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# Shock-free Race Track of Road Roller Vibration Exciters

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***Abstract* — This study is aimed at improvement of the vibration road rollers efficiency by means of asymmetrical planetary vibration exciter, characterized by the higher level of dynamic parameters indicating how the energy supplied to the vibration drum affects the increase of disturbing force and sealing capacity of the road rollers. To achieve the above goal several studies were conducted and one of their objectives was to develop the method of determination of the vibration exciter road rollers transition areas junction point that meets the integrity, tangency and curvature requirements. The original methodology of the specification of the combined race track shape composed by conic arcs and linked by easy curve was developed.**

***Index Terms* — vibration road rollers, integrity, tangency, curvature, conic**

## I. INTRODUCTION

THIS study is aimed at improvement of the vibration road rollers efficiency by means of asymmetrical planetary vibration exciter, characterized by the higher level of dynamic parameters indicating how the energy supplied to the vibration drum affects the increase of disturbing force and sealing capacity of the road rollers. To achieve the above goal several studies were conducted and one of their objectives was to develop the method of determination of the vibration exciter road rollers transition areas junction point that meets the integrity, tangency and curvature requirements. The original methodology of the specification of the combined race track shape composed by conic arcs and linked by easy curve was developed.

## II. MODEL MECHANISMS

Let us consider the planetary vibration exciter (figure 1) with the race track composed by half-arcs of the circle with the radius $a$ and ellipse with semi-axles $a$ and $b$. Junction points $A(a,\ 0)$ and $A'(-a,\ 0)$ are located along the axle $Ox$.

The circle has a curvature radius $\rho = a$, and the ellipse radius is

$$\rho = (b^4x^2 + a^4y^2)^{3/2} \big/ a^4b^4 .$$

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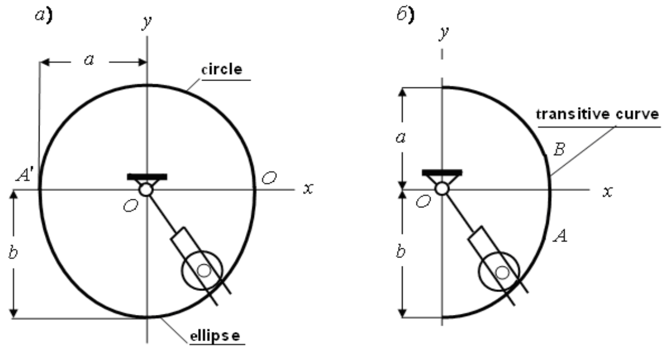


Fig.1 Vibration exciter with combined ace track

The vibration exciter runner wheel moves along race track composed by conic arcs with common tangents in junction points. When passing from one part of the track to another we have discontinuity in the curvature that causes jump of centrifugal force. To avoid such force jump it is necessary to insert special arc -curve shaped transition part (Figure 1b) meeting following requirements: a) the ach should pass through junction points $A$ and $B$; b) connecting and connected parts should have equal first derivative in junction points; c) curvature radiuses in junction points should be equal . The junction that meets the requirements a) and b) corresponds to the first degree of smoothness. The junction that meets the requirements a), b) and c) corresponds to the second degree of smoothness [1]. Let us consider the objective of achieving of the smooth curve.

Liming showed [2], that it is possible to derive the equation of conic with two preset tangents passing through the third point:

$$(1-\lambda)\cdot L_1 \cdot L_2 + \lambda \cdot L_3^2 = 0 \qquad (1)$$

(1) is a pencil of conics, passing through points $A$ and $B$, here the line $L_2 = 0$ - is the tangent in the point $A$, and the line $L_1 = 0$ - is the tangent in the point $B$, and the line $L_3 = 0$ - is a chord linking points $A$ and $B$ (figure 2). The parameter $\lambda$ is determined by setting up the point $M\ (x_M, y_M)$ then

$$\lambda = \frac{L_1(x_M, y_M)L_2(x_M, y_M)}{L_1(x_M, y_M)L_2(x_M, y_M) - L_3^2(x_M, y_M)} \qquad (2)$$

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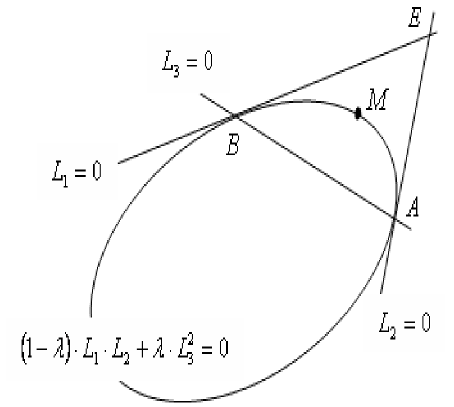


Fig.2 Conic

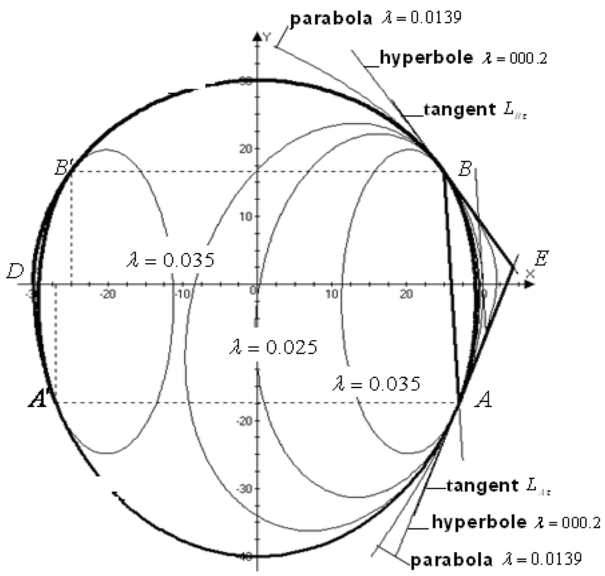


Fig.3 Pencil of conics

Thus, conic equations of race track transition part are defined by four points: two junction points $A$ and $B$; tangents intersection point $E$; a point $M$. By selecting point $M$ inside $\Delta AEB$ we define the first smoothness degree curve between points $A$ and $B$. Variants of race track transition part conics, connecting arches of the circle $x^2 + y^2 = 30^2$ and the ellipse $x^2/30^2 + y^2/40^2 = 1$ in points $A(27; -17.44)$ and $B(25; 16.58)$ are shown in the Figure 3. In the semiarches junction point $D$ the jump of curvature radiuses is observed: 1. For the arch with $\lambda = 0.035$ (ellipse): $\rho_A = 26.38$, $\rho_B = 13.4$; 2. For the arch with $\lambda = 0.025$ (ellipse): $\rho_A = 28.68$, $\rho_B = 23$. Use of Liming method allows to derive the expression describing connecting arch in form of the equation (1), provided the following five values are preset:

1,2) - two frontier points, satisfying the equation (1);
3,4) - two tangentials, passing through the frontier points;
5) - $\lambda$-parameter, determined by the formula (2).

## III. MATHEMATICAL MODEL CURVES

Resultant curve arch provides smoothness of the first grade. Proper selection of $\lambda$-parameter in the equation (1) allows to obtain curve shape satisfying the required smoothness condition. That is, the conic derived by the Liming method in points $A$ and $B$ should have curvature radiuses equal to the preset $\rho_A$ and $\rho_B$. For this purpose it is necessary to determine relations between curve radius and $\lambda$ parameter. Actually, [3] often the conic is preset by two lines tangent to it, and tangent points on them, plus one other point or by presetting $\lambda$-parameter. It is more practically useful to preset the conic by two lines tangent to it, and tangent points on them, and the engineering discriminate (Figure 4). In case of engineering method, the point $M$ on the curve between points $A$ and $B$ is preset as the cross point of the median $CE$ of the basic triangle $\Delta AEB$ with the target curve. In this case, point $M$ is defined by the segment $CM$ (cut off on median from the median base) to the median $CE$ value ratio: $f = CM/CE$ and is called the engineering discriminant. The radius of the curvature in the point $A$ is determined as [1]:

$$\rho_A = (2f^2 l_A^2)/((1-f)^2 h_B) \qquad (3)$$

where $l_A = AE$ is the length of the tangent, passing from the point $A$ through to the point $E$, $h_B$ - is the distance from the point $B$ to the tangent in the point $A$.

Let us assume that the transition part $\cup AMB$ has elliptic shape (figure 5). Let us consider points

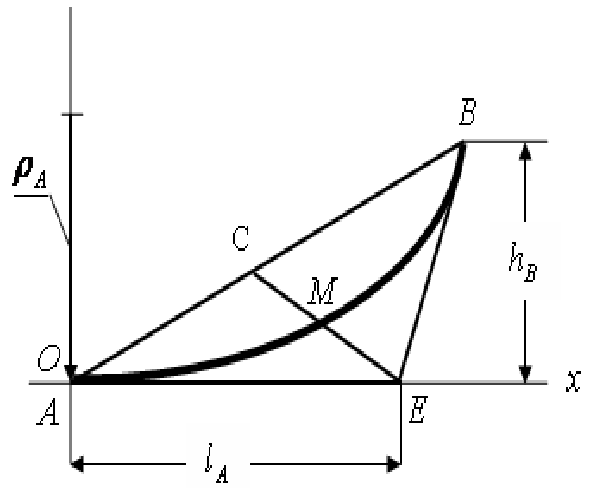


Fig.4 Engineering way of the task conics

$A(x_A, y_A)$ and $B(x_B, y_B)$ with $\rho_A$ and $\rho_B$ correspondingly and draw tangents $L_{A\tau}$ и $L_{B\tau}$ passing through them, these tangentials shall meet at the point $E$. By connecting points $A$, $B$ and $E$ we draw the basic triangle $\Delta AEB$,which is formed by tangents $L_{A\tau}$, $L_{B\tau}$, chord $L_{AB}$, $ED$ - is a median.

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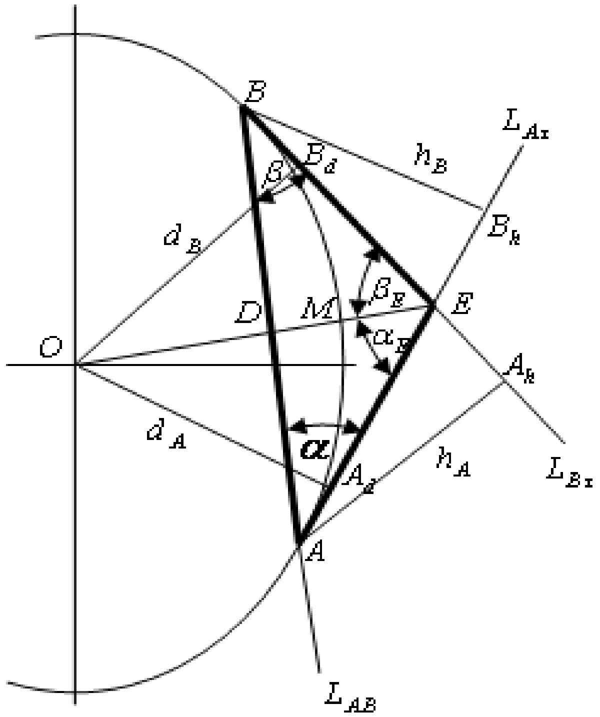


Fig.5 Basic Triangle

Let us denote the distances from the center $O$ to $L_{A\tau}$ and $L_{B\tau}$, as $l_B = BE$, $d_A = OA_d$, $d_B = OB_d$; and $h_A = AA_h$, $h_B = BB_h$ are the distances from points $A$ and $B$ to $L_{B\tau}$ and $L_{A\tau}$, $\alpha = \angle BAE$, $\beta = \angle ABE$, $\alpha_E = \angle AED$, $\beta_E = \angle BED$. It is known that the ellipse radius in a point equals to [4]: $\rho_A = a^2b^2/d_A^3$, $\rho_B = a^2b^2/d_B^3$. By using the above, let us introduce the radiuses ratio $\eta = \sqrt[3]{\rho_A/\rho_B} = d_B/d_A$. Ratio $\eta$ shall play the leading part in deriving smooth joint curve. Let us consider the triangles $\Delta OA_dE$ and $\Delta OB_dE$, in this case $\sin\beta_E/\sin\alpha_E = d_B/d_A = \eta$. Let us consider triangles $\Delta ADE$ and $\Delta BDE$, applying theorem of sins, in this case we get $\sin\beta_E/\sin\alpha_E = \sin\beta/\sin\alpha = \eta$. For triangles $\Delta AEB$, $\Delta AA_hB$ and $\Delta AB_hB$ we obtain $\sin\beta/\sin\alpha = l_A/l_B = h_A/h_B = \eta$. Thus, in case we have two points $A$ and $B$ of the ellipse with curvature radiuses of $\rho_A$ and $\rho_B$, the ratio between corresponding elements of the basic triangle $\Delta AEB$ and $\eta$ is:

$$\frac{\sin\beta}{\sin\alpha} = \frac{\sin\beta_E}{\sin\alpha_E} = \frac{d_B}{d_A} = \frac{l_A}{l_B} = \\ = \frac{h_A}{h_B} = \sqrt[3]{\rho_A/\rho_B} = \eta \tag{4}$$

The above ratios allow determining the junction area where the smooth transition from one part to another. Let us assume that the arch of the transition area $\cup AMB$ is the part of the drum roller with the combined shape consisting of arcs of circle and ellipse. Let us select a point $A$ on the given ellipse with the radius of the curvature $\rho_A$ and set it as a zero of the fixed coordinate system $Ax_1y_1$. Axis $Ax_1$ is directed along $L_{A\tau}$ tangential to ellipse at this point $A$, and axis $Ay_1$ is directed along normal $L_{An}$ (figure 6). The radius of curvature of any point $B$ in this circle equals to $\rho_B = r$. The tangent $L_{B\tau}$, drawn through the point $B$, crosses tangent $L_{A\tau}$ in the point $E$. When changing the position of the point $B$ each time a new tangent to the circle from the new position of the point $B$ is drawn and this leads to the change of the position of the point $E$ in the axis $Ax_1$.

Thus by changing the slope angle $\gamma$ of tangential $L_{B\tau}$ relatively to the fixed axis $Ax_1$, we can determine the position of the point $B$ in the circle. The angle $\gamma$ should ensure the correspondence with the type ratio (4). We propose to simulate the process of determination of the point $B$ position by use of the link mechanism, provided that the ratio (4) is correct. Stems $OB$ and $BE$, normal and tangential to the circle at the point $B$ and rigidly connected with each other at the point $B$ at right angle, form the link $OBE$ (figure 7). Link sliding block $E$ moves along the slot $BE$ and is pin connected at the point $E$ with the stem $Ex_1$ tangential to the ellipse at the point $A$. Rotation of the link $OBE$ about the fixed point $O$ in $Ax_1y_1$ plane sets in motion the block $E$ and sliding of the latter along the slot $BE$ in its turn causes translator motion of the stem $Ex_1$ along the axis $Ax_1$. Thus the block $E$ all the time it moves stays at the intersection of the guiding lines $BE$ and $Ex_1$. Such movement of the block $E$ leads to the simultaneous change of the distances $AE$ and $BE$. By deriving the motion equation of the block $E$ is possible to fulfill the ratio $l_A/l_B = \eta$. The angle $\gamma$ also determines the position of the link $BE$ relative to the fixed axis $Ax_1$. Let us assume that $d_A$ and $m_A$ are the distances from the fixed pin $O$ to the guiding line $Ax_1$ and the normal $Ay_1$, correspondingly. Then coordinates of the points $E$ and $B$ are:

$$\begin{cases} x_E = (m_A + r\sin\gamma) - d_A - r\cos\gamma/tg\gamma \\ y_E = 0 \end{cases}$$

and

$$\begin{cases} x_B = m_A + r\sin\gamma \\ y_B = d_A - r\cos\gamma \end{cases} \tag{5}$$

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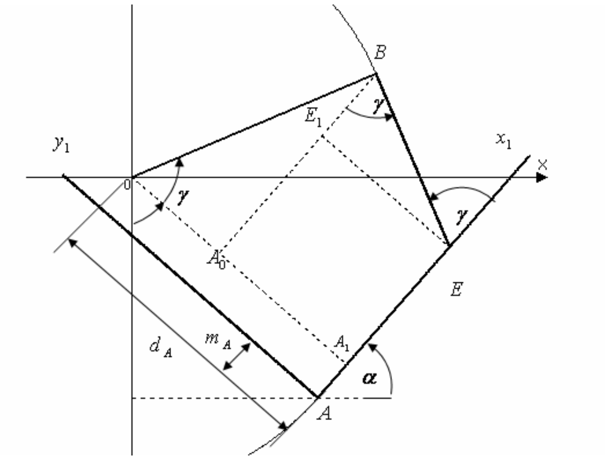


Fig.6 Definition of position of a point **B**

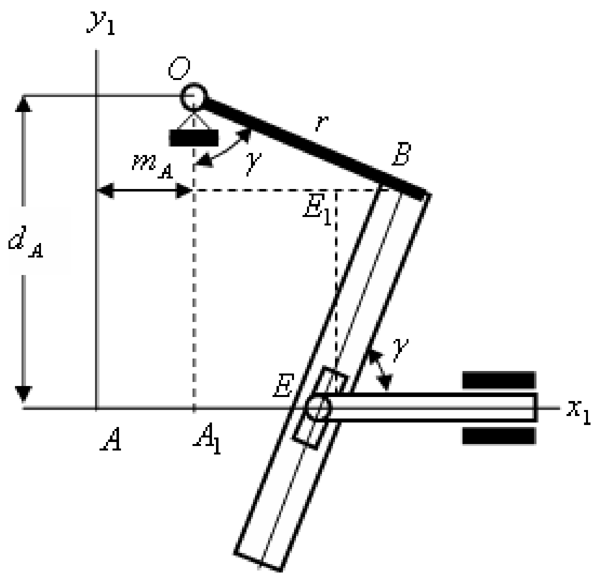


Fig.7 Link mechanism

Let us evaluate the length change as a function of the link rotation angle:

$$l_A = \frac{m_A tg\gamma\sqrt{1+tg^2\gamma} - d_A\sqrt{1+tg^2\gamma} + r(1+tg^2\gamma)}{tg\gamma\sqrt{1+tg^2\gamma}},$$

$$l_B = \frac{d_A\sqrt{1+tg^2\gamma} - r}{tg\gamma}$$

With the provision for the ratio (4) we deduce the equation relatively to $k = tg\gamma$ :

$$\frac{(m_A k\sqrt{1+k^2} - d_A\sqrt{1+k^2} + r(1+k^2))}{\sqrt{1+k^2}\left(d_A\sqrt{1+k^2} - r\right)} = \eta \quad (6)$$

## IV. CONCLUSIONS

Thus we have developed the method of determination of the shape of a combined race track, which is formed by conic arcs linked with each other by smooth curve. The algorithm of this method consists in the following: by the ratio (6) we obtain the value of $k = tg\gamma$ and $\gamma$, correspondingly. Then in accordance with (5) we determine the coordinates of the point E and B, basing on their values with the help of (3) we determine the value of $f$ and fix the point M, by the latter we evaluate the parameter $\lambda$ with the use of the formula (2). And finally, we deduce the equation of a smooth curve linking the ellipse and the circle in the points A and B using the parameters determined by the formula (1).

## REFERENCES

[1] N.A. Mishustin, Ye.P. Zhulenov, T.V. Tolkunova: Plane Curves in engineering practice: educational guidance/ VolgSTU, Volgograd, 1995.– 54 p.
[2] A. Fox A., M. Pratt: Computational Geometry. Use in design and manufacturing: Transl. From English– M.: Mir, 1982. -304 p.
[3] V.S. Levitsky, Machine Drawing. M., Vysshaya Shkola, 1988. -351 p.
[4] M.Ya. Vygodsky. Mathematics Manual. M.: AST: 2006. – 991p.

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