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Study on Preparation of Superhard Nanopowder by Chaos Vibration with High Strength

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Abstract: Superhard nanopowder has the advantages both of superhard and nanopowder but reaching to micron is called "Limit" by academics. It is found that the superhard tiny-powder continued to refine under high vibration intensity by pre-research, reliability and service life can be ensured by researching PLC advanced preview control system of vibration mill with high strength. The dynamic MATLAB simulation model of mill was built so that the behavior features of chaos vibration with high strength and vibration mechanism can be researched. The influence on energy transfer and the probability of collision of barrel medium granular flow can be analyzed. The mechanism of powder cracks and expansion with high vibration intensity can be researched; This research for solving bottleneck restrictions of low-cost, high-quality preparation of various functional ultra-fine, micro, nano powder, has important theoretical and practical value.

Key words: High vibration intensity, vibration preparation, superhard nanopowder, chaos vibration, vibration mill

INTRODUCTION

Superhard nanopowder has the advantages both of superhard and nanopowder, with a very broad application prospects in aviation, rail, machinery and electronics, research and development of new materials and many other fields (Wen *et al*., 2009; Wu and Yu, 2008; Wang *et al*., 2004). In the ways of preparation of superhard powder, the explosion method has entered nanoscale to 0.01 μm, single output is high but difficult to control particle size and purify: Growth method can reach 0.5 μm, high production efficiency and particle size can be controlled but it is a complex process and difficult to purify. Mechanical method which also known as grinding method, with such advantages as particle size control, easy to purify, low cost and so on but the production efficiency is lower than former (Wu and Yu, 2008). In order to deal with the problems of quality and cost, the study of mechanical method is attached great importance by industrial countries, because of the puzzles of superhard powder like not refinement and easy gathering, the mechanical method is considered that it can't produce nanopowder by many scholars. So far, the reaching to micron by mechanical method is called "Limit" by academics. Vibration mill with unique advantages in mechanical method, not only low energy consumption and high efficiency but also the products with high mechanical activity and mechanical chemical effects, providing conditions for the high quality synthesis of new materials (Wang *et al*., 2004). So many scholars made a lot of research on the filed of mechanical method with vibration preparation.

RESEARCH STATUS AT HOME AND ABROAD

Doctor D. Bachmann, German, proposed "grinding media resonance" theory. He thought the vibration intensity of vibration mill (referred to as vibration intensity) relates to the motion of grinding media resonance, while the vibration intensity correspond with the motion of grinding media resonance, the grinding efficiency is maximum (Chapman, 2004). Eccentric Vibratory Mill which was invented by doctor Gock who came from Clausthal university of technology in German, was adopted elliptical, circular and linear vibrations to improve grinding efficiency. The Researcher Ruzhong Qian believed when vibration intensity is K<3, it can not produce any crushed effects to high hard material and when K>7, the crushed effects are better. Chapman (2004) Wang *et al.* (2004) claimed. In order to improve the efficiency of medium energy transfer, it is a good choice to enhance vibration intensity. About vibration intensity K, Palla type vibration mill, produced by Humboldt company in German, is 6-8. CH-50 type vibration mill, designed by Zhushi clubs of Central Chemical Machinery in Japan, is 8. The eccentric vibration mill, designed by Doctor Gock, is close to 10. The Russia Doctor M. JI. Mooregrlis proposes that the vibration intensity should be at 20 (Chapman, 2004; Xu *et al*., 2001; Liu *et al*., 2008).

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The research of domestic and foreign scholars are focusing on improving the efficiency of collision probability and grinding and the refinement of powders and they continue to explore in principle, structure and the improvement of vibration intensity the problems in the preparation with mechanical method and vibration of superfine powder of general materials and superhard material are solved (Bernotat, 2004) and the problem in vibration preparation of superfine nano-powder is being researched and solved step by step (Jing *et al*., 2004). So technology of vibration mill becomes more and more perfect but the public useful reports about how to improve the vibration intensity is few and no involves in the preparation of superhard nano-powder because of high vibration intensity leads to noise and strong vibration which the mill can not bear, the problems like premature failure and damage of the main components or downtime would be found soon after so that lots of researches pay no attention to high vibration intensity and super-high vibration intensity (Wu and Yu, 2008; Chapman, 2004). Due to low vibration intensity (K = 6-10) or can not achieve high vibration intensity (K>10) and super-high vibration intensity (K>15), leads to the low efficiency of media energy transfer so the puzzles of superhard powder like not refinement and hard aggregation can not be solved.

In 2006, author adopted the method of improving vibration intensity (Kmax = 18) to prepare diamond superfine powder, during the process, the problems like spring broken and motor burned are found, the improved test find that: When vibration mill under the pressure of high vibration intensity, the rate of grinding media collision and the efficiency of energy transfer is increased and fracture resistance of powder is reduced, what's more, it was helpful for the refinement of powder and gathering broken, the result of test d_{50} = 0.195 μm and which broke the "Limit" of mechanical method preparation of superhard powder but there is still a gap from nanoscale and if the vibration intensity can be further improved , it will directly affect the reliable operation and service life (Chapman, 2004). So how to achieve the vibration preparation of high quality superhard nano-powder, perfect the basic theory of the vibration affects and the motion of powders is key issues (Jing *et al*., 2004). This research for solving bottleneck restrictions of low-cost, high-quality preparation of various functional ultra-fine, micro-powder, nano-powder, has great theoretical and practical value.

ANALYSIS OF PROTOTYPE COMPOSITION

The research program is determined based on the pre-study and investigate research. The mode is proposed which combined with three techniques research and test of prototype. Analysis of outside tube and data simulation of inside tube. The new ways are explored which people understand the crushed phenomenon of powder with high vibration intensity, when the mode worked. The results were compared with pre-study and made comprehensive evaluation, improved and until to achieve the desired results.

Intelligent convertible frequency advanced preview control system is constructed for vibration prototype. The ADAMS simulation model of outside tube dynamic is established. The chaos vibration motion of grinding media and powder refinement mechanisms under high vibration intensity were analyzed. The DEM data simulation of inside tube dynamic was made and the influence discipline of high vibration intensity to powder cracks and expansion was discussed. Perfect the basic theory of preparation of superhard powder with high vibration intensity and the motion of powders.

Research and test of prototype: The conditions which can product high vibration intensity are analysised. The vibration mill prototype which driven by multi-level partial block vibration motor was constructed, chaos vibration what can produce high vibration intensity, transient super-high vibration intensity was analyzed to solve the problems such as powders gathering and difficult to refine. Dual-quality structure of prototype was constructed to improve efficiency and reduce consumption of main vibration system and more efficient to reduce vibration and cut down noise of vibration isolation system. Diamond and cubic boron nitride was taken as grinding material of prototype and the media was steel ball, reliable operation with high vibration intensity of prototype was achieved to improve the performance like particle refinement, uniformity and so on. Efficient heavy liquid separation method is adopted to highlight the advantage of purify.

Advanced preview control system PLC: In a state of high vibration intensity, the actual vibration intensity, vibration amplitude and other main parameters will be a far cry from default value, leading the parameters overrun and timeout, the system transient failure or paralysis. Advanced preview control system is built which based on intelligent frequency-converter, monitoring online of the main parameters, amplifying sensor signal, conversing module, collecting and leading calculating data including follow-up variation of the main parameters, possible extreme points and distribution and then judging, reasoning and correcting constraint conditions, control decisions are made to avoid adverse effects such as the

parameters overrun and timeout and to achieve advanced preview control of high vibration intensity and reliable operation of system.

Dynamic simulation analysis of outside tube: Dynamic simulation analysis mode of outside tube of vibration mill is constructed to analyze the dynamic problems of vibration mill with multi-level partial blocks which is composed by following parts: upper body, down body, multi-level partial blocks vibration motor, main vibration and isolation vibration spring system and so on. The effects of chaos vibration with high vibration intensity can be analyzed and the influence of no refinement and strong gathering with change of system vibration and impact energy.

PROTOTYPING DESIGN AND SIMULATION

Prototyping design

The design of exiting source: The multi-level partial blocks vibration motor model as the excitation source is built which based on the pre-research, then strong non-linear chaotic vibration is produced. Iit makes the vibration mill produce planning high vibration intensity and transient super high vibration intensity by adjusting the mass-diameter ratio among multi-level partial blocks and combined with control technology. Building the vibration mill system and the exiting source is set to single offset type which makes grinding media have elliptical, circular and linear and other different tracks multi-direction vibration, it also can reduce poor energy area and improve the energy utilization efficiency of high vibration intensity and grinding efficiency.

The design of vibration mill: The scheme of the structure of vibration mill is shown in Fig. 1, the continuing role of excitation source of the high vibration intensity is considered, double-body vibration mill is designed, variable stiffness rubber coating composite spring is used in the main vibration spring which not only adapting the changing dynamic load and the effect of transient high vibration intensity but also saving energy and reducing consumption; variable stiffness rubber coating composite spring is used in the isolation vibration spring. Thus making the system has high internal damping, efficient vibration absorption for transient high vibration intensity which passed by the main vibration spring is achieved and vibration and noise reduction is achieved. Based on the pre-research preparation process, the process parameters such as ball-feed ratio, filling rate and so on are optimized to ensure the powder properties and quality of preparation.

The research of advanced control: It is shown in Fig. 2. The system is composed by upper computer, PLC,

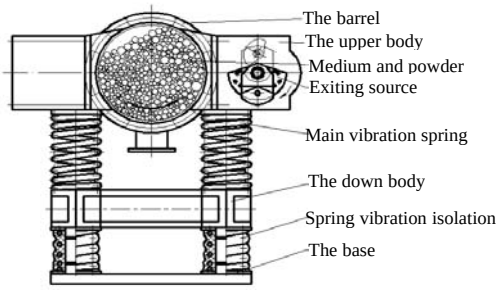

Fig. 1: Schematic of vibration mill

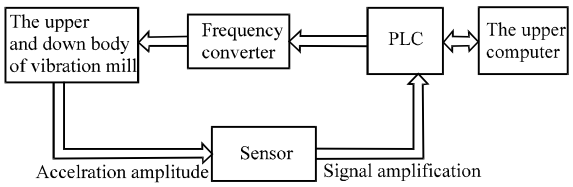

Fig. 2: Advanced control schematic of vibration mill

frequency converter, vibration mill and sensor. The upper computer is mainly used for programming and communication with the PLC, PLC which as the core controller. On one hand interacts with upper computer to achieve program adjustment; on the other hand through the conversion of advanced intelligent control software to control output of the frequency inverter, to make the high vibration intensity and the transient high vibration intensity of the vibration mill control efficiently and ensure the system operation normally.

The outer barrel dynamics and simulation: Multi-level partial blocks vibration mill is composed by following parts: upper body, down body, multi-level partial blocks vibration motor, main vibration and isolation vibration spring system and so on. Established simulation model of the outer barrel of vibration mill based on ADAMS, then for dynamic simulation analysis, high vibration intensity and vibration of system. The changes in impact energy to refinement of the superfine and the effects of hard aggregation are all researched. For the internal numerical simulation and the prototype test provided simulation analysis of data. MATLAB simulation, control systems of LABVIEW. The research on the study of S7-200 PLC are all used, thus gets a series of data. The phase track diagram, sectional view of the Poincare and graph of vibration intensity are showed as follows.

Figure 3 is the phase track diagram of two-level partial blocks while one-level partial block is running at the rotary speed n1 1800 r/min, the phase track diagram of two-level partial blocks at the beginning is the random distribution of longitudinal fluctuation changes in a

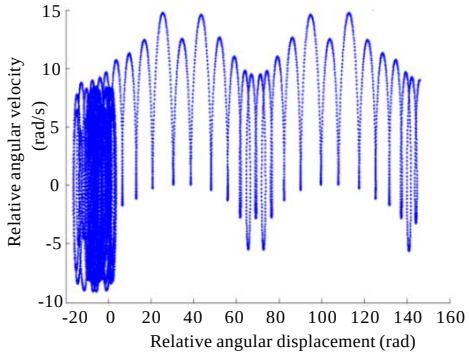

Fig. 3: The phase track diagram based on matlab

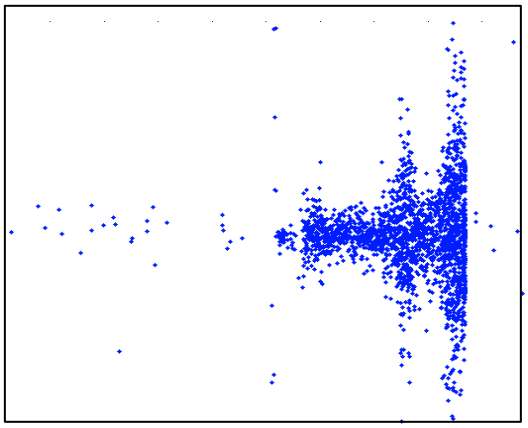

Fig. 4: Sectional view of the poincare

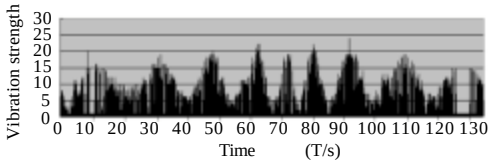

Fig. 5: Graph of vibration strength based on the advanced control of PLC

bounded domain which show above state, it can know the complexity of movement state from the distribution of mapping points. Sectional view of the Poincare is shown in Fig. 4, according to the distribution of points, the system motion is complicated. Figure 5 is graph of the measured vibration intensity which based on the advanced control of PLC. The sampling graph which got by Labview is similar to Fig. 6. It shows the simulation of movement or control sample results to high vibration intensity are basically consistent through different methods and the experiment also shows the advanced preview control of PLC is availability. The frequency of high vibration intensity control meets the requirements.

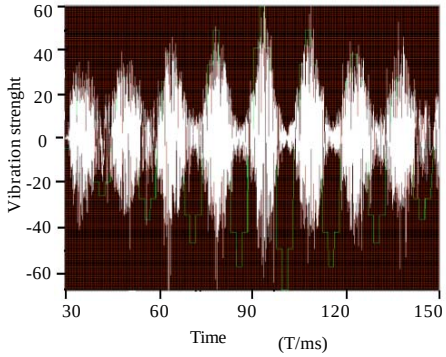

Fig. 6: The sampling graph of vibration intensity by Labview

It should solve effectively the problem that vibration intensity and other main parameters are overrun and timeouts and achieve the advanced control of high vibration intensity.

CONCLUSION

The designed two-level partial blocks vibration mill model with the advanced preview control system of PLC which runs. While the vibration intensity K<24 and gets the vibration intensity is K_{max} = 22.5 from the experiments, in a set time period, the appeared probability of high vibration intensity (K>15) is about 12% of the expected value. The control frequencies of high vibration intensity meet the requirement which solved effectively the problem that vibration intensity and other main parameters are overrun and timeouts and can make sure the safe operation and service life of the mill.

It has completed the operation of a model machine test and a phasic achievement was made. With the input particle size of diamond is d_{50} = 10 μm, while the output particle size can reach d_{50}= 0.195 μm. The distributed bandwidth is p≈0.35 μm which shown the effects of powder refinement and the narrowing bandwidth, this research solved the bottleneck restrictions of the hard gathering and not refinement of the super-fine grinding of super-hard powder.

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