Test-bed's Development of the Packed Bed with Both Revolution&Rotation's High Gravity

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Abstract: Rotating packed bed is a chemical reactor which used the effect of rotating centrifugal force to be equivalent in the gravity field. To increase the fluid flow time in bed, to extend the controlled process in bed's reaction and to strengthen the role of influencing factor, a new type of rotating packed bed is proposed in the paper which is running on the revolution platform. Unfortunately, the bad synergy effect of revolution&rotation in packed bed has induced the serious vibration problem. Through optimizing the mass center of packed bed and disposing local weight, the stability of the operation of the bench was more improved. The stability of the operation of the bench was that more improved the bed's vibration amplitude was analyzed by using the ANSYS. The results show that the test-bed of both the Revolution& Rotation's Packed bed is a practical project in the Rotating packed bed's development.

1.   Introduction

Rotating packed bed is a chemical reactor which uses the centrifugal effect to enhance fluid flow replacing and overreaching the equivalent gravity field [2, 3].The technology about rotating beds is called the high gravity technology by academician. Its researches mainly focus the following three aspects:①the high gravity of nanometer materials preparation; ②the high gravity of response reinforcement; ③the high gravity of separation technology[4-8]. Its core component is the internal rotor which filled with porous mediums. The chemical fluid flows in the porous medium. The fluid, running through the medium which rotates around rotor with high-speed, is crushed and teared into nanoscale wires, droplets and liquid membranes. Resulting in a huge phase interface which enforces gas-liquid contact and micro-mixing in a great extent [9].A typical High gravity packed bed is show in Fig. 1. The fluid flowing process in bed starts from the liquid distributor through being sprayed into the rotation filler.

Due to the packing is rotating at a high speed, the relative velocity with the liquid phase is very large and when the liquid phase passes through the first few layers of the packing, it was shattered, torn. The liquid phase mass transfer is given priority with dispersion of mass transfer at this stage; the crushed liquid to move forward after being trapped by the filler, and then flow along the packing in the form of brin or liquid film, with the droplets penetrating. This phase is given priority with the forced convection of mass transfer and mass propagation speed, after the liquid phase through the packing, it flowing out from the port d. The gas enter the packing from port c, under pressure to overcome the centrifugal force through the filler retroactively, through contact with the liquid phase interface to carry out the chemical reactions, then flowed out from port b. [11]

The three kinds of mass transfer in the high gravity packed bed are dispersion of mass transfer, the forced convection of mass transfer and mass propagation speed. The interaction in this Three-scale mass transfer determines the effect of chemical reaction. The effect of mass transfer is the largest among the three, and it is also the basis of convective mass transfer and mass propagation speed. Exist the following problems, problem 1: Dispersion of the mass transfer area is very thin, the reason is that the liquid phase is completely captured in several layers that are very thin in the front region of the packing, the relative velocity of fluid and filler is zero, and effect of dispersion disappear. In particular, more than two components of the fluid bed in the packed bed are required to have a higher degree of dispersion and mass transfer, resulting in a more severe problem. Problem 2: the limited thickness of the filler layer directly determines the course of liquid phase through the filler is too short. The process is too short and shortens the time of controllable chemical reaction, and affecting the final response. Such as method of gas-liquid based on high gravity packed bed to preparation of nanoparticles, etc.

Based on this, a new type of the Revolution& Rotation's Packed bed is proposed, which is based on the introduction of rotating system on the basis of the rotating packed bed and realize the continuous production

2.   The composition of test-bed

2.1   *The rotation orbit High gravity the general structure of the rotating packed bed*

The packed bed comprises a feed system, a revolution system, a rotation system and a discharge system. This paper increase one level of degree of rotational freedom in the filler area, change it into coexistence of revolution and rotation, so that we can rapidly change the direction of High gravity over time. One of the effect is effectively expanding the radial dispersion of the filler to the liquid phase, and enhance the effect on dispersion of mass transfer; second increase the total process of liquid phase in filler, and enhance the effect of integrated mass transfer.

In the Revolution&Rotation's Packed bed, the relative velocity of the fluid and the filler is increased by increasing the rotation of the reaction kettle, and expanded the course of liquid phase through the filler. In this study, the experimental platform of nanometer calcium carbonate was designed and prepared to predict the effect of the mass transfer. In order to promote the experimental work in a phased manner, the continuous pipeline composed of feeding and receiving system is simplified. The feeding box and the receiving box are fixed on the revolution platform, and the experimental platform is constructed.
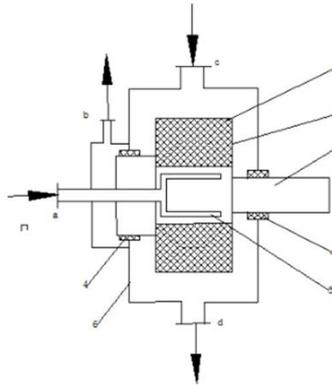
1 padding   2 otor   3 spindle   4 sealing gasket   5 The cloth liquid   6 shell   a liquid inlet   b gas outlet   c gas inlet

Figure 1. The traditional high gravity packed bed structure diagram

Figure 2. The physical Fig. of revolution&rotation high gravity packed bed

This experiment at the core of the reaction kettle using circular structure
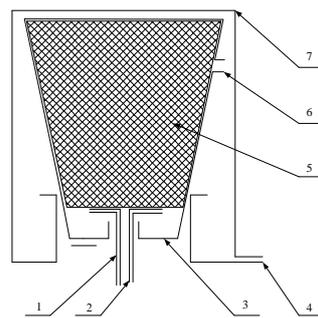
1 liquid inlet tube 2 intake-tube   3 Outside shell of the reaction kettle   4 discharge hole   5 Porous media filler   6 the discharge   7 hole of the reaction kettle shell   8 Outside shell of the reaction kettle

Figure 3. The Schematic diagram of the reaction kettle

3.   IMPROVEMENTS ON TEST-BED

In the first test, the test-bed has a large noise and swing seriously affected the experiment and the life of test-bed, and makes the speed ratio of rotation and revolution cannot be controlled, largely affected the experiment. The analysis of the reasons resulting from such a result may have the following

aspects. First, natural frequency of the test-bed and excitation frequency may resonate; Second, the reason for the swing may be that the amplitude of the mass center of the test-bed is too large. In the actual construction of the test-bed, many sizes of raw materials, relative position are difficult to balance. Therefore, this paper improve the test-bed from both the optimizing the mass center of packed bed and disposing local weight. This paper used simulation software to test the effect of the improvement.

3.1. Modal analysis was carried out on the test-bed

The layout of the test-bed is shown in the following Fig., Fig. 4 is the original layout, and Fig. 5 is the optimized layout. The black part is a clump weight

Because the mass distribution of the objects on the test-bed is not uniform, the mass center of the test-bed is not in the geometric center. As a result, the table turns unstable. To make the mass center of the test-bed in the geometric center, the sum of the centrifugal force in all directions should meet the following formula.

$$\sum_{i=1}^{n} m_i x_i \omega^2 = 0 \qquad (1)$$

$$\sum_{i=1}^{n} m_i y_i \omega^2 = 0 \qquad (2)$$

$$\sum_{i=1}^{n} m_i z_i \omega^2 = 0 \qquad (3)$$

Where m_i is the weight of each component, x_i, y_i, z_i is the mass center coordinates of each component, ω the angular velocity .

According to the actual situation to optimize the layout, take the lowest center of the axis as the origin, Solidworks can be used to calculate the location of the center of mass

$(x, y, z) = (614.95, 588.16, 749.39)$ All the objects on the test-bed equivalent to an object M, it can know the quality of all objects on the test-bed   M = 190895.11 g

$$Mx\omega^2 + m_a x_a \omega^2 = 0 \qquad (4)$$

$$My\omega^2 + m_a y_a \omega^2 = 0 \qquad (5)$$

$$Mz\omega^2 + m_a z_a \omega^2 = 0 \qquad (6)$$

Where m_a is the quality of the weight, x_a, y_a, z_a the coordinates of weight.

Combined with the actual situation of the layout shown in Fig. 5. In Fig. 4 and Fig. 5, the red coordinates is the position of the mass center, and it can be seen that the optimized layout is closer to the geometric center of the test-bed.
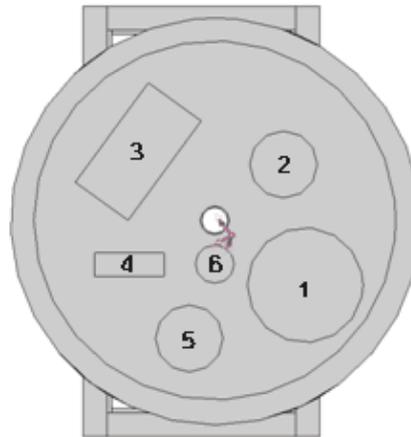
1 the reaction kettle   2 the electromotor   3 feeding equipment and receiving device   4 console   5 transducer   6 CO_2 battery

Figure 4. The original layout
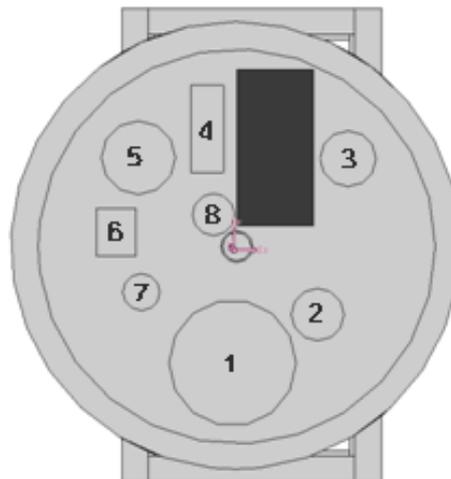
1 the reaction kettle   2 the incoming container 3 the transducer   4 the receiving device   5 the electromotor 6 the feeding equipment   7 the receiving bottle

Figure 5. The improved layout

3.2 The experimental modal analysis

As an auxiliary method in structural design, modal analysis can be used to determine the vibration frequency and mode of the structure, and to predict the influence of the external excitation frequency on the structure, so as to avoid the resonant frequency during the design process. Modal analysis on the overall structure of the test-bed can be carried out to analyze the influence of external excitation on the structure of the test-bed and further optimizes the structure of the test-bed. In this paper, the modal analysis of the test-bed is carried out, and the first 10 order vibration frequencies and the main vibration modes of the test-bed are obtained, and the results are used to provide the theoretical support for the

optimization design of the test-bed.

Using SOLIDWORKS to builds the three-dimensional geometry model of the test-bed, the original layout of the model into ANSYS for meshing. The meshes of the test-bed are triangular meshes, the number of nodes is 64041 and the number of units is 192060. The modal analysis in ANSYS is a linear analysis that requires specifying the modulus of elasticity EX and the density DENS. If there are nonlinear elements, default that it is linear. The model adopts high-order element entity, the material adopts Q235A, the thickness is 5mm, the density is 7.86g / cm³, the elastic modulus is 210Gpa, the Poisson's ratio is 0.3, and block lanczos modal extraction method is adopted.

3.3 modal analysis test-bed base

ANSYS was used to obtain the first 10 order modal frequencies of the test bed. As shown in Table 1 and Fig. 6.

Table.1 Modal frequency

Order/n	Modal frequency f/（Hz）
1	66.020
2	75.278
3	85.805
4	86.690
5	90.232
6	111.55
7	138.88
8	139.34
9	153.07
10	179.40
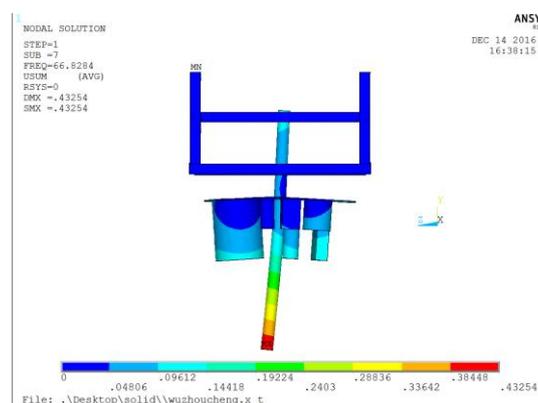
**Figure 6.** The first step model of the former improved test-bed
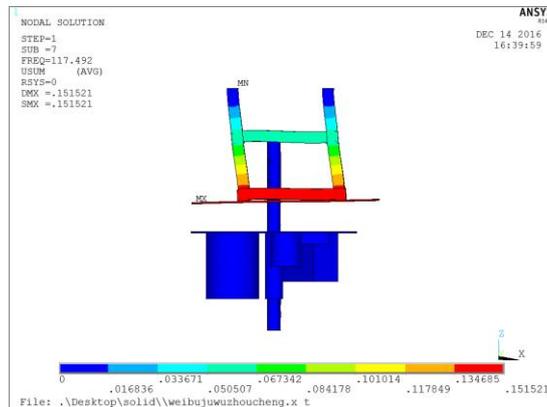
Figure 7. The first step model of the improved test-bed

When the natural frequency of the test-bed close to excitation frequency, it's easy to produce resonance. Therefore, it is better to ensure the excitation frequency is lower than the lowest natural frequency of the test-bed during the experiment, and the lowest natural frequency of the test-bed is more than 1.25 times to the maximum frequency. It is known that the maximum speed of the motor is 1400r／min and the maximum frequency is 50Hz. In this speed range, the lowest order natural frequency of the test-bed is 1.25 times to the maximum excitation frequency of the motor, so as to avoid its influence on the experimental study [12].

The speed of the test-bed is controlled by the transducer controlling the motor, and the excitation frequency of base of the test-bed is also changed. The excitation frequency at different speeds can be obtained from the following formula:

$$f = \frac{n}{60} \times \frac{P}{2} \qquad\qquad （7）$$

where n is the motor speed, 2p is logarithmic.

The natural frequency of the test-bed is calculated to be at least 62.5 Hz, while the first-order modal frequency of the test-bed is 66.020 Hz, which is close to that and should be improved.

The optimized first 10 modes are shown in Table 2 and Fig. 7

Table.2 Modal frequency

Order/n	Modal frequency f/（Hz）
1	117.49
2	122.07
3	143.34
4	181.55
5	197.26
6	212.00
7	233.87
8	296.51
9	299.48
10	333.18

It can be seen that the improved mode has a larger enhancement compared with the original layout mode, thus keep away from the excitation frequency.

4.   Conclusion

In this paper, the construction of a new type of high-gravity rotating bed is introduced. Considering the vibration of the test-bed is too large, it is improved from the optimizing the mass center of packed bed and disposing local weight, and the modal analysis was carried out before and after the optimization. It shows that the natural frequency of the improved test-bed avoids the influence of the excitation frequency and does not produce resonance phenomenon. Taking into account the swing of the test-bed, Adams analysis was performed before and after optimization of the test-bed, and the analysis results show the mass center amplitude of the improved test-bed. The later experiments also proved this point.

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