floating Roof Tanks */57*** Shoichi Yoshida	***M2_302_7*** **The Research on The Rain Noise Test for Lightweight Roofs */60*** XiaoYan Xue, Xiang Yan			***M2_304_7*** **Prediction of the Floor Impact Noise and Vibration using Frequency Response Function */70*** Daeho Mun, Hong Gun Park, Jae-Seung Hwang
17:15-17:30	***M2_301A_8*** **Research on Coupling Modeling Methods of Multi-shaft Rotor System */53*** Lisha Zhu, Yimin Zhang, Hui Ma, Quanbin Wang		***M2_302_8*** **Research on the Correlation between Gear Geometric Eccentricity and Transmission Error */61*** Song Liang, Yimin Zhang, Di Zhou, Xu Wang, Qian-Qian Wang			
17:30-19:00	Dinner [DELIZIA (3F)]					
19:00-19:30	**Keynote Lecture 2 [HALLA B Hall (3F)] : Prof. Kwang-joon Kim (KAIST)** **Pneumatic Vibration Isolation Table: From Passive Transmissibility Design to 6-DOF Active Control */27*** Chaired by Prof. Youngjin Park					
19:35-20:05	**Keynote Lecture 3 [HALLA B Hall (3F)] : Prof. Huajiang Ouyang (The University of Liverpool) */28*** **Assignment of Desirable Eigenstructures for Dynamic Performance** Chaired by Prof. Hong Hee Yoo					
20:05-20:15	Break [3F Hall]					
M3 **20:15 – 21:45**	**M3_301A** **Damping**	**M3_301B** **Vehicle Dynamics & Control**	**M3_302** **OS: Application of Rotor Dynamics (Dedicated to Prof. Emeritus, Chong-Won Lee)**	**M3_303A** **OS: SHM of Civil Structures**	**M3_303B** **Optimization**	**M3_304** **Earthquake Engineering**
Chaired by	Dr. M.S. Seong Prof. Akira Sone	Dr. M. Sonobe Prof. Ki Hong Shin	Prof. S. W. Hong	Prof. J.T. Kim	Prof. W. Kozukue Prof. Jae-Hung Han	Dr. Anas Batou
20:15-20:30	***M3_301A_1*** **Design and Damping Force Control of Frictionless MR Damper considering Hysteresis Behavior */71*** Min-Sang Seong, Seung-Bok Choi, Cheol-Ho Kim	***M3_301B_1*** **Evaluation of Dynamic Absorber to Suppress Shudder and Engine Forced Vibration in Automatic Transmission Powertrain */74*** Sofian Rosbi, Takashi Nakae, Takahiro Ryu, Kenichiro Matsuzaki, Atsuo Sueoka, Yoshihiro Takikawa, Yoichi Ooi	***M3_302_1*** **Lee Diagram for Bladed-rotor System Design and Operation */77*** Kyung-Taek Kim, Chong-Won Lee	***M3_303A_1*** **Identification of the Dynamic Parameters of a Real Bridge under Different Damage Conditions in a Field Experiment */79*** Patrick McGetrick, Kai-Chun Chang, Chul-Woo Kim	***M3_303B_1*** **Optimization of Resonance Frequency of Smart Helmholtz Resonator by Response Surfece Method */82*** Wakae Kozukue, Hideyuki Miyaji	***M3_304_1*** **A Study of Relationship between Damage indices and Design Eccentricities of Buildings Existing Torsional Irregularity */85*** Kwang-ho Lee, Seong-Hoon Jeong

20:30-20:45	*M3_301A_2* **Development of a Dynamic Absorber with Variable Stiffness Property using Magneto-rheological Elastomers /71** Toshihiko Komatsuzaki, Yoshio Iwata, Hirofumi Ringe, Keiji Kawagoshi	*M3_301B_2* **Study on Simplified Vibration Control Method for Small-size Helicopter with Slung Load System /74** Motomichi Sonobe, Masafumi Miwa, Junichi Hino	*M3_302_2* **Extension of Rotor Model with Breathing Crack /77** Oh Sung Jun	*M3_303A_2* **Smart Piezoelectric Sensor System for Cable Force Monitoring of Long-span Cable-stayed Bridges /80** Khac-Duy Nguyen, Thanh-Canh Huynh, Dong-Soo Hong, Jeong-Tae Kim	*M3_303B_2* **Optimization of Fibrous Composite Reinforced by Curvilinear Fibers /82** Ryo Tsubata, Shinya Honda, Yoshihiro Narita	*M3_304_2* **Generation of Accelerograms Compatible with Response Spectrum using Information Theory /85** Anas Batou, Christian Soize
20:45-21:00	*M3_301A_3* **Study on the Dynamic Characteristics of a Torsional Tuned Damper for Marine Diesel Engines by Fluid Structural Interaction Analysis /72** Young-Cheol Kim, Dong Hwan Lee, Tae Young Chung, Seok Jun Moon	*M3_301B_3* **Validation of a Military Vehicle Model for Ride Quality Analysis /75** Chi-Young Ryu, Jin-Seok Jang, Kwang-Suk Kim, Wan-Suk Yoo, Jongtak Song, Dokyung Kang, Byoungyong Lee	*M3_302_3* **Rotor Dynamic Model for Spindle-bearing Systems and its Applications /78** Seong-Wook Hong, Gyu-Hyun Bae	*M3_303A_3* **Decentralized Damage Detection of Building Structures using Wireless Sensor Network /80** Jong-Woong Park, Hyung-Jo Jung, Sung-Han Sim	*M3_303B_3* **Optimal Design of High Damping Force Engine Mount featuring Hybrid MR Valve Structure /83** Joon Hee Park, Quoc-Hung Nguyen, Do Xuan Phu, Seung-Bok Choi, Ok Hyun Kang	*M3_304_3* **The Seismic Analysis of the Ortho-grid Panel Liquid Reservoir Equipment by the Generation of the Artificial Earthquake Wave /86** Dae Woong Park, Hyuk Jung
21:00-21:15	*M3_301A_4* **Vibration Control of Military Vehicle Suspension System featuring MR Dampers /72** Hwan Choong Kim, Sung Hoon Ha, Seung-Bok Choi	*M3_301B_4* **Natural Frequency Evaluation of a Composite Bogie Frame and a Steel Bogie Frame /75** Il Kyeom Kim, Jung Seok Kim	*M3_302_4* **Experimental Investigation of Damage Detection Methods for Reduction Gear Tooth and Bearing of Wind Turbine System Simulator /78** Yun-Ho Seo, SangRyul Kim, Bong-Ki Kim, Hyun-Sil Kim, Jae-Seung Kim	*M3_303A_4* **Guided Wave Propagation in Waveguides surrounded by Rugged and Nonhomogeneous Media /81** Juwon Lee, Won-Bae Na, Dong-Ho Jung	*M3_303B_4* **The SA/GA Hybrid Optimization Method using a Procedure for Changing Mesh Size /83** Tomoyuki Taniguchi, Yasuhiro Bonkobara, Takahiro Kondou, Yuichiro Sakamoto	
21:15-21:30	*M3_301A_5* **Seismic Response Control of High-rise Building by Enlarged Mass Ratio of Mass Damper to Mass of Building /73** Akira Sone, Shinichi Ueyama, Arata Masuda, Sunao Kato, Makoto Yamada, Shizuo Yamamoto	*M3_301B_5* **Experimental Approach for Clarifying Mechanism of Generation and Development of Rail Corrugation /76** Naoya Hashiguchi, Takuya Saito, Tomohisa Ogino, Yoshiaki Terumichi	*M3_302_5* **Rotor-dynamic Design Requirements for Turbines in Power Plants /79** Jeong Hwan Seo	*M3_303A_5* **Temperature Effects on the Bridge Natural Frequencies /81** Yuhee Kim, Kyoung Keun Lee, Soobong Shin	*M3_303B_5* **Quantification of Interaction Force between a Machine and Soil by Distinct Element Method /84** Yuki Takase, Takayuki Koizumi, Nobutaka Tsujiuchi, Hirosuke Horii	
21:30-21:45	*M3_301A_6* **A Study on the Biomechanical Behavior Analysis of the Human Right Arm under Impact Condition /73** Je-Wook Chae, Eui-Jung Choe, Sung-Ho Choi, Jee-Won Kim	*M3_301B_6* **Dynamic Analysis and Modeling of Flexible Car Body of High-Speed EMU with Honeycomb Structure /76** Seung Guk Baek, Sung Soo Ryu, Sae Whan Park, Ja Choon Koo			*M3_303B_6* **Optimal Design of MR Mount for Ship Engine considering Saturation /84** Do Xuan Phu, Joon Hee Park, Nguyen Quoc Hung, Seung-Bok Choi, Ok Hyun Kang	

June 4 [Tue.]

* OS: Organized Session

Session \ Room	301A	301B	302	303A	303B	304
11:00-	Registration [3F Hall]					
13:00-13:30	**Keynote Lecture 4 [[HALLA B Hall (3F)] : Prof. Satoshi Fujita (Tokyo Denki University)** **Seismic Damage of Mechanical Structures Due to the 2011 Great East Japan Earthquake and Effective Technology for Seismic Disaster Mitigation *28*** Chaired by Prof. Nam-sik Kim					
13:30-13:40	Break [3F Hall]					
T1 **13:40 – 15:10**	**T1_301A** **Vibration of Beam, Plate & Shells**	**T1_301B** **Noise**	**T1_302** **OS: Structural Health Management using Ultrasound and Vibration**	**T1_303A** **Multibody Dynamics**	**T1_303B** **Vibration Mitigation / Energy Harvesting**	**APVC 2013 LOC Meeting**
Chaired by	Prof. Li-Qun Chen Dr. Jungsoo Ryue	Prof. S. H. Kim Prof. Seo Il Chang	Mr. Karl Jonietz	Prof. J. H. Sohn Prof. Liu Yu	Prof. K. Sunakoda Dr. Hanmin Lee	
13:40-13:55	***T1_301A_1*** **Vibration Analysis for Thermally Induced Bi-stable Composite Shallow Shell */86*** Keisuke Takahashi, Shinya Honda, Yoshihiro Narita	***T1_301B_1*** **Transmission Loss through Double Wall */89*** Sungmok Hwang, Boha Lee, Jongdo Kim, Hyuk Kwun, Yongsuk Suh	***T1_302_1*** **A Strategy and Technologies for Blade Health Management from Manufacturing to Operation */92*** Jung-Ryul Lee, Hyomi Jeong, Paritosh Giri	***T1_303A_1*** **Matching Technology of Multibody Dynamics with Experiment according to Gas Circuit Breaker */95*** Gyu Seok Choi, Jeong Hyun Sohn, Hyun Woo Kim, Wan-Suk Yoo	***T1_303B_1*** **Dynamic Properties of Passive Type MRF Damper */98*** Yusuke Sato, Hiroshi Sodeyama, Katsuaki Sunakoda	
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Chaired by	Prof. B. T. Wang Prof. Hyung-Jo Jung	Dr. Taichi Matsuoka Prof. Moon Kwak	Prof. Kyung-Su Park	Prof. Soobong Shin	Dr. Jinchen Ji Dr. Hiroki Mori	Prof. Chan Il Park Prof. Frank Feng
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18:00-20:30	Banquet [TAMNA B Hall (5F)]					

June 5 [Wed.]

* OS: Organized Session

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13:00-13:30	**Keynote Lecture 5 [HALLA B Hall (3F)] : Prof. Li Cheng (The Hong Kong Polytechnic University)** **Controlling Flow-Structure-Sound Interaction using Adaptive Structures */29*** Chaired by Prof. Jae-Hung Han					
13:35-14:05	**Keynote Lecture 6 [HALLA B Hall (3F)] : Prof. Jae Kwan Kim (Seoul National University)** **Fluid-structure-foundation-soil Interaction and Earthquake Responses of Offshore Structures */29*** Chaired by Prof. Soobong Shin					
14:05-14:15	Break					
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Chaired by	Prof. S. M. Wang	Prof. J. O. Kim Prof. W. B. Shangguan	Prof. T. Yoshimura	Prof. Hyung-Jo Jung	Prof. Jintai Chung Prof. Zhichao Hou	Dr. Chulho Yang Dr. A. Muniyappa
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14:45-15:00	***W1_301A_3*** **A Modal Energy Method for Dynamic Force Identification */123*** Chen Mao, Wai-on Wong, Li Cheng	***W1_301B_3*** **MR Grease Application to a Controllable Clutch */125*** Masato Kaneko, Shin Morishita	***W1_302_3*** **Evaluation of Friction Damping in Jointed Plates with Partially Overlapping Interfaces */128*** Kazushi Koide, Fumiyasu Kuratani, Takao Hirai, Ichiro Kido	***W1_303A_3*** **Evaluation of Vibration Control Performance of Active Mass Damper (AMD) through Wind Tunnel Test */131*** Seung Hwan Sin, Yoon Bong Shin, Young Min Kim, Jae Seung Hwang	***W1_303B_3*** **Modal Parameters Identification by Frequency Domain Subspace Approach (Consideration of Residual Terms and Estimation of Model Order) */134*** Junichi Hino, Tomohiro Masukawa, Motomichi Sonobe	***W1_304_3*** **Performance Evaluation of an Optimization-based Damage Detection Technique */137*** Chulho Yang, Douglas Adams, Taewon Lee

15:00-15:15	***W1_301A_4*** **The Effect of High Speeds on Inherent Frequency of Motorized Spindle System with FEM */124*** Bo Wang, Kunpeng Xu	***W1_301B_4*** **Radial-mode Vibration Characteristics of Disc-Type Piezoelectric Transducers */126*** Jin Oh Kim, Se Hwan Oh, Chunguang Piao	***W1_302_4*** **Automotive Body Concept Modeling Method for the NVH Performance Optimization */128*** Mohammad Fard, N. N. Zadeh, M. Tatari, M. Mahjoob	***W1_303A_4*** **Vibration Mitigation of Building Structure using Time Delay Control Algorithm */131*** Dong-Doo Jang, Jeongsu Park, Gil-Yong Lee, Hyung-Jo Jung	***W1_303B_4*** **Mass Identification by Digital Acceleration Control for Dynamic Systems */134*** Koichi Imaoka, Takanori Emaru, Yukinori Kobayashi, Yohei Hoshino	***W1_304_4*** **Real-time Data Processing Method for Structural Health Monitoring */137*** Kohji Sakata, Takuya Yoshimura
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Chaired by	Prof. Don Chool Lee	Dr. Daisuke Iba Prof. M. G. Noh	Prof. Y. H. Jeong Prof. Yimin Zhang	Prof. Sang-Hoon Oh	Prof. Dooho Lee Prof. K. Kudora	Prof. Yohei Hoshino Prof. Jae-Hung Han
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16:45-17:00		***W2_301B_4*** **A Mixed-axis Control Design for Reducing Synchronous Vibration of an AMB-supported Rotor */142*** Myounggyu Noh, Jinhong Jung, Seong-Yeol Yoo	***W2_302_4*** **Micro-flow Generation using a Shock Wave Vibration */145*** Jin Soo Kim, Young Hun Jeong, Wook Bae Kim	***W2_303A_4*** **A New Seismic Retrofit System for Existing RC Frames */148*** Sang-Hoon Oh, Kwang-Yong Choi, Hong-Sik Ryu	***W2_303B_4*** **On the Numerical Calculation of Periodic Vibrations of Transmission Systems */152*** Nguyen Khang, Nguyen Dien	***W2_304_4*** **Development of Micro-Vibration Isolator using Voice Coil Motor */155*** Daeoen Lee, Geeyong Park, Jae-Hung Han
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Aeroelastic Analysis of a Wind Turbine Blade under Different Inflow Conditions

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Abstract

Generally, high aspect ratio wings such as wind turbine blades are more likely to get damages from unexpected loads. To maintain those structures stably, studies on the reduction of the vibrations should be implemented at the design stage of the wind turbines. As the modern horizontal axis wind turbine blades have become larger, lighter and more flexible, the aeroelastic problems have become considerably important issue. For these reasons, the fluid-structure coupled simulations of comprehensive systems are required to evaluate and understand the complex interaction of the elastic deformations and the aerodynamic loads. Therefore, in this research, a beam model including geometric nonlinearity coupled with unsteady aerodynamics based on a free-vortex wake method was employed. The present method was verified through comparison with measurements and numerical results from previously published literature. Finally, the aeroelastic instabilities of a National Renewable Energy Laboratory 5MW reference wind turbine blade are investigated under different inflow conditions.

Key words: Aeroelasticity, Fluid-structure Interaction, Free-vortex Method, Wind Turbine

1. Introduction

Wind turbine aerodynamics for a uniform flow condition is able to be considerably well modeled and understood(1). However, large-scaled wind turbines usually operate with non-uniform wind flows, such as wind shear. The wind shear, which is inclined to produce larger variations of magnitude of wind speeds in a vertical direction, can significantly influence the aerodynamic characteristics(2). For this reason, the numerical predictions, which can consider not only the uniform inflow but also sheared inflow conditions, are required.

Moreover, because sheared inflow condition substantially affects the variations of the airloads, such a condition may cause an increase the blade deflections in flap and edge directions at a particular azimuthal position. Large blade deflections have caused one or more wind turbine accidents due to blade-tower collision(3), so the interactions between wind speed magnitude, collective pitch action, and blade deformations have become even more important to the model and analysis of newly developed wind turbines(4). Thus, numerical simulations for investigating the aerodynamic and aeroelastic characteristics for various types of inflow conditions should be performed. In present study, the aerodynamic responses of a National Renewable Energy Laboratory (NREL) 5 mega-watt Reference Wind Turbine (RWT) for the uniform and sheared inflow conditions were compared with simulation results from previously published literature(2, 5) so as to validate the present approach. Also, the blade behavior of the given turbine blade in wind shear with various terrain types was predicted, and the maximum blade deflections at tip were finally estimated to examine the probability of a collision between blade and supported tower of the particular horizontal axis wind turbine model.

2. Normal Wind Profile Model

Two logarithmic and power laws are the most commonly used model for predicting wind shear profiles. The logarithmic law, which is based on the principles of boundary layer flow, is defined as follows:

$$\frac{U(z)}{U(z_r)} = \frac{\ln(z/z_0)}{\ln(z_r/z_0)}, \quad (1)$$

where $U(z)$, $U(z_r)$, z, and z_r indicate the target height wind speed, reference height wind speed, the target height, and reference height, respectively, and z_0 denotes the surface roughness length(6, 7). However, the logarithmic low computations have limitations in getting the wind profile data for the following reasons: (i) the model cannot be applied to signify all sheared inflow conditions because this law is unable to be mathematically defined for time periods, where the wind speeds at two different heights are the same; (ii) the calculated surface roughness length for that time period is unrealistically large when the wind speed decreases with height(6). Another widely used model is the power law, which can overcome limitations of the logarithmic law. The power law can be defined as follows:

$$\frac{U(z)}{U(z_r)} = \left(\frac{z}{z_r}\right)^{\alpha}, \quad (2)$$

where α denotes the wind shear exponent (or power law exponent). Many researchers have examined empirical relationships for the wind shear exponent as function of parameters, such as the wind speed, and surface roughness length(8, 9).

3. Results and Discussions

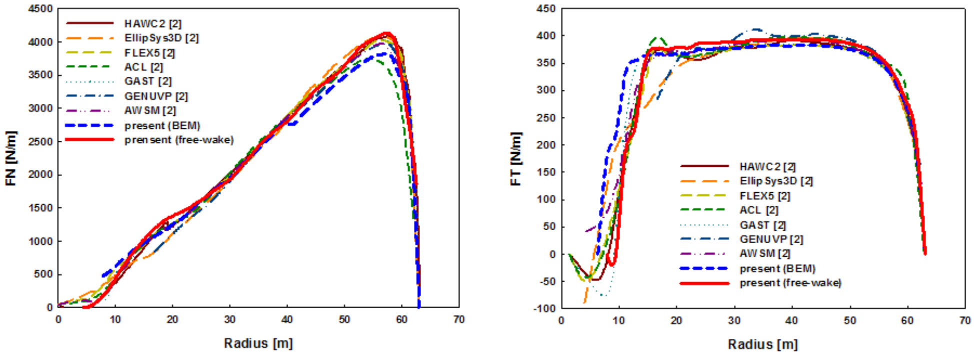
The aerodynamic and aeroelastic behaviors of large-scaled wind turbine blade are predominantly determined by the mean incoming speed. Thus, the numerical simulations of the NREL 5 mega-watt RWT were performed under the uniform and sheared inflow conditions. In this study, a nonlinear beam model was used and an unsteady aerodynamic model based on freewake method was employed to assess the aeroelastic responses. The NREL wind turbine has three-bladed with a span length of 63 meter, and the geometries of the airfoil types are based on the DU and NACA. The operational parameters are presented in Table 1. The details of the properties are given in reference(11).

Table 1. Operational parameters of the NREL 5 mega-watt RWT

Rated power	5 MW
Blade/ hub diameter	126 meter/ 3 meter
Rated wind speed	11.4 m/sec
Rated rotor speed	12.1 rpm

3.1 Uniform inflow condition

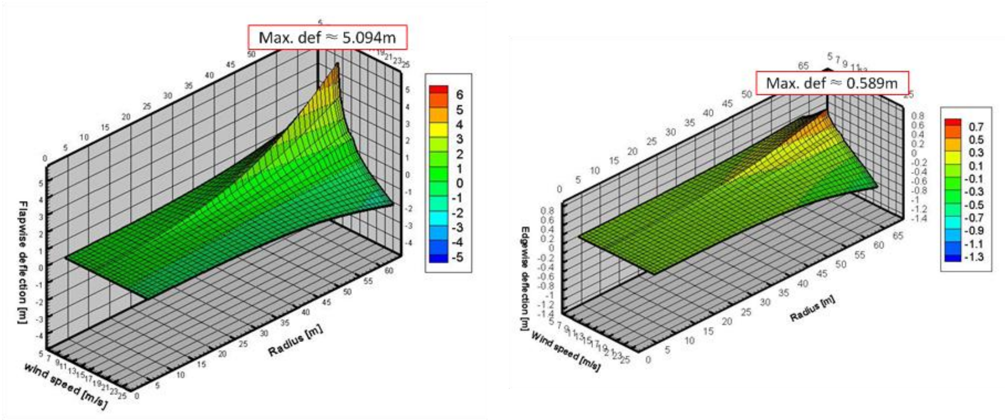
The aerodynamic characteristics of the NREL 5 mega-watt RWT blade were investigated for uniform inflow condition in order to validate the present approach. The predicted aerodynamic load distributions were shown in Fig. 1. Minor discrepancies between the results with various models were seen for the tangential force near the blade root. The reason of those offsets caused by the differences in aerodynamic models and correction methods. As seen in the figure, the results from the present methods correlated well to the majority of the numerical responses with different models(2).



(a) Normal force (b) Tangential force

Fig. 1 Normal and tangential force distributions for uniform inflow condition

Fig. 2 shows the radial distributions of the predicted blade deflections for entire wind speed range. It was observed that the overall flapwise deflections were much larger than the edgewise deflections. The absolute magnitude of the deformations increases along the blade tip. Also, it was seen that the steady-state blade deflections increase with wind speed in variable speed operation range (from 5 m/sec to 11.4 m/sec); however, in pitch controlled operation condition range (from 11.4 m/sec to 25 m/sec), those deflections decrease with wind speed due to the pitch control.

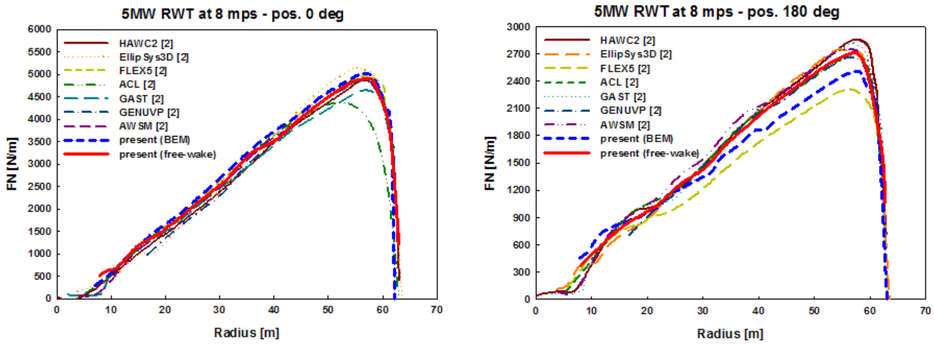


(a) Flapwise deflections (b) Tangential deflections

Fig. 2 Steady-state blade deflections for uniform inflow condition

3.2 Sheared inflow conditions

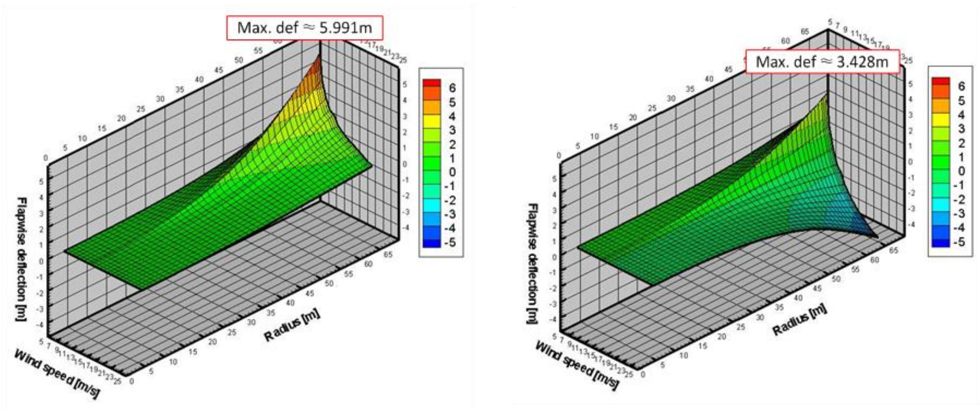
The wind speed in sheared inflow condition affects the distributions of the incoming velocity over a rotor plane; thus, the aerodynamic force along the blade varies. The simulations were performed at wind speed of 8 m/sec with wind shear exponent of 0.55. The wind profile data for sheared inflow can be obtained using the power law formulation as given in the International Standard IEC 61400-1 document(10). Fig. 3 shows the normal force distributions at blade top and blade bottom for sheared inflow condition. The computed aerodynamic loads in normal and tangential directions agree well with the different models(2).



(a) At blade vertical up (b) At blade vertical down

Fig. 3 Normal force distributions at blade top and bottom for sheared inflow condition

Moreover, the wind turbine blades are exposed to varying loads in consequence of existence of the wind shear, thus there are substantial deflections of the blades in out-of-plane and in-plane directions. The blade damage may arise if the blade deformation exceeds certain design limits. To prevent the wind turbine accidents, it is necessary to examine the structural behavior which can induce the blade damage of the system. For this reason, the blade behaviors in wind shear inflow conditions were investigated in this study. For simulations, a power law with a wind shear exponent of 0.4 was considered to predict the blade deflections.



(a) Flapwise deflections at blade top (b) Flapwise deflections at blade bottom

Fig. 4 Steady-state blade deflections for sheared inflow condition

The distributions of the predicted blade deflections were shown in Fig. 4. The blade behaviors have tendencies similar to the simulation results for the uniform inflow condition, as shown in Fig. 2. Also, it was clearly found that the largest deflection occurred when the blade is in the vertically upward position at rated wind speed.

4. Conclusions

The effects of inflow conditions on aerodynamic and aeroelastic characteristics were investigated. To validate the present methods, the aerodynamic loads of the NREL 5 mega-watt wind turbine blade were compared to the numerical results from previous study. The blade deflections in flap and edge directions under the uniform and sheared inflow conditions were estimated to examine the probability of the collision between the blade and tower of the particular wind turbine model. It was found that the maximum blade deflection occur at the rated wind speed when the blade is in the vertically downward position. Thus, certain design limits to prevent a blade damages can be provided by predicting the blade behavior when state-of- the-art wind turbines are newly developed.

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