

Dept of Mech Eng / Vib & Acoust Lab AITANVH National Pingtung University of Science and Technology

Noise and Vibration Techniques in Industry Application base on Industry 4.0

從工業4.0看振動噪音技術在產業的應用

振動噪音產業技術聯盟

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National Pingtung University of Science & Technology
機械工程系
振動噪音實驗室
VIBRATION AND ACOUSTICS LAB

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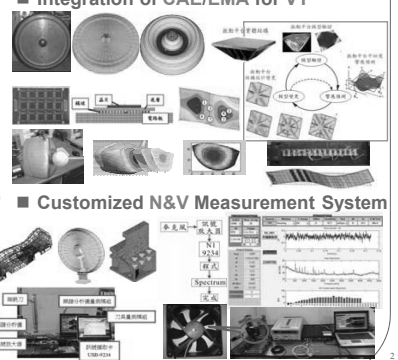
Professor Bor-Tsuen Wang



- Position:**
 - NPUST
 - Prof., Dept. of ME (1997~)
 - AITA/NVH Chair (2014~)
- Education:**
 - Virginia Tech, USA
 - MS (1988), PhD (1991)
- Experience:**
 - CSSV, Chinese Soc. of S&V
 - President (2014~2016)
 - Dean, R&D Office (2011~2014)
 - Dean, Eng. College (2007~2010)
 - Chief Secretary (2003~2005)
 - Director, Extension Education (2001)
 - Char, Dept. of ME (1997~2000)
 - Chief, RD Division (1994~1997)
 - Chief, Machinery Lab (1991~1994)
- Specialization**
 - Vibration & Acoustics
 - CAE/FEA & EMA
 - Vehicle Dynamics
 - Musical Instruments

Research Interest

- Integration of CAE/EMA for VT
- Customized N&V Measurement System



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Outline

1. Introduction
2. What is "Industry 4.0"?
3. N&V Techniques for Product Development
4. Approach to Product Design with N&V Concerns
5. General Approach for NVH Diagnosis
6. Future Development of NVH Techniques base on the Spirit of Industry 4.0
7. Conclusions

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1. Introduction

Keyword Analysis

- Noise and Vibration Techniques**
 - Analytical approach
 - Experimental approach
- in Industry**
 - Vehicle:
 - bike, motorcycle, automobile, aircraft, submarine, ...
 - 3C products:
 - computer, communication and consumer electronics
 - Many more...
- Application**
 - To solve NVH, N&V, S&V, BSR, etc. for
 - Product design (CAD/CAE) & Product testing (CAM/CAT)
 - Design Verification (DV) & Product Validation (PV) → V&V
- base on Industry 4.0 → Spirit of Industry 4.0**
 - Feedback
 - Solution

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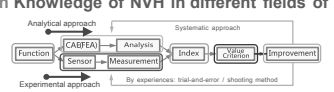
Noise and Vibration Techniques in Industry Application base on Industry 4.0

- Why this topic?**
 - Overview on the topic
 - From "theoretical/numerical" to "practical/experimental"
 - From the point of view of "engineer" to "manager"
 - Both analytical and experimental approaches
 - To be on the right track to the "success" in solving NVH
- What goals to achieve for this topic?**
 - Introduce Noise and Vibration Techniques
 - Identify the Industrials needs
 - Show the application of NVH concerns
 - Industry 4.0 spirit
- How to do and achieve the goals?**

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- How to do and achieve the goals?**
 - Reveal my special & unique concepts, such as
 - SPR
 - ISO
 - FSMICI & FCAICI
 - Industry 4.0: feedback & solution
 - Practical approach for NVH diagnosis and improvement
 - Concept about R-test for steady-state and run-up
 - Approach about P-test for determining structural modes,
 - CAE model for structural P-analysis → R-analysis
 - Practical approach in defining problem
 - to carry out the project
 - Background knowledges
 - Fundamental Knowledge of NVH
 - Domain Knowledge of NVH in different fields of engineering

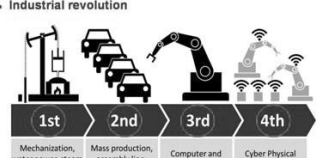


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2. What is "Industry 4.0"?

- Germany
 - Industry 4.0
- United State of America
 - Advanced Manufacturing Partnership (AMP)
- Japan
 - Industry 4.1 J
- China
 - Made in China 2025
- Korea
 - Industry Innovation 3.0
- Taiwan
 - Productivity 4.0

Industrial revolution



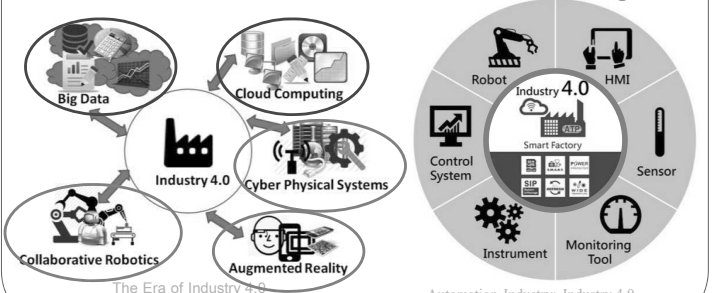
A critical look at Industry 4.0
Picture source: <http://www.allaboutlean.com/industry-4-0/>

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Two Issues in Industry 4.0

(1) Internet of Things (IoT)
(2) Cyber-Physical Systems (CPS)

From the point of view for "Design" "Manufacturing"



The Era of Industry 4.0
圖片來源: <http://vantage.net/internet-of-things-smart-manufacturing-the-era-of-industry-4-0/>

Automation Industry: Industry 4.0
圖片來源: <http://embedded-computing.com/white-papers/white-0-challenges-solutions-storage-devices/>

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My Perspectives of Two Keywords for Spirits of Industry 4.0

(1) **Feedback :**

- Ability to collect the product information during design, manufacture, transportation, market, etc.
- Information about reactions to a product, a person's performance of a task, etc., used as a basis for improvement.
 - Big data, IoT, Cloud, wireless sensor, smart sensing, etc.

(2) **Solution :**

- Ability to solve for the feedback problems and customer's concerns
- A means of solving a problem or dealing with a difficult situation.
 - Design (DV), Smart Manufacture, Testing (PV), etc.

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Industry 4.0 for Product Development

Sub-system

System

Feedback/Solution Know WHY?

Feedback from Market

Feedback → Know WHAT? Engineers/Techniques/Tools Manager/Strategy/Support \$

know what → know why → know how

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3. N&V Techniques for Product Development

- **KNOW-WHAT** Techniques
- **KNOW-WHY** Techniques
- **KNOW-HOW** Techniques

Steel HSP Chord Sound Plate (CSP)

Glass HSP Steel Chimes Complete set of Crotales

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How to perform "Engineering Design" ? "FCAICI" & "FSMCI"

- **Function :** what "purpose"?
- **Approach**
 - Analytical approach
 - CAE
 - Analysis
 - Experimental approach
 - Sensor
 - Measurement
- **Index :** Performance Index (PI)
- **Value → Criterion :**
 - From "Value" to acceptance "Criterion"
- **Improvement :** seek for proper solution

Brand, Reliability, Quality, Performance, Safety, Function

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How to perform "Engineering Design" ?

Mode	Frequency (Hz)	Amplitude (mm)	Phase (deg)
1	1159.3	0.32	-0.3
2	1457.1	0.28	0.1
3	1620.5	0.25	-0.3
4	2087.1	0.4	0.6
5	3104.4	0.15	0.4
6	3710.0	0.12	0.4

Wang, B. T., Chao, T. C., and Hsieh, M. H., Chord Plate Structure of Metallophones, Taiwan Patent No. 1 515718. (2016)

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"FCAICI" & "FSMCI" for know what → know why → know how

Category	Item	Value
C#D#E (和弦D和弦E和弦)	1	1.059
	D	1174.66
	D#E#F	1244.21
	F	1260
F#G#A (和弦G和弦A)	1	1396.91
	A	1414
	A#B#C	1479.98
	B	1498
A#B#C (和弦B和弦C)	1	1560.04
	B	1584.66
	C	1602
	B	1675.33

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SPR & ISO Concept

Source $f_j(t)$ → Structural Path → Response $a_i(t)$ → Air Path → Response $p_k(t)$

P-Test P-Analysis R-Test R-Analysis P-Test P-Analysis R-Test R-Analysis

輸入 (Input) 系統 (System) 輸出 (Output)

振動源 (Source) 路徑 (Path) 收受端 (Receiver)

系統分析 (P-Test) 信號分析 (R-Test)

• ISO

• SPR

Path Test/系統分析 (system analysis) :
 > 系統分析之目的則在了解【系統的內涵】

Receiver Test/信號分析 (signal analysis) :
 > 後針對所量測之輸出響應 (response)
 > 以了解此【輸出信號特性】，以作為其他之工程應用。

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System Block Diagram

Force → 1.Geometry 2.Material 3.Boundary → Deformation Stress → Acceleration

Striking force → Structural Path → Air Path → Sound Pressure → Ear → Brain → Feelings

Harmonic sound plate accelerometer

Notebook

NI 9234

microphone

Impact hammer

P-Test/P-Analysis (structure system)

Structural Vibration Sound Pressure

$f_j(t) \rightarrow H_{a_i, f_j}(f) \rightarrow a_i(t) \rightarrow H_{p_k, a_i}(f) \rightarrow p_k(t)$

$f_j(t) \rightarrow H_{p_k, f_j}(f) = H_{a_i, f_j}(f) H_{p_k, a_i}(f) \rightarrow p_k(t)$

P-Test/P-Analysis (air-structure system)

R-Test/R-Analysis

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4. Approach to Product Design with N&V Concerns

- Feedback ability:**
 - Tools to "know what"
 - Technique to "know why"
- Solution ability:**
 - Methodology to "know how"
- Fundamental knowledge**
 - Vibration/Dynamic
 - Acoustic (sound/noise)
- Domain knowledge**
 - Percussion instruments
 - Air Conditioner
 - Compressor...
 - Vehicle
 - Engine and power transmission
 - Tire
 - Vehicle performance
 - Handling
 - Ride comfort/quality
 - Aerodynamic ...

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From "Component" to "System"

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System Concept ISO - SPR - F → GMBI → R

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5. General Approach for NVH Diagnosis

1. Define the "Project"
2. Think:
 - Why to do?
 - What goals?
 - How to do?
3. Plan "How to do"?
 - Know what?
 - Know why?
 - Know how?
4. Diagnosis SOP
5. Report

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NVH Diagnosis Approach

4. Diagnosis SOP
 - R-test for S&V
 - Steady-state
 - Run-up / Coast-down
 - P-test (EMA)
 - For structure
 - Component → System
 - For air-structure
 - Compare R-test & P-test
 - Identify "resonance"
 - DM, design modification
 - Experimental
 - Analytical
 - Repeat above

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6. NVH Techniques Future Development base on Industry 4.0 Spirits

- "CPS" be "ALL in ONE"
- "IoT" be the "connection" among "ALL"

Smart monitoring self-diagnosis Objective oriented App

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7. Conclusions

- NVH issues in engineering
- Spirit of "Industry 4.0":
 - Feedback & Solution
 - (1) IoT → Feedback
 - Data → Information
 - Tools to "know what"
 - Technique to "know why"
 - (2) CPS → Solution
 - Testing → Virtual Testing
 - CAE → Experimental Verification
 - Verification → Validation
 - Component design → System design
 - Methodology to "know how"
 - Fundamental knowledge
 - Vibration/Dynamic
 - Acoustic (sound/noise)
 - VT (Virtual Testing)
 - Domain knowledge
 - Products?
- From "Component" to "System"
 - System Concept
 - ISO
 - SPR
 - F → GMBI → R
 - "FSMCI" & "FCAICI"
 - "know what" tools?
 - "know why" techniques?
 - "know how" methodology?
 - NVH diagnosis approach
 - Case study

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Thank you for your attention!

敬請指教

「振動噪音產學技術聯盟」
Academia Industry Technology Alliance for Noise, Vibration and Harshness (AITA/NVH)

服務：深入業界專業服務
創新：創意發想如山壯大
深耕：組織堅固信賴深耕
傳承：振動波般永續傳承