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COMPUTING CONTRIBUTIONS TO RESTORE AGRICULTURAL MACHINERY
(A CONTACT PROBLEM OF BEARINGS WITH DIAMETRICAL GAME RECONDITIONED BY COMPOSITE POLYMERS)

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Abstract. This study is dedicated to an important contact problem, which appears in the bearings with a diametrical game, when the shaft is restored by its coverage by a composite polymer layer. By using the method of incompressible influence elements there were constructed Green's matrices (GM) for displacements within a polymer composite circular layer with mixed boundary conditions. These GM were applied to solve the static contact problem, when the polymer composite circular layer contacts with a metallic piece. Thus, there were obtained two systems of equations, which permit to determine load capacity and the coverage angle of the compression zone of the polymer composite layer and a diametrical game of bearing. These results can be applied to determine parameters of restored bearings of an agricultural machine mentioned above.

Physico-mechanical contact surfaces in frictional systems, along with other factors, are influenced by the contact nature. In its turn, the contact nature is the determining factor in ensuring functional interchangeability of remanufactured parts.

However, the determination whether joint couplings are restored with composite polymers by means of an agricultural technique is influenced by a number of factors, such as the random nature of working parameters (pressure, relative speed, piedoclimatic terms); material properties (hardness, wear resistance, dimensional stability, moisture and oil absorption capacity, etc.); microgeometry baseline and functional characteristics, form and position accuracy; original and functional character of the joint.

The existing calculation methods of adjustments to the game refer to the joints made of homogeneous materials and lead to conflicting results when using them to calculate joints made of heterogeneous materials as determined as joints for a piece is reclaimed plastics. There are some recommendations regarding the calculation of adjustments with the game for polymer plain bearings [1], but these methods do not take into consideration a number of factors that occur during operation. The following presents a new method for calculating adjustments with the game, joints made of heterogeneous materials based on the use of Green functions to boundary joint problems.

We have developed the following Green's matrix for displacements to solve these problems

$$U_s^{(q)}(M,N) = \begin{pmatrix} U_r^{(q)} U_r^{(\psi)} \\ U_\varphi^{(p)} U_\varphi^{(\psi)} \end{pmatrix} \tag{1}$$

in the arbitrary point $M(r,\varphi)$ in the directions of the axis os, $s = r,\varphi$, caused by the concentrated body forces $\delta_{Sq}\ \delta(M-N)$, described by $\delta(M-N)$–the Dirac's function and by the Cronescker's symbol–δ_{Sq}. These body forces are applied to the inner arbitrary

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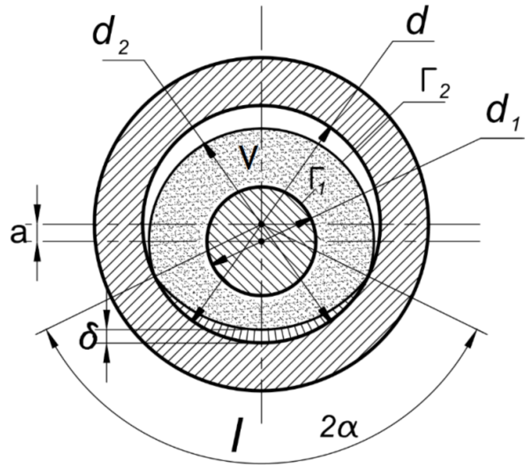

FIGURE 1. The scheme of loading of the polymer layer: I - the compression zone of the polymer layer which is applied to the shaft; d – the inner diameter of the metallic piece; d_1 – shaft's diameter which coincides with the inner diameter of the polymer layer; d_2- the exterior diameter of the polymer layer; a – the displacement of the shift's center; δ – the maximal deformation of the polymer layer; 2α – the coverage angle of the compression zone.

point $N(\rho,\psi)$ in the direction of the axis oq, $q=\rho,\psi$ of the circular elastic layer $V \equiv (r_1 \le r \le r_2,\ 0 \le \varphi \le 2\pi)$ with the mixed boundary conditions on the circular boundary counters $\Gamma_1, \Gamma_2 \in V$ (Figure 1).

From the mathematical point of view the solution of this problem led to the integration of the following fundamental system of Lame's equations written in the polar coordinates - r, φ:

$$\left.\begin{aligned} &\mu\left(\triangle U_r^{(q)} - \tfrac{1}{r^2}U_r^{(q)} - \tfrac{2}{r^2}\tfrac{\partial U_\varphi^{(p)}}{\partial\varphi}\right) + (\lambda+\mu)\,\tfrac{\partial\theta^{(q)}}{\partial r} + \delta_{rq}\delta\,(M-N) = 0;\\ &\mu\left(\triangle U_\varphi^{(q)} - \tfrac{1}{r^2} - U_\varphi^{(q)}\tfrac{2}{r^2}\tfrac{\partial U_\varphi^{(p)}}{\partial\varphi}\right) + (\lambda+\mu)\,\tfrac{1}{r}\tfrac{\partial\theta^{(q)}}{\partial\varphi} + \delta_{\varphi q}\delta\,(M-N) = 0 \end{aligned}\right\} \quad (2)$$

in inner points of the circular elastic layer V with the following mixed boundary conditions on the circular counters $\Gamma_1\,(r=r_1,\ 0\le\varphi\le 2\pi)$ and $\Gamma_2\,(r=r_2,\ 0\le\varphi\le 2\pi)$:

$$\mathrm{U}_r^{(q)}(M_1,N) = \mathrm{U}_\varphi^{(q)}(M_1,N) = 0,\ M_1 \equiv \left(r_1, \varphi^{/}\right),\ M_1 \in \Gamma_1; \quad (3a)$$

$$\sigma_{rr}^{(q)}(M_2,N) = \sigma_{r\varphi}^{(q)}(M_2,N) = 0,\ M_2 \equiv \left(r_2, \varphi^{/}\right),\ M_2 \in \Gamma_2 \quad (3b)$$

Where λ and μ are the Lame's constants of elasticity, $\triangle$ is the Laplace differential operator, $\theta^{(q)}$ is the elastic volume dilatation; $\mathrm{U}_r^{(q)}, \mathrm{U}_\varphi^{(q)}$ and $\sigma_{rr}^{(q)}, \sigma_{r\varphi}^{(q)}$ are the radial and circular displacements and stresses respectively.

The derivation of Green's matrix displacements (1) of the boundary value problem (2)–(3b) was made by using the Influence Elements Method (IEM) proposed by V. Șeremet in his works [2, 3]. This problem was solved during two stages.

At the first stage the Green's matrix displacements were derived for the fundamental Lame's system of equations (2) for a circular polymer layer, but the following homogeneous boundary conditions for displacements are given on its circular counters:

$$\mathrm{U}_r^{(q)}(M_1,N)=\mathrm{U}_\varphi^{(q)}(M_1,N)=0,\ M_1\equiv\left(r_1,\varphi^{/}\right),\ M_1\in\Gamma_1; \tag{4a}$$

$$\mathrm{U}_r^{(q)}(M_2,N)=\mathrm{U}_\varphi^{(q)}(M_2,N)=0,\ M_2\equiv\left(r_2,\varphi^{/}\right),\ M_2\in\Gamma_2 \tag{4b}$$

The Incompressible Influence Elements Method (IIEM) [2, 3] was used to achieve this aim. The IIEM is based on the special harmonic integral representations, the kernels of which are the Green's functions for the Poisson's equation. The solution of the boundary value problem (2), (4a) and (4b) by using the IIEM led to the solution of the boundary integral equations with respect to volume dilatation on the circular counters Γ_1 and Γ_2 of the polymer circular layer V.

At the second stage on the basis of the Green's matrix displacements for the boundary value problem (2), (4a), (4b) and by using the Compressible Influence Elements Method (CIEM) there are derived the Green's matrix displacements for the initial mixed boundary value problem (2)–(3b). The CIEM is based on certain integral representations, whose kernels are the components of the Green's matrix displacements for the boundary value problem (2), (4a) and (4b).

So, as a result of the solution of certain boundary integral equations we obtain the following expressions for the components of the Green's matrix displacements of the problem (2)–(3b):

$$\begin{gathered}\left\{\begin{array}{c}\mathrm{U}_r^{(q)}(M,N)\\ \mathrm{U}_\varphi^{(q)}(M,N)\end{array}\right\}=\left\{\begin{array}{c}F_0^{(1)}(r,\rho)\\ F_0^{(2)}(r,\rho)\end{array}\right\}+\\ +\left\{\begin{array}{c}F_1^{(1)}(r,\rho)\\ F_1^{(2)}(r,\rho)\end{array}\right\}\cos(\varphi-\psi)+\left\{\begin{array}{c}\overline{F}_1^{(1)}(r,\rho)\\ \overline{F}_1^{(2)}(r,\rho)\end{array}\right\}\sin(\varphi-\psi)+\\ \sum_{n=1}^{\infty}\left\{\begin{array}{c}F_{n+1}^{(1)}(r,\rho)\\ F_{n+1}^{(2)}(r,\rho)\end{array}\right\}\cos(n+1)(\varphi-\psi)+\sum_{n=1}^{\infty}\left\{\begin{array}{c}\overline{F}_{n+1}^{(1)}(r,\rho)\\ \overline{F}_{n+1}^{(2)}(r,\rho)\end{array}\right\}\sin(n+1)(\varphi-\psi)\end{gathered} \tag{5}$$

where the functions $F_0^{(1)}$, $F_0^{(2)}$, $F_1^{(1)}$, $F_1^{(2)}$, $\overline{F}_1^{(1)}$, $\overline{F}_1^{(2)}$, $F_{n+1}^{(1)}$, $F_{n+1}^{(2)}$, $\overline{F}_{n+1}^{(1)}$, $\overline{F}_{n+1}^{(2)}$ depend on the independent variable r and ρ.

In the case of frictional systems, which are composed of a recovered composite polymer piece and a metallic piece, it is necessary to solve the contact problem for the circular polymer layer applied to the shaft surface (Figure 1).

So, it is necessary to solve the contact problem in the case, when polymer composite is applied to exterior surfaces. In the case of the application of the polymer composite to the interior surface, the contact problem was studied in the works [4, 5]. The circular counter $\Gamma_1\left(r=r_1,\ 0\le\varphi^{/}\le 2\pi\right)$ of the polymeric layer $V\,(r_1\le r\le r_2,\ 0\le\varphi\le 2\pi)$ is considered non-deformable, because it is glued to the metallic surface of the shaft (Figure 1). The contact between the polymeric layer $\mathrm{V}\,(r_1\le r\le r_2,\ 0\le\varphi\le 2\pi)$ and non-deformable metallic piece takes place on the counter $\Gamma_2\left(r=r_2,\ 0\le\varphi^{/}\le 2\pi\right)$.

Thus, to determine deformations and stresses we need to state the polymeric layer and the values of magnitudes: a – the displacement of the shaft's center, caused by static loadings, α – a semi-angle of the compression zone; $\triangle_r$ – the radial game, it is necessary to solve the contact problem, which presupposes the integration of the following Lame's equations in polar coordinates $r,\ \varphi$:

$$\left.\begin{array}{l}\mu\left(\triangle U_r-\frac{1}{r^2}U_r-\frac{2}{r^2}\frac{\partial U_\varphi}{\partial\varphi}\right)+(\lambda+\mu)\frac{\partial\theta}{\partial r}=0;\\ \mu\left(\triangle U_\varphi-\frac{1}{r^2}U_\varphi-\frac{2}{r^2}\frac{\partial U_r}{\partial\varphi}\right)+(\lambda+\mu)\frac{1}{r}\frac{\partial\theta}{\partial r}=0\end{array}\right\} \tag{6}$$

in the exterior points of the polymeric layer V $(r_1 \le r \le r_2,\ 0 \le \varphi \le 2\pi)$ with the following boundary conditions:

$$\mathrm{U}_r\left(r = r_1,\ 0 \le \varphi^{/} \le 2\pi\right) = \mathrm{U}_\varphi\left(r = r_1,\ 0 \le \varphi^{/} \le 2\pi\right) = 0 \tag{7}$$

on the circular counter $\Gamma_1\left(r = r_1,\ 0 \le \varphi^{/} \le 2\pi\right)$, and

$$\sigma_{rr}\left(r = r_2,\ -\alpha \le \varphi^{/} \le \alpha\right) \ne 0;;\ \sigma_{\varphi r}\left(r = r_2,\ -\alpha \le \varphi^{/} \le \alpha\right) = f\sigma_{rr}\left(r = r_2,\ \varphi\right);$$

$$\sigma_{\varphi r}\left(r = r_2,\ -\alpha \le \varphi^{/} \le 0\right) = -\ f\sigma_{rr}\left(r = r_2,\ \varphi^{/}\right); \tag{8}$$

$$\sigma_{rr}\left(r = r_2,\ \left|\varphi^{/}\right| \ge \alpha\right) = 0;;\ \sigma_{\varphi r}\left(r = r_2,\ \left|\varphi^{/}\right| \ge \alpha\right) = 0; \tag{9}$$

on the circular counter $\Gamma_2\left(r = r_2,\ 0 \le \varphi^{/} \le 2\pi\right)$. In relation (8) f is the coefficient of friction between the metallic piece and the polymer layer.

The boundary value problem (6)–(9) can be solved by using the Green's matrix displacements $U_s^{(q)}(\mathrm{M},\mathrm{N})$, described by the expressions (5) of the similar problem (2)–(3b). So, displacements U_r and U_φ in the inner points of the polymer layer for the mixed boundary value problem (6)–(9), are determined by the following integral formulas:

$$\begin{aligned} U_r\left(r,\varphi\right) = -\int_{-\alpha}^{0}\sigma_{rr}\left(r_2,\varphi^{/}\right)\left[U_r^{(q)}\left(r_2,r,\varphi^{/},\varphi\right) + fU_\varphi^{(q)}\left(r_2,r,\varphi^{/},\varphi\right)\right]r_2 d\varphi^{/} - \\ \int_{0}^{-\alpha}\sigma_{rr}\left(r_2,\varphi^{/}\right)\left[U_r^{(q)}\left(r_2,r,\varphi^{/},\varphi\right) + fU_\varphi^{(q)}\left(r_2,r,\varphi^{/},\varphi\right)\right]r_2 d\varphi^{/} \end{aligned} \tag{10}$$

$$\begin{aligned} U_\varphi(r,\varphi)' = -\int_{-\alpha}^{0}\sigma_{rr}\left(r_2,\varphi^{/}\right)\left[U_r^{(\psi)}\left(r_2,r,\varphi^{/},\varphi\right) + fU_\varphi^{(\psi)}\left(r_2,r,\varphi^{/},\varphi\right)\right]r_2 d\varphi^{/} - \\ \int_{0}^{-\alpha}\sigma_{rr}\left(r_2,\varphi^{/}\right)\left[U_r^{(\psi)}\left(r_2,r,\varphi^{/},\varphi\right) + fU_\varphi^{(\psi)}\left(r_2,r,\varphi^{/},\varphi\right)\right]r_2 d\varphi^{/} \end{aligned} \tag{11}$$

In formulas (10) and (11) the kernels are determined on the basis of relations (5), with the following expressions:

$$\begin{aligned} U_r^{(q)}\left(r_2,r,\varphi^{/},\varphi\right) &= F_0^{(1)} + F_1^{(1)}\cos\left(\varphi^{/} - \varphi\right) + \sum_{n=1}^{\infty} F_{n+1}^{(1)}\cos\left(n+1\right)\left(\varphi^{/} - \varphi\right); \\ U_\varphi^{(q)}\left(r_2,r,\varphi^{/},\varphi\right) &= \overline{F}_1^{(2)}\sin\left(\varphi^{/} - \varphi\right) + \sum_{n=1}^{\infty} \overline{F}_{n+1}^{(2)}\sin\left(n+1\right)\left(\varphi^{/} - \varphi\right); \\ U_\varphi^{(\psi)}\left(r_2,r,\varphi^{/},\varphi\right) &= \overline{F}_1^{(1)}\sin\left(\varphi^{/} - \varphi\right) + \sum_{n=1}^{\infty} \overline{F}_{n+1}^{(1)}\sin\left(n+1\right)\left(\varphi^{/} - \varphi\right); \\ U_\varphi^{(q)}\left(r_2,r,\varphi^{/},\varphi\right) &= F_0^{(2)} + F_1^{(2)}\cos\left(\varphi^{/} - \varphi\right) + \sum_{n=1}^{\infty} F_{n+1}^{(2)}\cos\left(n+1\right)\left(\varphi^{/} - \varphi\right) \end{aligned} \tag{12}$$

Note that the problem can be considered as solved, if radial stresses - $\sigma_{rr}\left(r_2,\varphi\right)$ are known and they are present during the contact between the polymer layer and the compression zone $\left(-\alpha \le \varphi^{/} \le \alpha\right)$ of its exterior counter and the metallic cylinder (Figure 1). Unfortunately, stresses $\sigma_{rr}\left(r_2,\varphi^{/}\right)$ are unknown, this is why there is formed symmetrical consideration of the problem and we seek the stresses σ_{rr} in the form [1, p.71]:

$$\sigma_{rr}\left(r_2,\varphi^{/}\right) = A + B\cos\varphi^{/} \tag{13}$$

where A and B are unknown constants.

Substituting expression (13) in representations (10), (11) and calculating the respective integrals, we obtain the following expressions for displacements $U_r(r,\varphi)$ and $U_\varphi(r,\varphi)$:

$$U_r(r,\varphi) = -r_2 \Big\{ 2AF_0^{(1)}\alpha + 2BF_0^{(1)}\sin\alpha +$$
$$\cos\varphi' \left[2A\left(F_1^{(2)}\sin\alpha - fF_1^{(2)}(1-\cos\alpha)\right) + B\left(F_1^{(1)}\left(1+\frac{\sin 2\alpha}{2}\right) - \alpha F_1^{(2)}\sin^2\alpha\right)\right]$$
$$+\sum_{n=1}^{\infty}\cos(n+1)\varphi\left[A\left(F_{n+1}^{(1)}\frac{\sin(n+1)\alpha}{n+1} - 2f\overline{F}_{n+1}^{(2)}\frac{1-\cos(n+1)\alpha}{n+1}\right)+\right.$$
$$\left.\left. B\left(F_{n+1}^{(1)}\left(\frac{\sin(n+2)\alpha}{n+2} - \frac{\sin\alpha}{n}\right) - 2f\overline{F}_{n+1}^{(2)}\left(\frac{1-\cos(n+2)\alpha}{n+2}\right) - \frac{1-\cos\alpha}{2}\right)\right]\right\} \tag{14}$$

$$U_\varphi(r,\varphi) = -r_2\Big\{\sin\varphi\Big[A\left(-2F_1^{(1)}\sin\alpha - fF_1^{(2)}(1-\cos\alpha)\right)+$$
$$B\left(-F_1^{(1)}\left(\alpha+\frac{\sin 2\alpha}{2}\right) - fF_1^{(2)}\sin^2\alpha\right)\Big] -$$
$$\sum_{n=1}^{\infty}\sin(n+1)\varphi\left[A\left(2F_{n+1}^{(1)}\frac{\sin(n+1)\alpha}{n+1} + 2F_{n+1}^{(2)}\frac{1-\cos(n+1)\alpha}{n+1}\right)+\right. \tag{15}$$
$$\left.\left. B\left(F_{n+1}^{(1)}\left(\frac{\sin(n+2)\alpha}{n+2} + \frac{\sin\alpha}{n}\right) + fF_{n+1}^{(2)}\left(\frac{1-\cos(n+2)\alpha}{n+2}\right) - \frac{1-\cos\alpha}{2}\right)\right]\right\}$$

Applying the condition of non-deformability of the metallic cylinder from geometrical consideration we can write the expression for displacements $U_r(r=r_2,\varphi)$ in the form [1, p.41]:

$$U_r(\varphi) = a\cos\varphi - \triangle_R \tag{16}$$

Passing the relation (14) to the limit $r \to r_2$ and omitting the terms, which have the inferior index n, after equality of the transformed relation (14) with relation (16), we obtain the equation:

$$-r_2\left\{(2A\alpha + 2B\sin\alpha)F_0^{(1)} + \cos\varphi\left[\begin{array}{c} 2A\left(F_1^{(1)}\sin\alpha - fF_1^{(2)}(1-\cos\alpha)\right)+ \\ B\left(F_1^{(1)}\left(1+\frac{\sin 2\alpha}{2}\right) - fF_1^{(2)}\sin^2\alpha\right)\end{array}\right]\right\} \tag{17}$$
$$= a\cos\varphi - \triangle_r$$

Eq. (17) is followed:

$$-2r_2(A\alpha + B\sin\alpha)F_0^{(1)} = -\triangle_r; \tag{18}$$

$$-r_2\left[2A\left(F_1^{(1)}\sin\alpha - fF_1^{(2)}(1-\cos\alpha) + B\left(F_1^{(1)}\left(1+\frac{\sin 2\alpha}{2}\right) - fF_1^{(2)}\sin^2\alpha\right)\right)\right] = a \tag{19}$$

If we solve the system of equations (18), (19) with respect to constants A and B, taking into account the equality:

$$U_r(\varphi=\pm\alpha) = 0 \Longrightarrow a\cos\alpha - \triangle_R = 0 \Longrightarrow a = \frac{\triangle_R}{\cos\alpha}, \tag{20}$$

one can obtain:

$$A = \triangle_R \frac{\frac{1}{2r_2F_0^{(1)}}\left[F_1^{(1)}\left(1+\frac{\sin 2\alpha}{2}\right) - fF_1^{(2)}\sin^2\alpha\right] + \frac{\sin\alpha}{r_2\cos\alpha}}{K} \tag{21}$$

$$B = -\triangle_R \frac{\frac{\alpha}{r_2\cos\alpha} + 2\left(F_1^{(1)}\sin\alpha - fF_1^{(2)}(1-\cos\alpha)\right)\frac{1}{2r_2F_0^{(1)}}}{K}; \tag{22}$$

$$K = 2F_1^{(1)}\alpha - \left(F_1^{(1)} + 2fF_1^{(2)}\right)\sin^2\alpha + \left(2F_1^{(1)}\alpha - F_1^{(2)}\right)\frac{\sin 2\alpha}{2} + fF_1^{(2)}\sin\alpha. \quad (23)$$

Based on those findings, we recommend the following sequence of calculation adjustments of the metalo-polymer game:

I. Knows diametrical game $\triangle_R$ and compressive strength of the polymer layer $[\sigma_{rr}]$. It is necessary to determine angle α and load capacity P of the polymer layer.

1. Determination of the angle α. From relation (13) we have that $\sigma_{rr(\max)} = [\sigma_{rr}]$, so

$$A + B = [\sigma_{rr}]\,, \quad (24)$$

Substituting (21) and (22) into (24) we obtain:

$$\begin{gathered}\frac{1}{2r_2F_0^{(1)}}\left[F_1^{(1)}\left(1+\frac{\sin 2\alpha}{2}\right) - fF_1^{(2)}\sin^2\alpha\right] - \frac{\alpha}{r_2\cos\alpha} + \\ 2\left(F_1^{(1)}\sin\alpha - fF_1^{(2)}\left(1-\cos\alpha\right)\right)\frac{1}{2r_2F_0^{(1)}} = \frac{K\left[\sigma_{rr}\right]}{\triangle_R}\end{gathered} \quad (25)$$

Solving equation (25) by using numerical methods we determine angle α.

2. Determination of the load capacity P. To determine load capacity we use the relation [1, p.40]:

$$P = -r_2 l\int_{-\alpha}^{\alpha}\sigma_{rr}\left(\varphi,\alpha\right)\cos\varphi d\varphi \quad (26)$$

Substituting relation (13) into (26) and taking the respective integral, we obtain:

$$\begin{gathered}P = -r_2l\left[A\cdot 2\sin\alpha + B\left(\alpha + \frac{2}{4}\sin 2\alpha\right)\right]; \\ P = -Er_2l\triangle_R\left[\overline{A}\cdot 2\sin\alpha + \overline{B}\left(\alpha+\frac{1}{2}\sin 2\alpha\right)\right];\ \overline{A} = \frac{A}{E};\ \overline{B} = \frac{B}{E}.\end{gathered} \quad (27)$$

So, if we adopt the notations

$$L = P/Er_2l\triangle_R; L_1 = -2\overline{A}\sin\alpha + \overline{B}\left(\alpha + \frac{1}{2}\sin 2\alpha\right), \quad (28)$$

then from equality $L = L_1$, we can determine load capacity P of the polymer layer.

II. Knows compressive strength $[\sigma_{rr}]$ and load bearing capacity of polymer layer P. It is necessary to determine angle α and a diametrical game $\triangle_R$. To achieve this aim we need to solve the following system of equations, obtained from Eqs. (24) and (27) by using expressions (21) and (22):

$$[\sigma_{rr}] = \frac{\triangle_R}{K}\left[\begin{array}{c}\frac{1}{2r_2F_0^{(1)}}\left(F_1^{(1)}\left(1+\frac{\sin 2\alpha}{2}\right) - fF_1^{(2)}\sin^2\alpha\right) + \frac{\sin\alpha}{r_2\cos\alpha} - \\ \left(\frac{\alpha}{r_2\cos\alpha} + 2\left(F_1^{(1)}\sin\alpha - fF_1^{(2)}\left(1-\cos\alpha\right)\frac{1}{2r_2F_0^{(1)}}\right)\right)\end{array}\right] \quad (29)$$

$$-P = \frac{\triangle_R}{K}Er_2l\left[\begin{array}{c}\frac{\sin\alpha}{r_2F_0^{(1)}E}\left(F_1^{(1)}\left(1+\frac{\sin 2\alpha}{2}\right) - fF_1^{(2)}\sin^2\alpha\right) + \frac{2\sin^2\alpha}{r_2\cos\alpha E} - \\ -\frac{\left(\alpha+\frac{1}{2}\sin 2\alpha\right)}{E}\left(\frac{\alpha}{r_2\cos\alpha} + 2\left(F_1^{(1)}\sin\alpha - fF_1^{(2)}\left(1-\cos\alpha\right)\frac{1}{2r_2F_0^{(1)}}\right)\right)\end{array}\right] \quad (30)$$

Solving numerically the system of equations mentioned above, we will determine angle α and game $\triangle_R$.

Conclusions

The methods applied in this article permit us to determine the maximal diametrical game - maximum $2\triangle_{R(max)}$ of the metalo-polymer systems, influenced practically by all the parameters, which depend on material properties of semi-couplings and on its conditions of exploitation.

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