

Preface

In recent years, “Intelligent manufacturing+tri-co robots” are particularly eye-catching, presenting the characteristics of the era of the perception of things,the interconnect of things,the intelligence of thing. Intelligent manufacturing and tri-co robots industry will be the strategic emerging industry with priority development,it is also a huge engine for “Made in China 2049”. It's remarkable that the large-scale tri-co robots industry formed by smart cars ,drones and underwater robots will be a strategic area of countries to compete in the next 30 years, and have influence on economic development, social progress, and war forms. The related manufacturing sciences and robotics are comprehensive disciplines that link and cover material sciences, information sciences, and life sciences. Like other engineering sciences and technical sciences, tri-co robots industry also will be the big science that provides a way to understand and transform the world. In the mid-20th century,the publication of Cybernetics and Engineering Cybernetics created a new era of engineering sciences. Since the 21st century, the manufacturing sciences, robotics and artificial intelligence and other fields have been extremely active and far-reaching,they are the sources of the innovation of “Intelligent manufacturing+ tri-co robots”.

Huazhong University of Science and Technology Press follows the trend of the times, aiming at the technological frontiers of intelligent manufacturing and robots, organizes and plans this series of Intelligent Manufacturing and Robot Theory & Technology Research. The series covers a wide range of topics,experts and professors are warmly welcome to write books from different perspectives,different aspects, and different fields.The key points of the topics include but are not limited to:the links of intelligent manufacturing,such as research, development, design, processing, molding and assembly, etc;the fields of intelligent manufacturing,such as intelligent control, intelligent sensing, intelligent equipment, intelligent systems, intelligent logistics and intelligent automation, etc;development and application of robots,such as industrial robots, service robots, extreme robots, land-sea-air robots, bionics/artificial/robots, soft robots and micro-nano robots;artificial intelligence, cognitive science, big data, cloud manufacturing, Internet of things and Internet,etc.

This series of books will become a platform for academic exchange and cooperation between experts and scholars in related fields, a zone where young scientists thrive, and an international arena for scientists to display their research results.Huazhong University of Science and Technology Press will cooperate with international academic publishing organizations such as Springer Publishing House to publish and distribute

this series of books. Also, the company has established close relationship with relevant international academic conferences and journals, creating a good environment to enhance the academic level and practical value, expand the international influence of the series.

In recent years, people from all walks of life, university teachers and students, experts, scientists and technicians in various fields are more and more enthusiastic about intelligent manufacturing and robotics. This series of books will become the link between experts, scholars, university teachers, students and technicians, enhance the connection between authors, editors and readers, speed up the process of discovering, imparting, increasing and updating knowledge, contribute to economic construction, social progress, and scientific and technological development.

Finally, I sincerely thank the authors, editors and readers who have contributed to this series of books, for adding, gathering, and exerting positive energy for innovation-driven development, thank the relevant personnel of Huazhong University of Science and Technology Press for their hard work in the process of organizing and scheming of the series of books.

Professor of Huazhong University of Science and Technology
Academician of Chinese Academy of Sciences

Youlun Xiong
September, 2017

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Foreword

Vibration, or oscillation, is a periodic movement in time of a system around a certain equilibrium position. The system consists of at least one element for storing kinetic energy and one for storing potential energy. The vibration is a process of energy-type exchanges between the kinetic and potential energies. The equilibrium position is the position in which the potential energy becomes zero. The periodicity of the movement is described in frequency which is the measurement of the numbers of times of the repeated events that occurred in a unit time. Vibration is an omnipresent type of dynamic behavior of a system and exists in many forms, such as sound and music.

Human beings first recognized the vibration phenomenon by entertaining themselves with percussion, string, and plate music instruments in ancient times. Just like the time when the lever principle was discovered is much later than that of its real utilization in human history, the time when the vibration and acoustics theory on the principles of the music instruments were discovered is much later than the time when the music instruments were made and played. The earliest music instrument unearthed in Henan Province, China, is a bone flute, which can be traced back about 6000–5000 years B.C., while the earliest string vibration frequency and music acoustic theory for a string instrument ever written and published in Chinese history is around 700 B.C. in “Guanzi” by Guan Zhong (?–645 B.C.). In his music-scale algorithm, if the length of the basic string for the major tone is 1, the string lengths of the next scales are either added $1/3$ ($4/3$) of the basic length or subtracted $1/3$ (or $2/3$), other music scales are determined by this $1/3$ length rule, and he obtained five tones by this algorithm: C, D, E, G, A. It’s amazing that more than 100 years later the Greek philosopher and mathematician Pythagoras (580–500 B.C.) discovered independently the very similar theory for seven tones: The Pythagorean Scale.

Human beings first learned the vibration and acoustics of the plates and shells also from music instrument manufacturers. “Kaogongji” or “Artificer’s Record” 500 B.C. in Chinese history, recorded the Bian-Qing (sound bian-ching). It is a set of percussion, made of high-quality stones such as jade, with several fixed music scales. The “Kaogongji” specifically described how to adjust the percussion music scale: “if music scale is higher, filing the surfaces of the plate, if the scale is lower, then filing the edges of the plate”. These technological processes, even though not giving exactly the

quantitative relation between the natural frequencies of the plate and its geometrical parameters, are indeed in accordance qualitatively with the contemporary vibration and acoustic principles of the plate and shells: filing the surfaces of the plate makes the plate thinner and natural frequencies will be decreased while filing the edges of the plate makes the plate relatively thicker thus the natural frequencies will be increased.

One of the most important dynamic properties for the vibrations of a system is the inherent frequency or natural frequency. The vibrating movements of a system occur by external forces or internal self-excitement. When the frequencies of the excitation are the same or near the system's natural frequencies, the responses of the systems will become larger and larger, which is called the resonance. The resonance has a variety of applications, such as radio, television, and music. The large magnitude vibrations, such as large magnitude earthquakes, tsunamis, could bring harmful, devastative, and even catastrophic damages to properties and human lives. People tried to predict the earthquake by vibrating devices. In 132 A.D. Zhang Heng (78–139 A.D.), a Chinese mathematician, an astronomer, and a geographer, invented the vibration utilization device: Seismograph. The shape of the device looks like a goblet. Eight (8) exquisitely casting dragons, upside down, attached to the body of the device. The eight dragons are mounted in the North, South, East, West, Northeast, Southeast, Northwest, and Southwest directions, respectively, representing the earthquake directions. There is a ball in each dragon's mouth. There is a vivid toad, mounted separately to the body, under each dragon. It is said that when an earthquake occurs the dragon in the earthquake direction will release its ball in its mouth into the toad's mouth as a prediction indication. The exact mechanism inside was not well documented. It was recorded in history books that this device had successfully predicted an earthquake about 600 miles away in 138 A.D. just 1 year before he died.

In modern days, tens of thousands of types of vibrating machines and instruments have been successfully used to accomplish a variety of technological procedures in the fields of mining, metallurgical industry, coal mining, petro-chemistry industry, mechanical industry, electronic industry, hydraulics and civil engineering construction, food and grain processing, biological industry and process of human everyday life. The technologies involved in this science branch are so closely associated to agricultural and industrial production that it can create great economical and social benefits, and can provide great convenience and excellent service for people's life. It becomes an inevitable means and a necessary mechanism for human production activities and life processes. A study of "Vibration Utilization Engineering" as a new branch of science has been gradually formed and developed in the latter part of the twentieth century to cope with the increasing demands of the vibration utilization.

The literature on vibration utilization is scattered over all the magazines, books, journals, and conference proceedings in different academic fields and different science branches. It would be difficult to look into and collect the information and references on different vibrating machines. It would be informative and convenient to have an encyclopedia type of a book to cover as many types of vibrating machines and as many aspects of vibration utilization as possible and provide multi-sources

and cross-references for scientists and engineers to use. This is part of our intention in writing this book. The authors attempt to summarize the scientific research works on the vibration utilization over more than 30 years. The book also includes the following original and creative results led by the first author and Professor Bangchun Wen and his team colleagues:

1. The authors constructed a theoretical framework for "Vibration Utilization Engineering", this terminology is first born in domestic and international areas.
2. In the technological theory and technology creativities, the authors introduced the creative results obtained on technological theories and practical applications in the Vibration Utilization Engineering such as probability ISO-thickness screening theory; material sliding and throwing theory on different surfaces; and screening process theory and their applications in the vibration machine processes.
3. In mechanism creativities, the authors proposed a variety of new vibrating mechanisms, such as exciter-eccentric type of self-synchronously vibrating mechanism, special forms of non-linear inertial resonant type of vibrating mechanism, etc., patent approved.
4. In the nonlinear dynamic theory creativities, the authors summarized the systematic studies and experiments conducted on vibration and wave utilization technology and equipment working theories and derived theory basis on many branches of the Vibration Utilization Engineering, such as vibration synchronization and application of the controlled synchronization theory, application of the nonlinear vibration, etc. For example, the dynamic theory of a variety of vibrating machines and equipments, the equivalent mass and damping of vibrating machine systems, the theory and computing methods of the second vibration isolation of the vibrating machines and equipments, the vibrating synchronization theory and methods on dual- or multi-motor-driven vibrating machines, dynamic analysis, and dynamics parameter computation methods on nonlinear vibrating machines, the dynamic design methods on vibrating machines and their main components, many of them are first published in this book.
5. In the design theory and method creativities, the authors proposed the systematic vibrating machine dynamic design theory and method, especially those for the non-linear vibrating machines and the comprehensive design methods which contain the dynamic optimization, intelligent optimization and visualization.
6. In the engineering applications, the authors have applied their theoretical results to engineering for over 30 years. For example, the inertia-resonance-probability screens, new mechanism type of vibrating cooling machines and new mechanism type of vibrating crushers, etc. These machines are rewarded by the National Invention, National Technology Progress, etc.

This book contains seven chapters. Chapter 1 introduces the formation and development of the Vibration Utilization Engineering; Chap. 2 devotes to some of the important research results in the vibration and wave-energy utilization in some technological processes; Chap. 3 describes the theories on the technological process

of the vibration utilization technology and equipment; Chaps. 4 and 5 discuss the vibration utilizations of the linear, pseudo-linear, and nonlinear systems; Chap. 6 presents the utilization of the wave and wave-energy; and Chap. 7 briefly illustrates the vibration phenomena and utilizations in nature and human societies.

The authors include Bangchun Wen, Xianli Huang, Yinong Li, and Yimin Zhang. During the editing it absorbed the research results by the team members: they are Profs. Lizhang Guan, Guozhong Zhang, Liyi Ren, Shengqing Ji, Shuying Liu, Chengxiu Wen, Zhishan Duan, Jie Liu, Tianxia Zhang, Xun He, Haiquan Zeng, Peimin Xu, Yannian Rei, Shirong Yan, Huiqun Yuan, Qingkai Han; Associate Professors Jian Fan, Jingyang Qi, Chunyun Zhao, Fenglan Wang, Suying Shu, Hongguang Li, Wali Xiong, Shide Peng; Senior Engineers Xiangyang Lin, Mingfei Luo, Yongxi Liu, Zhaomin Gong, Hong Zhang, Tianning Xu, Qinghua Kong, Huajun Wang, and Naiqing Ma; Doctors He Li, Hongliang Yao, Zihé Liu, Haiyan Wei. We also received help from Academicians Wenhua Huang, Shuzi Yang, Jinji Gao; Professors Yushu Chen, Zhaochang Zheng, Haiyan Hu, and Dianzhong Wang; Doctoral students Hong Chen, Xiaowei Zhang, Xiaopeng Li, Xueping Song, Li Wang, Tao Yu, Wei Sun, Hui Ma, and Juequan Mao. Thanks also go to Electronics and Machine Institute of Northeastern University, the Group of Xuzhuo Engineering Machines, the Capital Iron and Steel Corp, Luoyang Mine Machine Design and Research Institute, Anshan Mine Machine Limited, Henan Weimeng Vibrating Machine Limited, Chaoyang Vibrating Machine Factory, Haian Vibrating Machine Factory, and Zhongxiang Machine and Electrics Corp for their assistance.

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Shenyang, China
Liaocheng, China
Chongqing, China
Shenyang, China

Bangchun Wen
Xianli Huang
Yinong Li
Yimin Zhang