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The research of new block molding technology based on chaotic vibration

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ABSTRACT

The essence of current block-molding exciter, whether single frequency or modulated frequency vibration exciter, is to produce harmonic periodic vibration simply, leading to the problems such as the instability of block compactness and the long cycle of production. Based on chaotic vibration, this thesis proposes a block-molding exciter characteristic of wide frequency which can produce wider vibration frequency than periodic vibration and help to vibrating compaction positively. In this paper, it designed a chaotic vibration exciter based on chaotic vibration and established its mechanics model. Through simulation identification, it turns out that the dynamic response is chaotic vibration. In order to make material in concrete get more sufficient energy, it propose bidirectional vibration pressure technology based on traditional technology. Through numerical simulation and experiment research show that the new block-molding technology based on the chaotic vibration technology can improve block compactness obviously and strengthen block compressive strength significantly.

Key words: Molding process technology; chaotic vibration; bidirectional vibration; compactness

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INTRODUCTION

Vibrotechnique plays the key role in the process of block-molding, and the modes of vibrating machine mainly include mechanical single-frequency exciter; flexible link type exciter; electromagnetic type exciter and hydra-exciter domestically and abroad. Mechanical single-frequency exciter is the main stream which has been widely used. Hydra-exciter can also realize stepless frequency modulation and amplitude modulation and obtained wide spread application. But no matter which exciter is chosen in the existing forming technology, the problems of block compactness instability and long productive cycle and so on will appear with different degrees. But it is still unable to meet the compactness of the ideal by changing the parameters. It is because that the existing vibrotechnique cannot make all kinds of material in concrete which is at or near the resonance of full frequency domination. To solve this kind of problem effectively, this paper puts forward the application of chaotic technology in the new process of block-molding, and makes use of the method of bidirectional vibration pressure, therefore, material in concrete get more sufficient energy and the highest degree of compaction.

VIBRATORY COMPACTNESS MECHANISM AND CHAOTIC VIBRATION

2.1 Vibratory Compactness Mechanism

The process of block-molding is to re-arrange the particles in material through vibration and compact, so it needs some equipment to impose a certain style load to compact material, particles in material, and then it can also obtain energy to overcome internal friction and cohesive force and occur relative displacement lead to close each other to reduce air and moisture, thus block become close-grained. Under the effect of vibration and press, the compactness has been improved and the block compression has been strengthened.

The study of the vibratory compactness mechanism is mainly focus on resonance, antifriction and impaction. In which resonance can get best effect. It will accelerate particles in material realign when vibration frequency in accord with the inherent frequency of material. Because of the complex of blocks material composition and the different scale of particles; because of the change of physical and mechanical properties; because of the different

material have the different inherent frequency and constitute a frequency band ,it difficult to meet all material in the existing single vibration exciter and the single frequency cannot meet frequency band, too.

2.2 Chaotic Vibration

Chaotic vibration is a reciprocating non-periodic motion which caused by the impose deterministic system on initial conditions and inherent randomness and the possibility of long-term projections. It shows that even simple nonlinear system, it can still show up complicated dynamics behaviors. For example, Duffing oscillators in Holms modal:

$$\ddot{x} + u\dot{x} - x + x^3 = F\cos\omega t$$

Where the following symbols are define:

F is the amplitude of the excition force,

ω is the frequency of the excition force,

u is damping coefficient.

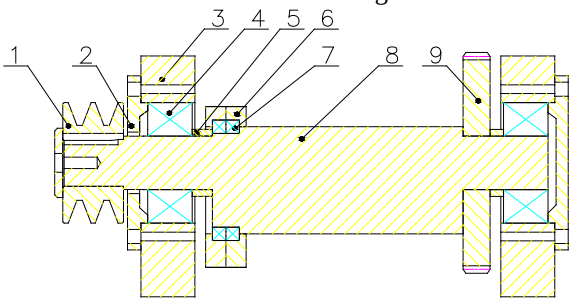
In the equation, there is no existing random factor in the dynamic system, but its trajectory can mutually settled constantly, the shape of trajectory and settlement situation change constantly too, it show that the system appear boundary, attraction in general and exclusion in local, non-periodic random state, it's a chaotic vibration based on the above listed characteristics.

The chaotic vibration with high, medium and low three-part broad-frequency domain and its the character of broad-frequency domain can approach full-frequency domain resonance. It not only meets multi-frequency in various materials in blocks, but also vibration energy evenly distributed than single frequency vibration. Thus, chaotic vibration can approach optimal results of compact and pressure.

THE NEW BLOCK MOLDING TECHNOLOGY BASED ON CHAOTIC VIBRATION

3.1 The Design of Chaos Exciter

The new process program provides a new vibration equipment which have a broad vibration frequency and high vibration efficient through experimental measure, and have chaotic and harmonic vibration performance at the same time, can adapt to different material in concrete vibration .The design of chaos exciter is given by Fig.1:



1-belt wheel; 2-bearing end plate; 3-support plate; 4-center-adjustable bearing; 5-shield ring; 6-eccentric rotor plate; 7-rolling bearing; 8-eccentric shaft;9-drive gear

Fig.1 The structural graph of chaos exciter

The chaos exciter mainly consists of eccentric shaft, eccentric rotor plate, rolling bearing, and drive gear and belt wheel. The realization process is that eccentric rotor plate is loaded with eccentric shaft, and eccentric rotor plate and eccentric shaft connect with rolling bearing, so eccentric rotor plate will ring round eccentric shaft. The structural graph of double eccentric system is given by Fig.2:

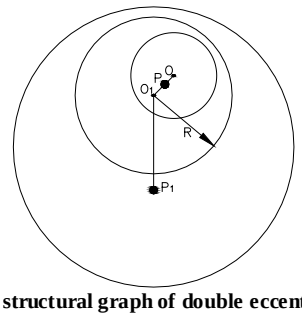


Fig.2 The structural graph of double eccentric system

Where the following symbols are define:

O is the rotation center of eccentric shaft,

O_1 is the rotation center of eccentric rotor plate,

P is the mass center of eccentric shaft,

P_1 is the mass center of eccentric rotor plate,

R is the diameter of eccentric rotor plate.

Double-eccentric system has strong geometric nonlinearity, eccentric rotor plate is driven by eccentric shaft in the process of turning, the motion of eccentric rotor plate regard as planar motion that around the eccentric shaft for relative rotation. Thus, compared to the motion trajectory of eccentric shaft, the eccentric rotor plate is much more complexed. Establishing mathematical model can verify motion trajectory, which can prove its motion is chaotic vibration.

3.2 Establishing Chaotic Exciter Mathematical Model and Identification

To verify whether the motion trajectory generated by double-eccentric system is chaotic motion, Lagrange equation of the second kind with integral system of ideal constrain on the basis of mechanical model and establish the motion differential equation of chaotic exciter and finally identify vibration generated by exciter to find out whether it is chaotic vibration through simulation software Matlab/Simulink..

3.2.1 Establishing Chaotic Exciter Mathematical Model

According to Figure 2, obtain the simplified mechanical model:

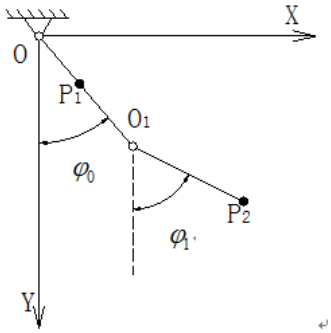


Fig.3 The mechanical model of double eccentric system

Where the following symbols are define:

φ_0 is the relative rotation of the eccentric shaft

φ_1 is the relative rotation of the eccentric rotor plate

There are rolling bearing in the position of O and O_1, the fraction can be neglectable. Using of Lagrange equation to verify the rotation chaotic exciter, the rotation of φ_0 is function of time and take φ_1 as generalized coordinate, according to Lagrange equation of the second kind with ideal constrain and integral system, the equation is given by:

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\varphi}_i}\right)-\frac{\partial L}{\partial_i}=0 \qquad i=1,2 \tag{1}$$

We define L to be $L=T-U$

Where the following symbols are define:

T is the total kinetic energy of system;

U is the total potential energy of system;

L is the Lagrange equation.

3.2.1.1 The Establishment Of The System Kinetic Energy Equation

In fig.3 There could be rearranges, as given by $L_{OP_1} = L_1, L_{OO_1} = l_1, L_{O_1P_2} = L_2$.There make the eccentric shaft short for Ecc.1 and the eccentric rotor shaft short for Ecc.2

Where the following symbols are define:

l_1 is the geometric eccentricity of Ecc.1

L_1 is the mass eccentricity of Ecc.1;

L_2 is the mass eccentricity of Ecc.2;

m_1 is the mass of Ecc.1;

J_{P_1} is the rotational inertia of Ecc.1;

m_2 is the mass of Ecc.2;

J_{P_2} is the rotational inertia of Ecc.2

The Ecc.1 make rotation round the fixed axis and the kinetic energy is given by:

$$T_1 = J_0\omega^2 / 2 \tag{2}$$

Where the following symbols are define:

$J_0 = J_{p_1} + m_1L_1^{\ 2}$ (The parallel axis theorem of rotation inertia)

The eccentric rotor plate make plane motion and the kinetic energy is given by:

$$T_2 = m_2l_1^{\ 2}\omega^2 / 2 + \left(m_2l_2^{\ 2} + J_{P_2}\right)\dot{\varphi}_1 / 2 + m_2l_1l_2\omega\cos\left(\omega t - \varphi_1\right)\dot{\varphi}_1 \tag{3}$$

The total kinetic energy of system is given by:

$$T = T_1 + T_2 \tag{4}$$

That is $T = k_0 + k_1\dot{\varphi}_1^{\ 2} + k_2\omega\cos(\omega t - \varphi_1)\dot{\varphi}_1$ (5)

Where

$k_0 = (J_{P_1} + m_1L_1^{\ 2} + m_2l_1^{\ 2})\omega^2 / 2$

$k_1 = (J_{P_2} + m_2L_2^{\ 2}) / 2$

$k_1 = (J_{P_2} + m_2L_2^{\ 2}) / 2$

3.2.1.2 The Establishment of the System Potential Energy Equation

There present the system potential energy is zero which in the position of $t = 0, \varphi_0 = 0, \varphi_1 = 0$,that is in any position, the system potential energy is given by:

$$U = m_1gL_1(1 - \cos\omega t) + m_2g[l_1(1 - \cos\omega t) + L_2(1 - \cos\varphi_1)] \tag{6}$$

This is writer as

$$U = u_0 - u_1\cos\varphi_1, \tag{7}$$

Where

$u_0 = (m_1L_1 + m_2l_1 + m_2L_2)g - (m_1L_1 + m_2l_1)g\cos\omega t$

$$u_1 = m_2 L_2 g$$

3.2.1.3 Lagrangian Function

Lagrangian function can be written as

$$L = T - U,$$

Where

$$L = (k_0 - u_0) + k_1 \dot{\varphi}_1^{\,2} + k_2 \omega \cos(\omega t - \varphi_1)\dot{\varphi}_1 + u_1 \cos\varphi_1 \tag{8}$$

Finally, establish the motion differential equation about φ_1 of chaotic exciter , by substitution of the equations into the Lagrangian function is give by:

$$2k_1\dot{\varphi}_1 + u_1 \sin\varphi_1 = k_2\omega^2 \sin(\omega t - \varphi_1) \tag{9}$$

3.3 The Identification of Chaotic Vibration

In order to identify whether mathematical model is Chaotic vibration model, it is necessary to identify the process of motion track of equation, that is, Chaotic identification. The chaotic identification is the foremost condition and the necessary prerequisite to study chaos. In general case, chaotic vibration identification consists of qualitative identification and quantitative identification. The ways of qualitative identification are: phase, Poincare and power spectrum analysis chart, the quantitative identification have mainly Lyapunov index.

The chaotic vibration is a complicated motion and it can not accurately identify rely on one or two ways,it adopt normally multiple ways in a process of real application.

The chaotic exciter is composed of Ecc.1 and Ecc.2,the Ecc.1 generate vibration which is regular harmonic vibration mainly because it rotate with constant angular velocity is writer as ω ,the motion of eccentric rotor plate could be regard as rotate round Ecc.1. The chaotic exciter generate chaotic vibration depend on Ecc.2 .The motion differential equation have derived about the chaotic exciter substitute into simulation software Matlab/Simulink to identify, let be

$$y_1 = \varphi_1, y_2 = \dot{\varphi}_1 . y_3 = \ddot{\varphi}_1 .$$

The result of chaotic identification as follows:

3.3.1 Phase Locus

There could get the phase locus figures of eccentric rotor plate when eccentric rotor plate be in steady state (y_1, y_2).As shown in Fig.4 ,the abscissa of figure is angular displacement (rad) and the ordinate of figure is angular velocity (rad/s) .

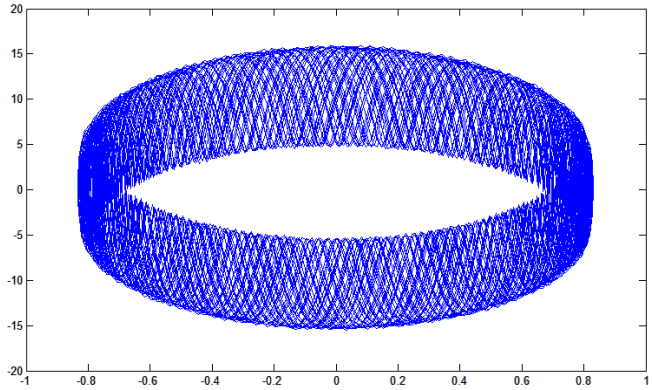


Fig.4 The root locus of Ecc. 2

It is shown that trajectory can mutual settlement constantly, the shape of trajectory and settlement situation change constantly too, the system appears boundedness, attraction in general and exclusion in local, non-periodic random state.Those phenomenon is the traits of chaos.

3.3.2 Poincare

There take y_1 and y_2 of the Ecc.2 to sampling adopt inspiring period T =0.02857s when the Ecc.2 in a steady state, it use sampling site and dislodge the transient response could get Poincare figure, As shown in Fig.5,the abscissa of figure is angular displacement (rad) and the ordinate of figure is angular velocity (rad/s) .

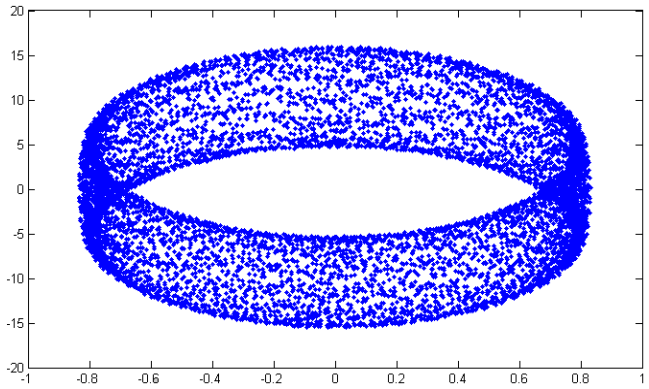


Fig.5 The Poincare of Ecc.2

In Poincare, when have only one fixed point or few discrete point, the motion is periodic; when have a closed curve, the motion is quasi-periodicity; when have a flaky fractal structure point of density, the motion is chaos.

It's found that the Poincare of Ecc.2 demonstrate dense and regular-shape graph through survey to the distribution of sampling site, so it can infer to the Ecc.2 is chaotic in process of motion.

3.3.3 Power spectrum chart

There take the simulation result y_3 of the eccentric rotor plate in steady state according to sampling period T =0.0002s to sample 2048 and make power spectrum analysis to sample result, it can get acceleration power spectrum of the eccentric rotor plate. As shown in Fig.6, the abscissa of figure is frequency (Hz) and the ordinate of figure is power spectral density (dB) .It show that the power spectral density of the eccentric rotor plate has continuity and wide-frequency.

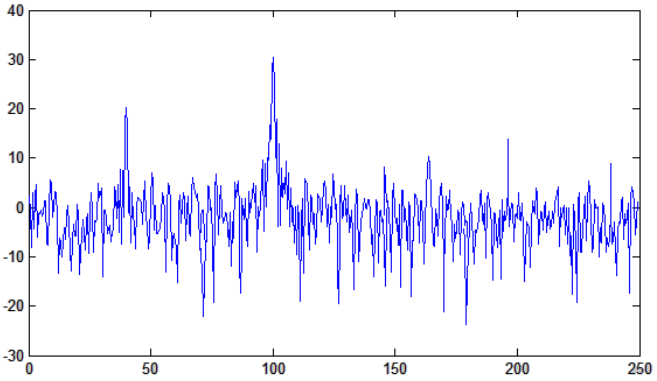


Fig.6 The acceleration power spectra of Ecc.2

On the basis of the above analysis, the result of qualitative identification show that the motion of the eccentric rotor plate is chaotic and have broad-frequency domain,it can meet the broadband which formed by the inherent frequency of multiple raw material in process of block-molding.

THE REALIZATION WAY OF NEW BLOCK-MOLDING TECHNOLOGY

Molding is the key step in process of concrete block molding. In the paper, it is direct at block-molding to study mainly, the special technological process of molding process is given by Fig.7:

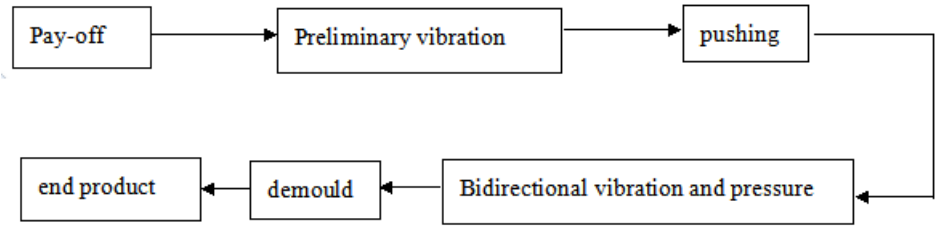


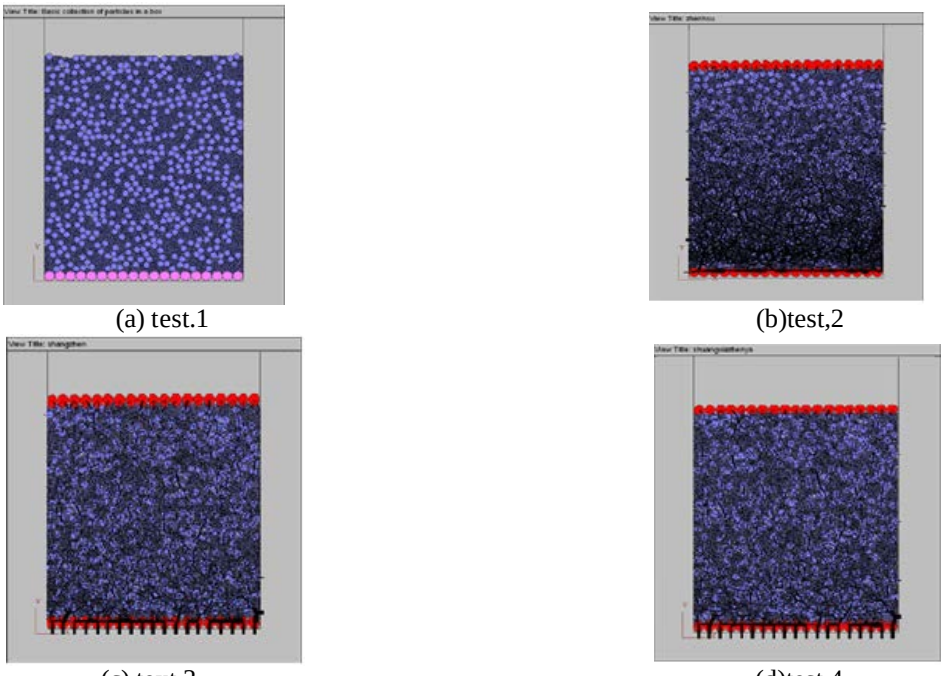
Fig.7 The new technological flow chart of concrete block forming

In Fig.7, the vibration mode use bidirectional vibration pressure replace traditional down-vibrate and upper-pressure technology. On the basis of vibration wave transfer principle can get to know energy transfer in material weakening quickly and appear vibration energy shortage in position far from vibration source ,it will appear material can't vibrate sufficient and lead to low compactness. There propose bidirectional vibration pressure technology. There set a vibration resource under molding box and set another on upper-mould head, exert certain pressure in process of upper-mould head pushing at the same time, then, it can make vibration energy transfer from up and down direct of material and increase vibration energy, make vibration and compactness effect well and material granule uniform and compacting, then, block strength magnify.

SIMULATION UNDER DIFFERENT PROCESS CONDITIONS

To verify preliminarily feasibility and effect of new technologic, make simulation under different process conditions through software PFC2D (Particle Flow Code 2D).In order to simulate particle compactness change rule under vibration and pressure, it supposed to particle as follows:

(a) Take standard blocks size190mm×190mm×390mm,make concrete block particle equivalent two types particle diameter, particle diameter ratio is 6:1, particle diameter are 6mm and 1mm;
(b)Particle unit is rigid body and inexistence pressure-fed problem;
(c)It's point contact among particles and exist overlap amount, but very small for itself size, the size of overlap amount depend on contact force;
(d)Particle unit is spheroidal particle;
(e)The friction coefficient among particles and between particle and wall is 0.6, particle proportion is 2.65 and tangential and heave rigidity is 1.0E+09N/m.



(a) test.1 (b)test,2

(c) text.3 (d)test.4

Fig.8 The forming simulation of different processes

The result of simulation is given by Fig.8:

Fig8.(a) is show that particles arrange status in natural accumulation. Because the bottom side bear the gravity of upper particles, the compactness of bottom side is better than above side, but not obvious.Fig8.(b) is show that particles arrange status that offer monochromatic simple harmonic vibration and exert pressure on upside, the bottom side have compactness well and well-distributed, the compactness is reduce with altitudinal increase gradually because vibration energy decay in the process of transmission. Fig8.(c) is show that particles arrange status that offer single frequency vibration source in the above and bottom and exert certain pressure on the upside .It's observed that particles compactness is improve obviously and well-distributed, but compare particles compactness in middle part change not obvious with Fig.b.Fig8.(d is show that the arrange status of particles with two kinds frequency in bottom side with the purpose of imitate the broadband trait of chaotic vibration and exert single frequency and certain pressure on upside, it can see that compactness increase in different altitude direction.

EXPERIMENTAL RESULTS

There make multigroup experiment to verify the actual compressive strength in the condition of new technology and compare with traditional technology. The experimental process as follows:

There is take the raw material which is use for produce blocks such as cement, coal ash, dinas, additive, water and so on according to certain proportion to mix and stir mixture uniformity, make use of traditional technology and new technology separately to produce standard concrete blocks which have single row role and size is 390x190x190, and the quantity of blocks between 50~60 pieces. The shape of blocks is given by Fig.9.

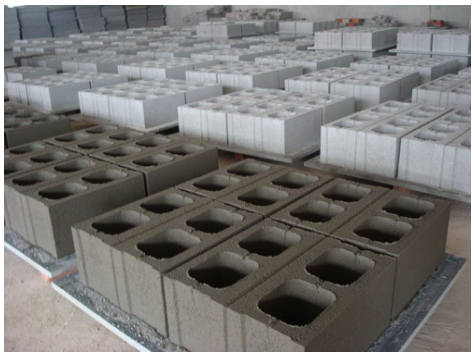


Fig.9 Formed concrete block

It extracts randomly 4 pieces form two sets technology separately to do strength test. The measuring instrument adopt Y-2000 electronic-hydraulic press(range of measurement is 0KN~1000KN and class of accuracy is class 1),put block on central position of lower platen flat and the press direction of block perpendicular to block, exert continuous and uniform load with the velocity of (20±0.5)kN/s until block is damaged and take notes the maximum collapsing force and make use of $f = p/A$ determine compressive strength, it's defined by f is compressive strength(Mpa), p is the maximum collapsing force (N)and A is the block area(m^2),at last, record the text result. Repeat experimentation more than once and result is given by Tab. 1.There define 1 is different technology,2 is sample,3 is test number and the average of compressive strength short for AOCS.

Tab.1 The compressive strength of difference produce technology

1 / 2 / 3	Traditional technology					New technology				
	1	2	3	4	AOCS	1	2	3	4	AOCS
1	5.7	5.5	5.2	5.1	5.23	6.0	6.4	6.3	6.4	6.28
2	5.4	5.5	5.2	5.4	5.38	5.8	5.9	6.2	6.1	6.00
3	5.3	5.4	5.1	5.4	5.30	6.1	6.3	5.8	6.0	6.05
4	5.4	5.1	5.4	5.5	5.35	5.9	6.1	5.8	6.2	6.00
5	5.7	5.6	5.5	5.4	5.55	6.0	6.3	6.1	5.9	6.08
6	5.5	5.5	5.7	5.2	5.48	5.8	5.9	6.0	6.1	5.95
7	5.5	5.4	5.2	5.6	5.43	6.0	6.3	5.8	6.0	6.03
8	5.5	5.3	5.4	5.3	5.38	5.9	6.1	6.0	6.3	6.08
9	5.9	5.4	5.4	5.4	5.53	6.2	6.0	5.9	6.1	6.05
10	5.4	5.5	5.8	5.3	5.50	6.2	5.9	6.0	5.9	6.00

The Tab.1 is show that the compactness of blocks strengthens in the condition of chaotic vibration and compressive

strength improve obviously. The compressive strength increases by an average of 9.5% through collect test data.

CONCLUSION

Based on chaotic vibration, this thesis presents a new exciter which can generate broad-frequency range which has a better vibration effect than traditional single frequency harmonic vibration. In addition, it presents bidirectional vibration technology which can solve the problem of the rapid decline of vibration energy with the increase of distance, thus achieving the purpose of compactness and uniformity of concrete block.

Simulation software-facilitated mathematical simulation under the mathematical model established for chaotic vibration exciters proves vibrations such exciters generate are chaotic vibra-tions and data obtained in experimental verification show chaotic vibration exciters can improve the strength of blocks effectively, thus evidencing universality and availability of chaotic vibration in block-molding technologies.

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