Hydraulic vibration hammer without resonance technology status study

ABSTRACT

Hydraulic vibratory hammer using the working principle of vibratory pile sinking is an important equipment in pile foundation construction, which can be used for sinking and extracting piles. It has a wider range of application than the drop hammer for sinking piles by the impact method and the static hammer for sinking piles by the press-in method, which can significantly reduce the resistance of piles during sinking and extraction and enhance the work efficiency. In this paper, the resonance-free technology of hydraulic vibratory hammer is studied in the hope of promoting the development of hydraulic vibratory hammer. Based on this, we expect to innovate the technology of hydraulic vibratory hammer without resonance, reduce its cost and promote commercialization.

Keywords: Hydraulic vibratory hammer; vibratory pile-sinking; resonance-free.

1. INTRODUCTION

Hydraulic vibratory hammer has been playing an important role in the construction of bridges, ports, flood control and urban residential projects[1-4]. When the hydraulic vibratory hammer works, the hydraulic motor drives the active shaft to rotate, and one or more groups of eccentric wheels rotate in the same direction to generate the excitation force in the vertical direction, which makes the pile vibrate with the surrounding soil under the action of the periodically changing excitation force, and the periodic vibration can reduce the frictional resistance between the pile side and the soil particles, and the pile relies on its own weight to overcome the frictional resistance on the pile side and the resistance of the pile tip to penetrate the ground and sink[5]. Therefore, it is important to research and develop the hydraulic vibratory hammer to produce products with better performance to improve the working efficiency[6]. The structure of the hydraulic vibratory hammer is shown in Figure 1.

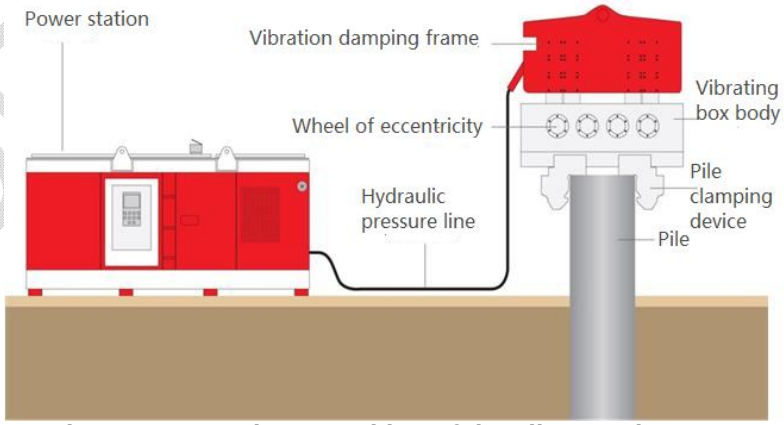

Fig. 1. Structural composition of the vibratory hammer

2. DEVELOPMENT OF HYDRAULIC VIBRATORY HAMMERS

The theory of sinking piles by vibration was developed in the 1930s[7]. Pavyluk in the former Soviet Union discovered that vibration reduces the shear strength of the soil, resulting in a reduction in soil friction, and thus introduced the concept of vibratory pile sinking[8]. In 1931, Barkan found that vibratory pile sinking reduced the friction between the side of the pile and the soil to a much greater extent than conventional pile sinking[9]. In 1934, he invented the world's first vibratory hammer based on the principle of "liquefaction" of vibration[10]. The basic principle of high frequency vibratory piling was elaborated in 1949[11]. In 1950, Tatarnikov of the former Soviet Union designed the BII-1 vibratory hammer for sinking reinforced concrete piles[12]. In 1959, Japan successfully developed the first electric vibratory hammer[13]. In the 1960s, the United States developed the ultra-high frequency hydraulic vibratory hammer[14].

3.RESEARCH STATUS OF RESONANCE-FREE TECHNOLOGY OF HYDRAULIC VIBRATORY HAMMER

Hydraulic vibratory hammer enhances the piling efficiency, but it is difficult to avoid the resonance phenomenon during the starting and stopping process of hydraulic vibratory hammer[15]. Therefore, when the pile hammer accelerates or decelerates through the self-oscillation frequency area, it will resonate for a short period of time, causing a high concentration of stress in the pile hammer parts and reducing its service life[16]. The working process of hydraulic vibratory hammer resonance frequency interval diagram is shown in Figure 2.

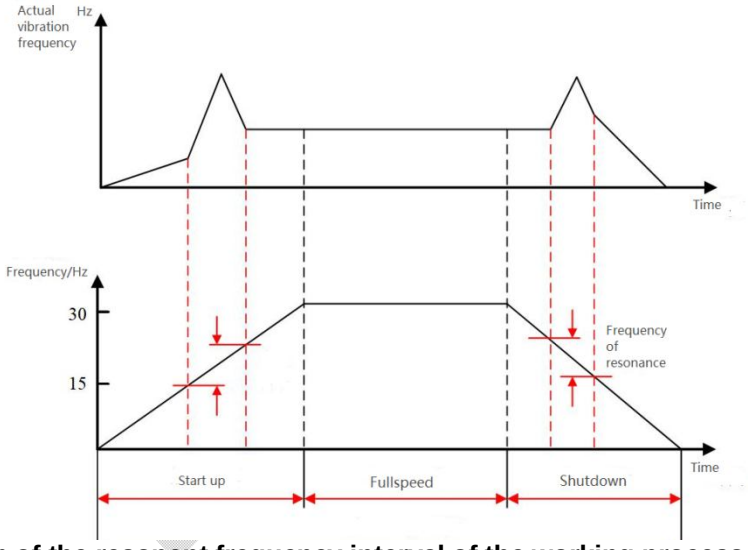

Fig.2. Schematic diagram of the resonant frequency interval of the working process of hydraulic vibratory hammer

3.1 STUDY ON THE PROCESS OF SINKING AND EXTRACTING PILES BY VIBRATORY HAMMER

Some researchers firstly investigated the dynamic properties of the vibratory hammer. Liu Guihua et al [17]. studied the dynamic performance of vibratory hammer and found the effect of the variation of vibratory hammer amplitude on the efficiency of vibratory hammer when sinking and extracting piles by studying the differential equations of motion of vibratory hammer, which provided a theoretical basis for the design and development of the system of vibratory hammer amplitude adjustment mechanism for achieving higher efficiency in sinking and extracting piles. Zhou Linsen et al [18]. studied the dynamics model of two-degree-of-freedom vibratory impact hammer, used the first harmonic to describe the nonlinear interval impact force of the vibratory hammer, and obtained the dynamic parameters of the vibratory hammer by calculating and solving the system of differential equations of motion, which provided the basic theory and method for the in-depth study of the dynamics characteristics of the vibratory hammer. Based on the working principle and main parameters of the vibrating hammer, Yu Guoping established a dynamics model and solved the dynamics equations to find out the dynamic response of the system under the action of the excitation force. The study of the dynamics of the vibratory hammer provides a theoretical basis for the study of the working process of the vibratory hammer[19].

Then the researchers studied the mathematical model during the working process of the vibratory hammer. Li Husheng studied the two-degree-of-freedom mathematical model during the working process of hydraulic vibratory pile hammer and used Matlab software to simulate and analyze the two-degree-of-freedom mathematical model during the working process of hydraulic vibratory pile hammer, and obtained the vibration hammer displacement, velocity and acceleration during the vibration hammer[20]. Zhang et al [21]. established the equations of motion of the pile sinking process during the operation of the vibratory hammer according to the structural dynamics and calculated the amplitude during the pile

sinking process, and the obtained calculation results provide guidance for the vibratory hammer to mitigate the resonance phenomenon and avoid excessive amplitude. Wang Kai et al [22]. established a finite element model by simplifying the vibratory hammer and soil, and simulated the pile sinking process of the vibratory hammer by using ANSYS software to obtain the influence curves of excitation force frequency, excitation force, and mechanical properties of soil on the pile sinking of the vibratory hammer, and the obtained curves can reflect the unreasonable parameters of the pile driver. For the simulation level of vibratory hammer in China, Yunfei Jiang et al [23]. first carried out the solution of the two-degree-of-freedom mathematical model of the vibratory hammer to derive the expression of the regular relationship between amplitude and frequency, and used Matlab software to simulate the amplitude-frequency response under different parameters, and obtained the relationship between the amplitude of the beam and the sunken pile and each parameter. The study of the mathematical model during the operation of the vibratory hammer provides support for the study of the prototype of the vibratory hammer.

Tao Li performed dynamics analysis and modeling simulation on the experimental prototype of vibratory hammer, and found the laws of pile end resistance, pile side friction resistance, sinking pile displacement and velocity change with time[24]. Liu Wei took ZZY160 vibrating hammer as the research object, and studied the system of vibrating hammer and soil separately, and discovered the frequency characteristics of the working process of the vibrating hammer[25]. Through the study of the eccentric moment adjustment principle, he designed and manufactured the hydraulic frequency and amplitude adjustment system, and realized the change of eccentric moment by changing the eccentric distance, and used the stepless adjustment and remote control of the hydraulic control system to realize the vibration of the vibrating hammer The frequency and amplitude of the vibration hammer were adjusted by changing the eccentric distance. Wu Shuai et al [26]. used Adams software to simulate the 3D model of the inertia hammer and obtained the curves of the motion trajectory of the hammer under different initial parameters, and then obtained the displacement, velocity and acceleration of the parts, so as to find the unreasonable parameters and optimize the design of the pile driver. Bian Hongye et al [27]. studied the hydraulic system of the vibratory hammer and the pile and soil system of the pile sinking process with the new hydraulic vibratory hammer, modified the structure of the vibratory hammer and the hydraulic system, and simulated the pile sinking process of the vibratory hammer using ANSYS software to obtain the vibration curves of the vibratory hammer under different parameters.

By comparing the data, the relationship between the vibration parameters of the vibratory hammer and the effect of sinking and extracting piles was obtained. By reasonably selecting the vibration parameters of the vibratory hammer, the resistance of sinking piles can be overcome and the effect of sinking and extracting piles can be improved by increasing the impact force of piles on soil. [28]

Some researchers have studied the exciter of the vibratory hammer immediately afterwards. Fu Maojing designed a new broadband shaker that excites in the frequency range of 20 Hz to 20 kHz[29]. The new broadband shaker combines electrodynamic excitation with piezoelectric excitation. The no-load acceleration and force-frequency response of the new shaker passed a series of tests to verify the possibility of the new shaker and provide a reference for the improvement of the vibration hammer. Qingkai Han et al [30]. studied the vibration system with reverse rotary excitation, established the kinetic equations for the drive motor, and obtained the influence law of the eccentric moment of the shaker, motor power, eccentric rotor rotary frictional resistance moment and other parameters on the self-synchronous motion through software simulation analysis. A theoretical basis was provided for the design and development of the vibration hammer. Luo Chunlei et al [31]. designed a new type of hydraulic vibratory pile hammer exciter and its hydraulic control system. The designed hydraulic vibratory pile hammer exciter is a four-axis vibratory pile hammer structure, and the hydraulic cylinder oil pressure is not used to adjust the gear, and the eccentric block is driven by the hydraulic cylinder to produce changes in eccentric distance; the designed hydraulic control system realizes one valve for multiple uses, and takes into account various conditions during operation, which provides safe operation and efficient operation. The designed hydraulic control system achieves multiple uses of one valve and considers various conditions during operation, providing a guarantee for safe and efficient operation. Che Renwei et al [32]. designed a new vibratory hammer exciter, established a vibration model, and further carried out a dynamic analysis of the system, and found that in the process of sinking and extracting piles by vibratory hammer, the magnitude of the excitation force is related to the eccentric distance, and changing the magnitude of the amplitude can make the vibratory hammer sink piles faster. These studies provide a theoretical basis for the design and research of resonance-free vibratory hammers.

3.2 RESONANCE-FREE TECHNOLOGY RESEARCH

Zhao Yucheng et al [33]. designed a new type of eccentric wheel mechanism, which can produce wide frequency excitation and can improve the working efficacy of the vibratory hammer and expand the working range of the vibratory hammer. The dynamics model was established by combining the working process of the vibratory hammer, and the simulation analysis was carried out for different time periods during the operation process to verify the feasibility of the eccentric wheel mechanism and provide a reference basis for the improvement of the vibratory hammer. Feng Haifeng

conceived and designed a new type of resonance-free electrodynamic vibratory pile hammer, and made a detailed introduction to the principle of resonance-free eccentric wheel[34]. The simulation of eccentric wheel motion was made by MATLAB simulation software to verify the vibration avoidance capability of the eccentric wheel, and different excitation forces were obtained by adjusting the relationship between the parameters to meet the requirements of different working conditions.

Chen Jianye et al [35]. designed the metal compression spring as the vibration damping element of the vibration hammer by using the reliability design method for the violent vibration phenomenon during the operation of the vibration hammer, and the design check of the vibration damping spring was carried out by calculation, which provided the theoretical basis for the design and development of the vibration hammer. Zhou Hongxia used AMESim software to simulate the hydraulic vibration hammer model, analyzed the parameters affecting the resonant frequency of the system, and found that the resonant frequency of the system is determined by the length of the rodless cavity of the hydraulic cylinder, and the length of the rodless cavity can also affect the magnitude of the excitation force, which provides a reference for adjusting the resonant frequency of the hydraulic vibration hammer [36].

Shanghai Zhenzhong Company uses adjustable eccentric distance technology to solve the resonance problem of hydraulic vibration hammer[37]. This technology is through the adjustment mechanism to change the relative position of the eccentric wheel so that the amplitude can be adjusted. When the vibration hammer starts to reach the resonance frequency, the relative phase angle of the eccentric wheel is adjusted so that the eccentric moments of the relative eccentric wheels cancel each other and no vertical excitation force is generated, thus eliminating the disturbance vibration in the starting process. The principle of adjustable eccentric distance technology is shown in Figure 3. The DZP resonance-free frequency conversion vibration hammer developed by Shanghai Zhenzhong Company adopts inverter frequency conversion, and by adjusting different vibration frequencies of vibration hammer work, the working frequency of vibration hammer is rapidly raised when starting, while using energy conversion system, the kinetic energy of eccentric wheel rotation is quickly converted into electric energy, and the reserve electric energy is finally converted into heat energy, so as to avoid resonance phenomenon.

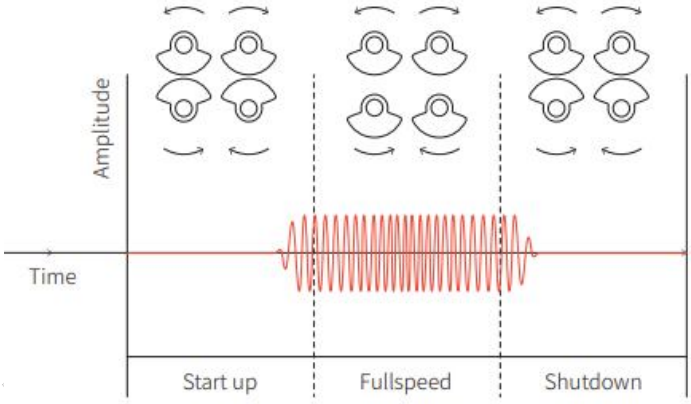

Fig. 3. Principle of Adjustable Eccentricity Technology

Yu Kun optimized and improved the hydraulic control system of vibration hammer, designed the hydraulic soft start controller and ran it in LabVIEW software, and conducted comparative experiments on the vibration hammer experimental prototype with hydraulic soft start control. The experimental results obtained through sensors verified that this hydraulic soft start controller could make the hydraulic vibration hammer attenuate resonance in the starting stage[38].

4.CONCLUSION

In summary, exempting the resonance phenomenon of hydraulic vibratory hammer is an important development direction of hydraulic vibratory hammer, and the resonance-free technology of hydraulic vibratory hammer has made important progress after in-depth research for the development of hydraulic vibratory hammer with higher efficiency and longer life of sinking and extracting piles. Hydraulic vibratory hammer work process is very easy to cause damage to the structure of the vibratory hammer, the use of resonance-free technology can effectively overcome the shortcomings of hydraulic vibratory hammer, in the demand for commercial hydraulic vibratory hammer applications, the hydraulic vibratory hammer resonance-free technology has put forward higher requirements.

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