ISSN: 0975-766X
CODEN: IJPTFI
Available Online through **Research Article**
www.ijptonline.com

EXPERIMENTAL STUDIES OF VIBRATIONAL ABRADING ON INNOVATIVE EQUIPMENT WITH SIDE SHAKING TABLE

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Received on 14-08-2016 *Accepted on 20-09-2016*

Abstract

1. The article describes the experimental studies of vibroabrasive processing using innovative equipment with special vibration platforms needed to form a uniform path of abrasive particle movement.

2. This article presents the methods of research performance and the experimental evaluations of various technological parameters impact on the performance, the radius of a sharp edge rounding and an alloy surface layer quality.

3. The research results are presented concerning the metal removal across a container section depending on the displacement vibration sites for the samples from different alloys. The study of received dependences showed that the nature of metal removal change along a container perimeter is the same at the change of the process amplitude and frequency. The vibroabrasive processing without vibration sites revealed an uneven metal removal along the container section.

4. The study results showed that during the process of additional vibration sources as vibration site systems the performance of an vibroabrasive machine increases. At that the uniformity of metal removal increases.

5. The performed complex of experimental studies concerning the vibroabrasive processing on a vibration machine with the container fitted with side and central vibration platforms demonstrated the ability to provide the same metal removal rate, regardless of a sample location in a container and revealed the peculiarities of sample surface roughness.

Keywords: Vibroabrasive processing, abrasive particles, vibration platforms

Introduction

The parts of vehicles and their aggregates are subjected to a large alternating loads during the operation. Theoretical and experimental studies, the practice of motor equipment operation show that its reliability and service life are provided, among other conditions, by the given quality of the processed part surfaces, which depends on the adopted technology of their production.

The car structures are provided with the parts which represent a variety of frames, enclosures and bases. They have a spatial shape formed by various surfaces which are intersected at different angles. The technical specifications for the manufacture of such part working surfaces include low roughness, the rounding of sharp edges and a defective layer removal [1,2].

All these operations can be successfully performed on the machines for vibroabrasive processing which are increasingly used in our country and abroad [7,8,9]. This equipment is fairly universal. It is used for the machining of parts with different sizes and made of different materials.

However, it is impossible to receive the parts with the same characteristics of their surface layer quality due to the presence of different performance areas in a machine container [3,5,6]. Typically, critical parts are processed during their fixing to the container walls along its cross section, or on special mandrels to avoid the collisions between them. Therefore, the processed surfaces may be in different container performance zones simultaneously, resulting in different characteristics of processed surface quality.

Methods

When the processing takes place in a vibratory machine container for large parts with complex shaped surfaces, regardless of a performed technological operation type the evenness of material surface quality distribution characteristics becomes a particularly important within the overall dimensions of a part. The main difficulty of this task is in the non-uniformity of the working environment dynamic pressure along container zones. The unevenness of dynamic pressure along container zones is explained by different ratios of oscillating and circulating movement in accordance with the following expression:

$$F_{д} = \text{к} \cdot \text{M} \cdot \text{A} \cdot \omega^2$$

where:

$F_{д}$- detail and medium mutual pressure force;

к– the coefficient which takes into account the velocity vectors ratio of oscillating and circulating movement;

M– the mass of working load capacity, making an impact on a part;

$\text{A} \cdot \omega^2 -$ vibroacceleration.

The pressure reduction occurs in the areas where the impact of the container walls on the working environment decreases.

An uneven pressure along the container cross section is explained by force pulse damping during their transfer to the working medium from the container walls towards its center. The damping intensity is characterized by a damping factor:

$$\gamma_{д}=\frac{P_{i+1}}{P_i}$$

where

Pi- the medium pressure in the i-th point;

P_{i+1} - Working fluid pressure at the point located at a distance from i.

In order to eliminate the specified drawbacks by creating the zones of equal working medium pressure in the container on the processed products an experimental machine structure was designed and manufactured for research (Figure 1). The machine design is protected by the copyright certificate concerning the invention and its experimental industrial design was manufactured.

Fig.1. General view of experimental vibration machine.

The main difference between a new vibrating machine and currently available is the presence of U-shaped container whose side walls are designed as vibration sites and are linked with central vibration sites by levers. These sites are mounted in the central part of the container (Figure 2).

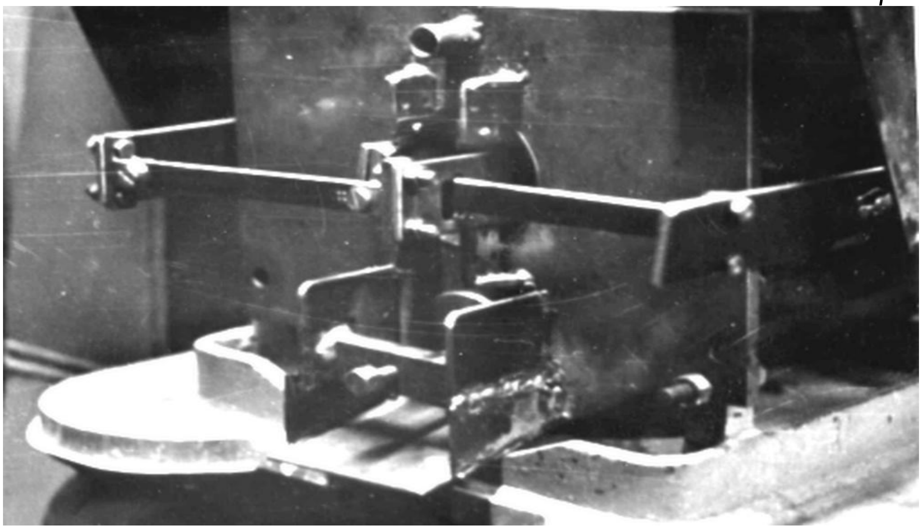

Fig.2. The relation of side and central vibration sites

The movement of vibration sites and the transfer of additional power pulses from them to the abrasive medium particles occurs due to the container vibrations under the action of the horizontal component of the vibrator disturbing force [4]. Under these conditions the zone of pressure distribution from central sites overlaps the pressure distribution zone from the outer container wall and the outer vibration site. The channel is formed along which the load is moved between the central and lateral vibration sites receiving power pulses from them. However, the distance reduction between the central and lateral vibration sites leads to the working environment speed decrease. The main condition for the setting of maximum distance value $(\tilde{\Delta})$ is the permissible value of force pulse damping. The distance $(\tilde{\Delta})$ can be determined from the following expression:

$$(\tilde{\Delta})=(1-\gamma_{д})*L$$

where

$\gamma_{д}$ – damping ratio (0,35-0,45)

L- the distance at which the total damping of force pulse occurs.

– The conducted theoretical - experimental studies of vibration machine mass motion center allowed to determine the trajectory of the mass center motion is a circle at a certain bias of vibration sites relative to the container walls.

At that the difference of the numerical values concerning the normal component of the particle pressure forces in the abrasive medium along the container section does not exceed 7%. Consequently, in this case the process efficiency will be the maximum one and the processing uniformity is achieved along the the container section at the same time

[4]. In order to establish the optimum technological conditions of processing the performance of projected vibrating machine was studied.

– Due to the fact that they aimed to provide a uniform effect of the working environment on a processed workpiece during the machine creation the operability of operational chamber zones in a vibration container was studied, including the container radius direction.

– In order to reduce the amount of experiments the whole area of the operation chamber was divided into separate sectors. The test samples are fixed on a special device in the working part of the sector. Such experimental studies allow to determine the following:

– the efficiency of each container zone operation;

– to study the change the power impact efficiency on the processed surface in the direction of the container radius within the working environment;

– to identify the nature of workload movement vector impact on the quality characteristics of material

sample surface layer made of the following aluminum alloys D16T, AK4T, AL4 and set in the various areas of the container.

Results and discussion

During the vibration processing technology development using a new design machine the main task was reduced to the required quality provision concerning the material surface layer at the highest performance. There is the relationship of any quality indicator from the combination value of technical factor due to multifactorial process:

$$Пк=f(M,A,f,T.Рж,\tau,\tilde{\Delta})$$

The most important here are the following ones:

M- working environment material;

A- oscillation amplitude;

f- oscillation frequency;

T– movement, load weight trajectory provided by vibration drive;

Рж–working fluid

τ- processing period;

$\tilde{\Delta}$- the distance between external and internal vibration sites.

A number of technical factors such as the offset of outer vibration sites relative to container walls Δd1 is selected according to the results of previous works Δd1=0,06 Rк, where Rк - is the radius of the container cylindrical part.

The distance between the central and lateral vibration sites $(\tilde{\Delta})$ can be adjusted. The system of differential equations (1) describing the motion of the vibration machine provided mass center is as follows:

$$\begin{cases} m\ddot{x} + 4b_{11}\dot{x} + 4c_{11}x \pm 2\tilde{\Delta}\tilde{b}_x\dot{\psi} \pm 2\tilde{\Delta}\tilde{c}_x\psi = m_0 r\omega^2 \cos\omega t; \\ m\ddot{y} + 4b_{22}\dot{y} + 4c_{22}y - m_0 r\ddot{\psi} + 4b_{y2}\dot{\psi} + 4c_{y2}\psi = m_0 r\omega^2 \sin\omega t; \\ m_0 a_0^2\ddot{\psi} + 2\left(p_0 + 2\dot{b}_0\right)\ddot{\psi} + 2\left(s + 2c_0\right)\psi \pm 2\tilde{\Delta}\tilde{c}_x x \pm 2\tilde{\Delta}\tilde{b}_x\dot{x} - m_0 r\ddot{y} + 4b_{y2}\dot{y} + 4c_{y2}y = m_0 hr\omega^2 \sin\omega t. \end{cases} \quad (1)$$

The upper signs (+) in the resulting equations during the container motion to the left of the vertical axis, and the lower ones (-) during the container movement to the right from the vertical axis.

The estimated scheme and sample securing scheme in the vibration machine container is shown on Figure 3.

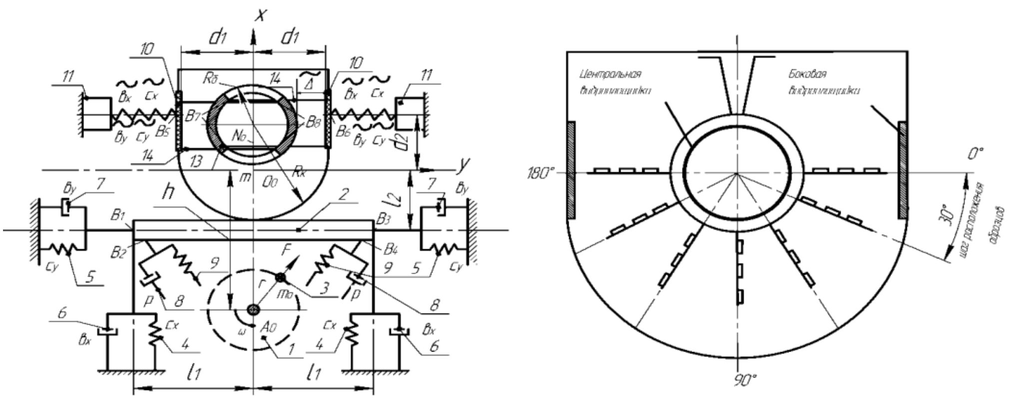

Fig.3. Design scheme and sample layout scheme in the container.

The location of the processing area across the container section is characterized by the angle α with the pitch of 30˚. Figure 4 shows the results of metal removal experimental studies across the container section: without vibration sites, with side vibration sites, with the system of lateral and central vibration sites.

The analysis of obtained relationships shows that the weight removal in the container without vibration sites on the samples depends significantly on the angle of their location. In the areas of 0˚, 90˚, 150˚ the removal decrease is observed. This is explained by the lack of an effective force action of container walls on the abrasive environment, which gets the lowest density in these areas.

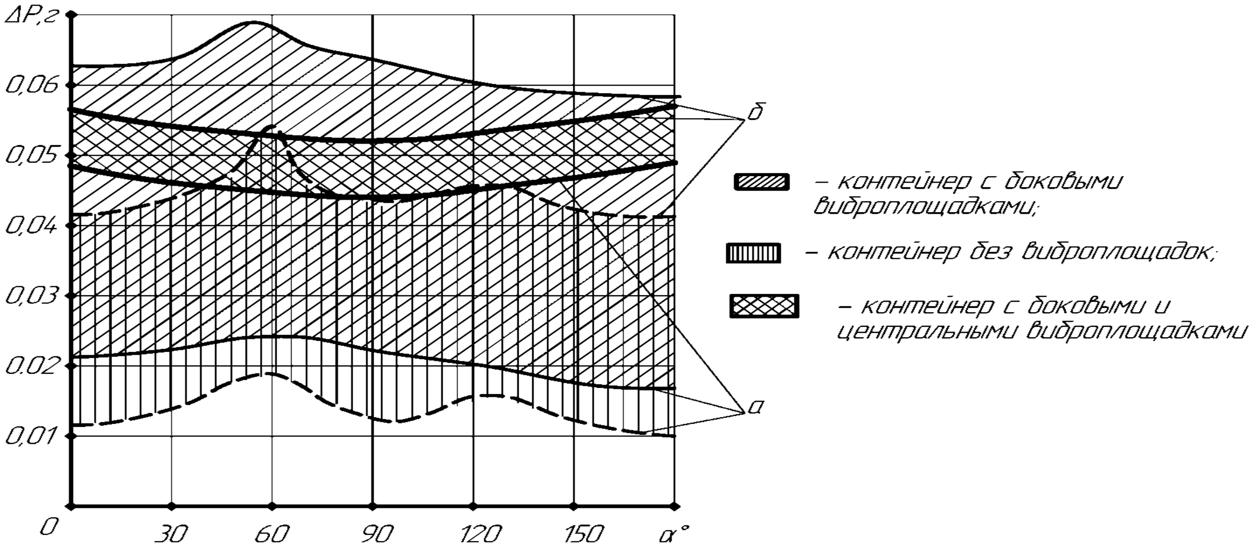

Fig. 4. The dependence of metal removal along the container section.

Processing conditions: f = 24 Hz; a - at $\tilde{\Delta}$ = 1 mm; б – at $\tilde{\Delta}$ = 3 mm ; t=45 min.

The processing in the container with the external vibration sites aligns the metal removal in the container areas significantly, however, there is a large spread of metal removal rate, depending on oscillation amplitude. Thus, the amplitude change from 1mm to 3mm increases the metal removal more than three times. The metal removal rate is almost the same along the container section in the container with lateral and central vibration platform. At that, it is greater in the zones of least material removal (0˚, 180˚) as compared to the other container structures at lower values of oscillation amplitude.

They also studied the processing performance according to the weight removal from the sample c made of the alloy AL4 with different values of the initial weight located at different distances from the lateral and the central vibration sites. The results are shown on Fig. 5.

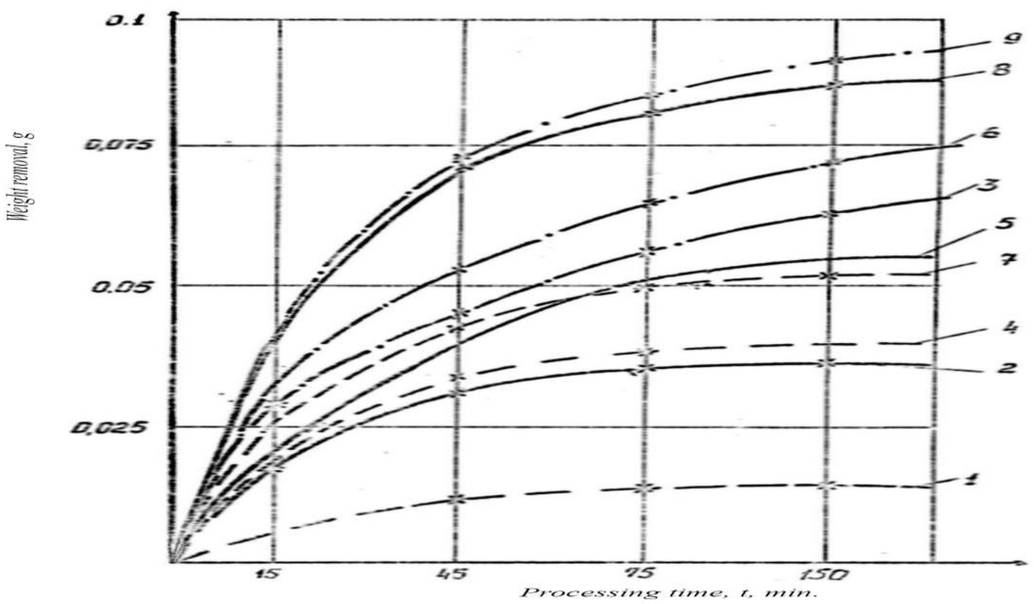

Fig. 5. The dependence of metal weight removal from the flat samples on the processing time and their locations in the radial direction (1, 2, 3. - A = 1 mm, - 4, 5, 6. - A = 2 mm, 7,8,9 - A = 3 mm.

--- - without vibration sites, with ——lateral vibration sites, -·-·-· with lateral and central vibration sites).

The processing of A, B sample groups with different initial weight values showed that the rate of metal removal is independent of the sample location along a container radius and the arithmetic mean value of removal is described by the following equation:

$$\Delta G = a - б \cdot T,$$

where

a and б - empirical coefficients

T- processing time

For the first group of samples – A

$$\Delta G = 0,8494 - 0,0010T;$$

for the second group of samples – Б

$$\Delta G = 0,6655 - 0,0014T$$

The results of studies confirmed that the metal removal rate does not depends on the sample location area and also on the distance from central and lateral vibration sites.

In order to determine the effect of lateral and central vibration sites on metal removal performance the comparative tests were conducted and material removal dependencies on the processing time and the oscillation amplitude were set. They are presented on Figure 6.

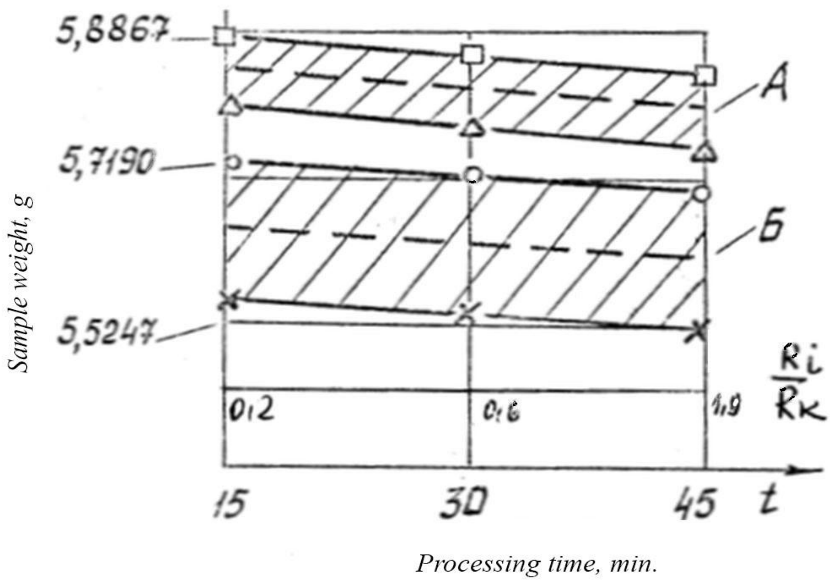

Fig. 6. Metal removal dependence on processing time and oscillation amplitude.

The displacement of vibration sites relative to the container walls makes a significant impact on the uniformity of metal removal along the cross section.

Conclusions

The research results show that the performance of a vibroabrasive machine increases in the process of additional vibration source operation in the form of vibration site system. This increases the uniformity of metal removal.

The most uniform intense metal removal occurs during the first 45 ... 60 min, after which the process takes place not so actively. After 45 minutes of treatment the range of values in a standard container without vibration sites will make 0.017 - 0.04 g. The change of metal removal rate makes 57,5 %. The change of removal in the container with lateral vibration sites makes 0.03 - 0,68 g or 53 %. The organization of counter vibration excitement by lateral and central vibration sites narrows the metal removal range to 31% or 1,8-fold, which is consistent with the data of the dynamic pressure studies along the container zones, as well as with the presented above data of weight removal dependence on the location in a particular zone.

Besides, the proposed processing method enhances the process productivity, particularly at the processing with the amplitude A = 2 mm, which is assumed as an operational one in most cases.

The surface roughness was studied using the samples whose surface was treated up to the roughness value of Ra 0,8 ... 1,25 microns. The samples were fixed in different container zones, however, the results of roughness value measurements did not reveal the surface formation features. In this regard the general pattern of vibroabrasive processing is traced. The increase of surface roughness up to the Ra value of 2.2 ... 3.0 microns takes place during the first 15 minutes. The increase of processing time does not make a significant impact on the magnitude of the initial roughness change. The schedule of roughness change is shown on Fig. 7.

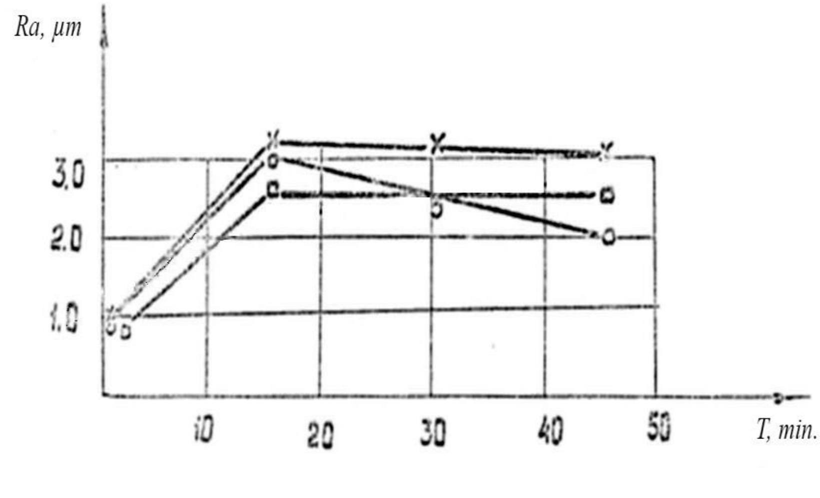

Fig. 7. The graph of roughness dependence on the processing time.

- in the container without vibration sites; - in the container with lateral vibration sites; - in the container with lateral and central vibration platforms.

Any traces of surface orientation irregularities, formed after milling, disappear completely. The tops of irregularities have larger fillet radii than at the original sample blade processing, which should enhance the supporting surface of parts, by the stress concentrator elimination.

Summary

Thus, the performed range of experimental studies concerning vibroabrasive processing on a vibration machine with the container fitted by lateral and central vibration sites demonstrated the ability to provide the same metal removal rate, regardless of sample location in the container and revealed the peculiarities of sample surface roughness development.

Acknowledgements

The work is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University.

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