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The Circulation Rate in U-shaped Working Chamber

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Abstract

The aim of this pilot study is to examine the circulation flow rates of the working media and workpiece in different working media densities, shapes and granulations in the U-shaped working chambers with different length and width of the working chambers. This study was conducted in Don State Technical University (DSTU) in Russia. Below tabulated results show to what extents depend circulation rate on working media heights in the working chambers, working chambers length and width and working media densities.

Keywords: working media (medium); working chambers; granulations; circulating rate.

I. Introduction

The action of vibrations transmitted to working media and the workpiece, to the greatest extent propagated approaching to the chamber walls and reduced far from it. Vibration and acceleration variables along with a circulating working fluid causing dynamic influence (pressure) and integral action of micro-impacts on the surface of the workpiece. Vibration parameters of the working chamber (amplitude, frequency, path and its shape) have a decisive impact on the working media effect, its dynamic characteristics, and formation and circulation flow patterns. These conditions determine the intensity of the treatment process. Parameter relationships of vibration, the nature of the circulating rate of the working media and the intensity of the treatment were investigated in several studies.

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It was studied, in particular, in the following areas: the influence of vibrations of the working chamber trajectories at different forms and its orientation relative to the vibrator, the state of the working media and the formation of flow rates and so on [1].

Working chambers with U-shaped cross-section (a rectangular shape in plan) have a different width and length ratio. Length and width ratio is determined by the application and processing conditions. For small volumes working chambers generally width to length ratio close to 0.7 - 0.9. For vibration of passage types of machines to handle long items, working chambers elongated to length width ratio of from 5: 1 to 10: 1 [1,2].

The shape and dimensions of the working chambers affect the efficiency of the process and its technological capabilities. In the works of A.P. Babichev, I.F. Goncharevich, Y.R. Kopylova, Y.U. Dimova etc., systematically conducted researches improving the design of the working chambers. Thus it is proved that with equal volumes of vibration processing, effectiveness performance of the working chambers increased to 30 - 40 %[3]. The reason is that with a decrease in the curvature of the walls and parts of the bottoms, reduced weight of the layers depth of the load (working media height) and, therefore, decreases the degree of damping of the amplitude of vibrations. It is recommended to apply the working chambers with elliptical shapes of bottom [4].

The intensity of the circulation of the working media and the vibrations of its particles depend on the regime (parameters) of vibration, shape of vibration trajectory, properties of the working media, working media mass, the working chamber mass, working chamber size, location of the vibrator, and some other features. The increase in circulation rate is achieved by eccentric placement of the vibrator from the working chamber center mass line (Figure 1). In this case, the ratio of the velocity of circulation of the working media in the chamber with eccentric placement and central placement has the following relations: [1,5,6,7,8,9]

$$V_e/V_c = 1 + \frac{m_b r l \cdot \sin\theta}{J_c} \ldots\ldots\ldots(1)$$

where – m_b - mass of the unbalanced vibrator;

r - eccentricity of the vibrator;

l - the distance from the geometric center of the chamber to the center of the shaft of the vibrator;

θ - the angle located in the eccentric placed vibrator in Figure 1b. and the optimal angle is 45^0;

J_c - moment of inertia of the working chamber mass lying on the springs.

The above equation shows that, the increasing distance of the vibrator from geometrical axis of the working chamber increasing circulation rate. With the increment of speed and acceleration of vibration, we can mark an increase in the intensity of circulation of working media and vibration of particles. This, however, increases the load on the working chamber machine parts. Because of this, we have to select the optimal process parameters that ensure a sufficiently high intensity of process and performance of durability and reliability of the machine parts. Usually the vibration acceleration of vibration machines lies in the range of 50 - 500 m/s^2. There is a minimum mass of the working media in which it has been a steady circular motion and maximum mass above which the circulation rate starts to decrease at constant parameters of vibrations. The coefficient of friction increases with the reduction of working media particle sizes, and the parameters of the vibration increases with the circulation rate at a certain mass of working media. Noted that for sufficiently intense vibration occurs an effect not only in the circulation, mixing or grinding of the particles of the workpiece, but also a violation of the crystal or molecular structure of the material (destruction) [4].

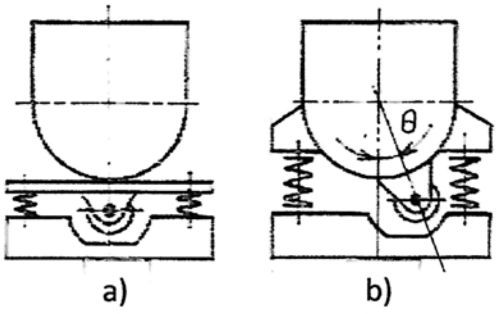

Figure 1: Working chamber with a) central vibrator placement and b) eccentric vibrator placement

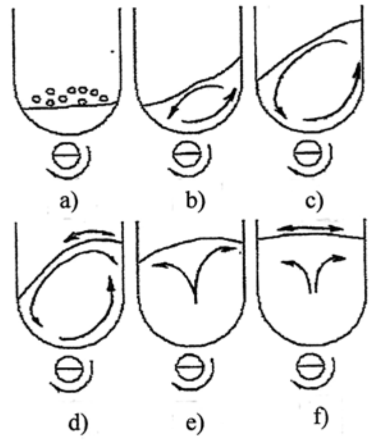

Figure 2: Six position of working media height.

Analysis of experimental data revealed the character of six phases that influence the intensity of the circulation rates with the consideration of different levels of the working media height (Figure 2.). At relatively low loading heights of vibration found in a condition of ebullient (Figure 2. a): individual particles separating from the surface and makes gaps between the particles in a randomly moving situation. In this instance there is no circulation [3].

As the height of the working media level increased, appears circular movement of the working media directed in accordance with the rotation shaft of the unbalanced vibrator (Figure 2. b). A further increase in the height of the working media level initially leads to an increase in the circulation rate (figure 2. c); then the circulation rate begins to decline and at the same time, in the walls of the working chamber appearing secondary vortices (fig 2.

d). This leads to the rise of the free surface of the working media moves to the middle of the chamber (Figure 2. e, etc.). Further, the formation of two equivalent circulating flows directed in opposite directions. In this interval, the level of medium circulation rate slows down considerably (Figure 2. f). It is noted that this state is unstable circulation movement of the working media and a slight change in external factors violates circulation.

2. Materials and Methods

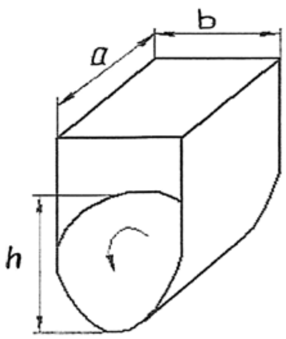

Figure 3: Conventional working chamber.

Studies were carried out using a conventional working chamber (Figure 3.).

Observed design has a width (a) (Figure 3.) of 80 mm, 160 mm and 200 mm and a length (b) (Figure 3.) of 90 mm and 200 mm. The bottom of the camera is rounded to eliminate the influence of eddy currents on the main circulating fluid flow. The camera was based on vibration table machine УВГ 4x10. Vibration trajectory is an ellipse; the vibration amplitude A = 2 mm; vibration frequency f = 33 Hz. Change in the character of circulation motion of the working media observed with in the chamber by a gradual increment of working media height (h) (Figure 3.) from 75 mm up to 225 mm. The time rotation of the working media measurement was carried out with a stopwatch 6 times, after which the mean values are taken. We calculated linear working media speed by taking outer loop of the working chamber. It is believed that the working media moves in an ellipse outline, inscribed into the container sidewall of the working chamber. Depending on the greater value (the length or height) of the working chamber or medium height the minor and major axis of the ellipse will be determined, and then found its perimeter. In our situation the linear velocity of the working media determined by dividing ellipse perimeter by the period of rotation of the working media. In this research determined the average linear velocity of the circulation of the following working media (Table 1.).

Table 1: Properties of working media that we used for the research.

Type of working media	Size of working media in mm	Weight of working media in g.	Bulk density of working media in kg/l
Porcelain bowl	∅ 9	1,23	1,4
Polymer-bonded cones	7x7	0,27	1,06
Polished steel balls	∅ 10	3,4	4,5

Table 2: Circulation rate in m/s of working media in 90 mm length and polymer-bonded cones of 7x7 mm

Width of working chamber in mm.	Velocity of working media in different heights in m/s						
	in 75 mm	in 100 mm	in 125 mm	in 150 mm	in 175 mm	in 200 mm	in 225 mm
80	0,23	0,26	0,28	0,25	0,166	0,127	0,082
160	0,25	0,301	0,285	0,21	0,161	0,112	0,077
200	0,28	0,358	0,35	0,272	0,2	0,144	0,089

Table 3: Circulation rate in m/s of working media in 200 mm length and polymer-bonded cones of 7x7 mm

Width of working chamber in mm.	Velocity of working media in different heights in m/s						
	in 75 mm	in 100 mm	in 125 mm	in 150 mm	in 175 mm	in 200 mm	in 225 mm
80	0,133	0,155	0,172	0,166	0,161	0,144	0,122
160	0,127	0,138	0,15	0,155	0,15	0,145	0,135
200	0,072	0,101	0,122	0,15	0,153	0,155	0,157

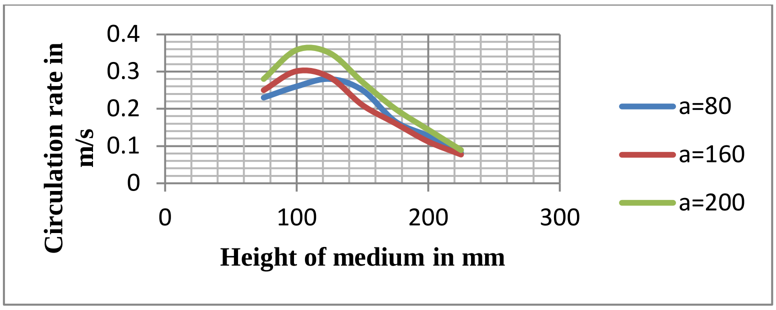

Figure 4: Circulation rate in polymer-bonded cones of 7x7 mm, working media of 90 mm length and different height of working media from table 2.

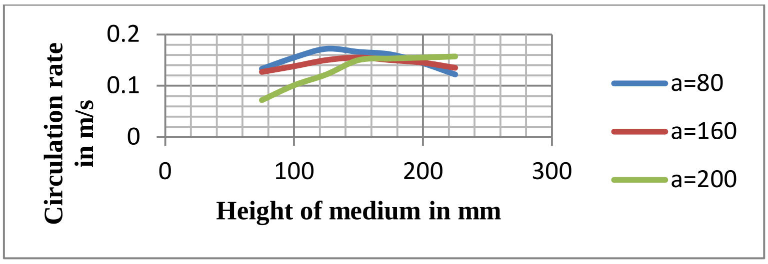

Figure 5: Circulation rate in polymer-bonded cones of 7x7 mm, working media of 200 mm length and different height of working media from table 3.

Table 4: Circulation rate in m/s of working media in 90 mm length and porcelain bowl of ∅ 9 mm

Width of working chamber in mm.	Velocity of working media in different heights in m/s						
	in 75 mm	in 100 mm	in 125 mm	in 150 mm	in 175 mm	in 200 mm	in 225 mm
80	0,133	0,238	0,261	0,216	0,144	0,088	0,05
160	0,1	0,2	0,227	0,2	0,155	0,1	0,061
200	0,083	0,177	0,272	0,25	0,194	0,133	0,077

Table 5: Circulation rate in m/s of working media in 200 mm length and porcelain bowl of ∅ 9 mm

Width of working chamber in mm.	Velocity of working media in different heights in m/s						
	in 75 mm	in 100 mm	in 125 mm	in 150 mm	in 175 mm	in 200 mm	in 225 mm
80	0,083	0,1	0,111	0,116	0,111	0,1	0,083
160	0,083	0,105	0,116	0,122	0,116	0,111	0,088
200	0,083	0,111	0,122	0,133	0,133	0,116	0,094

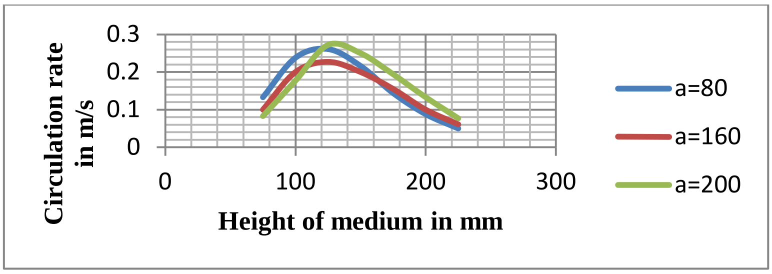

Figure 6: Circulation rate in porcelain bowl of ∅ 9 mm, working media of 90 mm length and different height of working media from table 4.

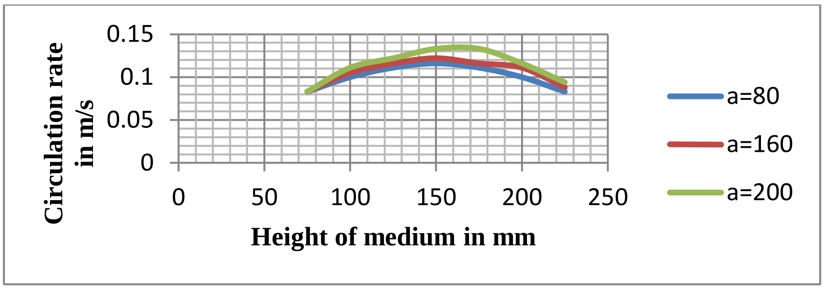

Figure 7: Circulation rate in porcelain bowl of ∅ 9 mm, working media of 200 mm length and different height of working media from table 5.

Table 6: Circulation rate in m/s of working media in 90 mm length and steel bowl of ∅ 10 mm

Width of working chamber in mm.	Velocity of working media in different heights in m/s						
	in 75 mm	in 100 mm	in 125 mm	in 150 mm	in 175 mm	in 200 mm	in 225 mm
80	0,1	0,2	0,272	0,239	0,155	0,088	0,05
160	0,1	0,188	0,238	0,222	0,188	0,133	0,088
200	0,1	0,194	0,25	0,239	0,2	0,155	0,1

Table 7: Circulation rate in m/s of working media in 200 mm length and steel bowl of ∅ 10 mm

Width of working chamber in mm.	Velocity of working media in different heights in m/s						
	in 75 mm	in 100 mm	in 125 mm	in 150 mm	in 175 mm	in 200 mm	in 225 mm
80	-	-	0,066	0,072	0,077	0,066	0,061
160	-	-	0,1	0,088	0,083	0,072	0,055
200	-	-	0,116	0,127	0,122	0,116	0,108

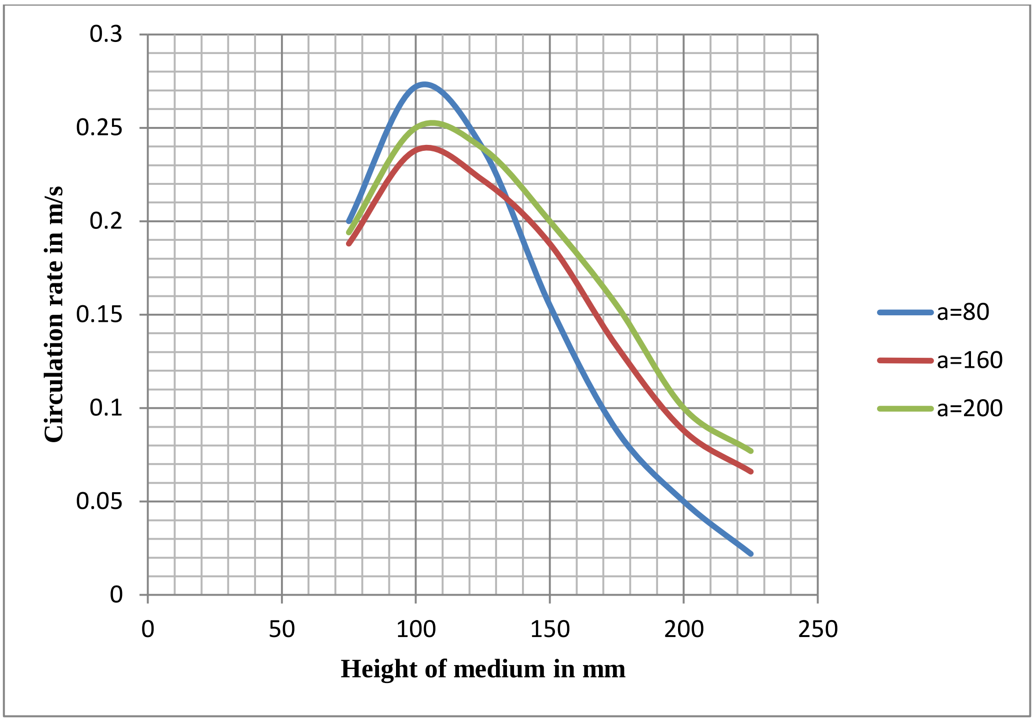

Figure 8: Circulation rate in steel bowl of ∅ 10 mm, working media of 90 mm length and different height of working media from table 6.

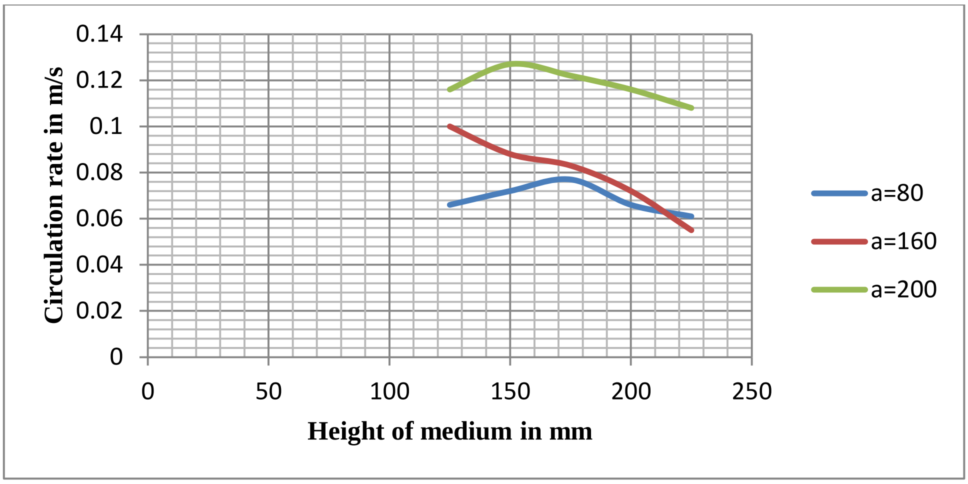

Figure 8: Circulation rate in steel bowl of ∅ 10 mm, working media of 200 mm length and different height of working media from table 7.

3. Conclusion and Recommendation

The efficiency of vibration processing (vibration polishing, vibration cleaning, rounding edges and others) depends on so many factors. Circulation flow rates in the working chamber having a great effect to get uniformly processed workpiece and having also certain effect on metal removal rate. As indicated in the above tabulated results and graphs, the ratio of the length of the chamber (b) and the height of working media (h) has the greatest impact on the value of the circulation rate. Maximum linear velocity is observed at $0{,}9 \leq b/h \leq 1{,}2$. Changes of the predetermined ratio within $1{,}3 \leq b/h \leq 1{,}9$ and $b/h \leq 0{,}9$ reduces circulation rate, while for $b/h \geq 1{,}9$ causes dramatic decrease in the circulation rate and formation of vortex flow. The width of the chamber (a) has little effect on the circulation of working media and workpiece. Working media particle size (d) has smaller impact on the linear velocity of its circulation.

The most intense circulation rate takes place at $20 \leq b/d \leq 35$. The ratio of the width of the working chamber to the working media diameter has little influence on the linear velocity of circulation of the working media [3]. Particularly in small working chamber design we can use the above conclusion to have intensive operation of vibration polishing, vibration cleaning, rounding edges and other relevant operations.

This study contains certain limitations and can be further developed concerning to the results in future research. In this study circulation rate calculated by taking the outer ellipse outline, this may not be always true for real circulation condition in addition to this the above conclusion working for small sizes of U-shaped working chambers. For processing long specimens and large sized specimens needs further investigations.

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Note: References indicated in № 7, 8 & 9 are written in Russian language to find on sites.