Materials of Conferences

«CONCENTRATION WAVES» MODEL FOR THE TRIBOLOGIC SYSTEM CM1/LL,°/CM2

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Model of non-interacted «concentration waves». The «third body» of the complex tribologic system CM1/LL,°/CM2 is presented by wear products of the composition materials CM1 and CM2 and the liquid lubricant (LL). In this case the volume concentration of the solid components is may be presented by next relation:

$$\alpha = \langle\alpha\rangle - \Delta\alpha = \langle\alpha\rangle / (1 + \alpha_{LL}),$$

where $\langle\alpha\rangle$ is the average concentration of the solid components without taking into consideration the volume share of the LL and the change of α is the following $\Delta\alpha = \langle\alpha\rangle\, \alpha_{ll}/(1 + \alpha_{LL})$.

If the tribologic properties () of the compositional materials CMi (i = 1, 2) in CMi/°/CMi systems are may be calculated by next relations:

$$f_i^{o} = f_{lub,i}^{o} + (\alpha_i - \delta_i)\left(f_{sol,i}^{o} - f_{lub,i}^{o}\right);$$

$$I_i^{o} = I_{lub,i}^{o} + (\alpha_i - \delta_i)\left(I_{sol,i}^{o} - I_{lub,i}^{o}\right),$$

then the properties of these materials in system CM1/LL,°/CM2 are may be calculated by the following formulae:

$$f_i^{*} = f_i^{o} - \Delta f_i \cong f_i^{o} - (\Delta\delta_i - \Delta\alpha_i)\left(f_{sol,i}^{o} - f_{LL}^{o}\right) - (\delta_i + \alpha_i - 1)\left(f_{lub,i}^{o} - f_{LL}^{o}\right);$$

$$I_i^{*} = I_i^{o} - \Delta I_i \cong I_i^{o} - (\Delta\delta_i - \Delta\alpha_i)\left(I_{sol,i}^{o} - I_{LL}^{o}\right) - (d_i + \alpha_i - 1)\left(I_{lub,i}^{o} - I_{LL}^{o}\right),$$

where $\delta_i \cong 2\alpha_i^2(1 - \alpha_i)$ and $\Delta\delta_i \cong 2\alpha_i\Delta\alpha_i(3\alpha_i - 2)$ are the relative value of the synergic effect and the change of its for surface of the i-composition (i = 1, 2) by friction, and $\Delta\alpha_i \cong \alpha_i\alpha_{LL}/(1 + \alpha_{LL})$ is the change of the volume concentration for according solid component.

It's need to note, this additive model of non-interacted «concentration waves» are may be used for prediction of CM properties in any tribologic systems [1–4].

Model of interacted «concentration wave». The tribologic properties of the compositional materials CMi (i = 1, 2) in CMi/°/CMi systems are may be calculated by next relations:

$$f_i^{o} = f_{lub,i}^{o} + \left(\langle\alpha_i\rangle - \langle\delta_i\rangle\right)\left(f_{sol,i}^{o} - f_{lub,i}^{o}\right);$$

$$I_i^{o} = I_{lub,i}^{o} + \left(\langle\alpha_i\rangle - \langle\delta_i\rangle\right)\left(I_{sol,i}^{o} - I_{lub,i}^{o}\right),$$

where $\left(f_{sol,i}^{o}, I_{sol,i}^{o}\right)$ and $\left(f_{lub,i}^{o}, I_{lub,i}^{o}\right)$ are the sets of the properties values of the solid (with average concentration $\langle\alpha_i\rangle$) and lubricant CMi components according to «standard scale», the symbol ° is denotes the «third body» (TB) without liquid lubricant (LL), δ_i – are the relative synergic effect for each system [5]. The interacted «concentration waves» from each CMi are determine the composition of the TB. Then the additive model of the friction coefficient and the sum velocity of linear wear calculation may be presented by next formulae:

$$f = f_{lub} + (\alpha - \delta)(f_{sol} - f_{lub});$$

$$I_i = I_{lub,i} + (\alpha_i + \delta_i)(I_{sol,i} - I_{lub,i}),$$

where:

$$f_{lub} = (1 + \mu_{lub}\gamma_{lub} + \mu_{LL}\gamma_{LL})\, f_{lub,2}^{o} / (1 + \mu_{lub} + \mu_{LL});$$

$$f_{sol} = (1 + \mu_{sol}\gamma_{sol})\, f_{sol,2}^{o} / (1 + \mu_{sol});$$

$$\mu_{lub} = I_{lub,1}^{o} / I_{lub,2}^{o}; \quad \gamma_{lub} = f_{lub,1}^{o} / f_{lub,2}^{o};$$

$$\mu_{sol} = I_{sol,1}^{o} / I_{sol,2}^{o}; \quad \gamma_{sol} = f_{sol,1}^{o} / f_{sol,2}^{o};$$

$$\mu_{LL} = I_{LL}^{o} / I_{lub,2}^{o}; \quad \gamma_{LL} = f_{LL}^{o} / f_{lub,1}^{o};$$

$$I_{lub,i} = \left[1 - (1 - \gamma_{lub} - \gamma_{LL})\mu_{lub}^2 / (1 + \gamma_{lub} + \gamma_{LL})(1 + \mu_{lub})\right] I_{lub,i}^{o};$$

$$I_{sol,i}^{o} = \left[1 - (1 - \gamma_{sol})\mu_{sol}^2 / (1 + \gamma_{sol})(1 + \mu_{sol})\right] I_{sol,i}^{o},$$

the value

$$\alpha = \langle\alpha\rangle - \Delta\alpha = \left(\alpha_1 I_{sol,1} + \alpha_2 I_{sol,2}\right) / \left(I_{sol,1}^{o} + I_{sol,2}^{o}\right)(1 + \alpha_{LL})$$

– is the concentration of the solid components into TB volume.

The relative synergic effects are may be presented by following relations:

$\delta_i \cong 2\alpha_i \langle\alpha\rangle (1 + \alpha_{LL} - \langle\alpha\rangle)/(1 + \alpha_{LL})^3$ (for the velocity of linear wear) and

$\delta \cong 2\langle\alpha\rangle^2 (1 + \alpha_{LL} - \langle\alpha\rangle)/(1 + \alpha_{LL})^3$ (for the friction coefficient).

It's need to note, this additive model of interacted «concentration waves» are may be used for prediction of CM tribologic properties in some systems [5–7].

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Model of non-interacted «concentration waves». In simple case the tribologic system from two compositional materials (CM1 and CM2) may be presented by following scheme CM1/°/CM2, where the symbol ° is denotes the «third body» without liquid lubricant. The composition of «third body» is the rezult of the «concentration waves» addition from CM1 and CM2. Then the friction coefficient and the sum velocity of linear wear are the following:

$$f = \left(I_1/(I_1+I_2)\right)f_1^o + \left(I_2/(I_1+I_2)\right)f_2^o = \left(I_1 f_1^o + I_2 f_2^o\right)/\left(I_1+I_2\right);$$

$$I_1 + I_2 = I_1^o + I_2^o,$$

where $\left(f_1^o, I_1^o\right)$ and $\left(f_2^o, I_2^o\right)$ are the tribologic properties of the CM1 and CM2 in the CM1/°/CM1 and CM2/°/CM2 systems, accordingly. The CM1 tribologic properties are may be calculated by next formulae:

$$f = \left(I_1 f_1^o + I_2 f_2^o\right)/\left(I_1^o + I_2^o\right);$$

$$I_1 = \left(f_1^o - f\right)\left(I_1^o + I_2^o\right)/\left(f_1^o - f_2^o\right);$$

$$I_2 = \left(f - f_2^o\right)\left(I_1^o + I_2^o\right)/\left(f_1^o - f_2^o\right).$$

If the relative synergic effect for each CM is the next relation:

$$\delta_i = 4\alpha_i^2\left(1-\alpha_i\right)\left[1-k_i\left(1-k_{n,i}\right)\right] \cong 2\alpha_i^2\left(1-\alpha_i\right)$$

(by $\alpha = \alpha_i$ and $k_i \cong 0{,}5$; $k_{n,i} \cong 0$),

the common synergic effect may be determined by following form: $\langle\delta\rangle = 2\langle\alpha^2\rangle(1-\langle\alpha\rangle)$, where: $\langle\alpha\rangle = \left(\alpha_1 I_1 + \alpha_2 I_2\right)/\left(I_1^o + I_2^o\right)$ is the average concentration of the CM1ÇCM2 solid components into the «third body» volume. It's note, this additive model of non-interacted «concentration waves» are may be used for prediction of CM tribologic properties in some systems [1–5].

Model of interacted «concentration waves». The tribologic properties of the compositional materials (CM) CMi ($i = 1{,}2$) in CMi/°/CMi systems are may be calculated by next relations:

$$f_i^o = f_{lub,i}^o + (\alpha_i - \delta_i)\left(f_{sol,i}^o - f_{lub,i}^o\right)$$

$$I_i^o = I_{lub,i}^o + (\alpha_i - \delta_i)\left(I_{sol,i}^o - I_{lub,i}^o\right)$$

where $\left(f_{sol,i}^o, I_{sol,i}^o\right)$ and $\left(f_{lub,i}^o, I_{lub,i}^o\right)$ are the sets of average properties values of the solid (with concentration α_i) and lubricant CMi components according to «standard scale», the symbol ° is denotes the «third body» without liquid lubricant, δ_i – are the relative synergic effect for each system.

Let's assume that the interacted «concentration waves» from each CMi are determine the composition of the «third body». Then the additive model of the friction coefficient and the sum velocity of linear wear calculation may be presented by next formulae:

$$f = f_{lub} + (\langle\alpha\rangle - \langle\delta\rangle)(f_{sol} - f_{lub});$$

$$I_i = I_{lub,i} + (\langle\alpha\rangle + \langle\delta\rangle)(I_{sol,i} - I_{lub,i}),$$

where

$$f_{lub} = \left(1+\mu_{lub}\gamma_{lub}\right)f_{lub,2}^o/\left(1+\mu_{lub}\right) = \left(1+\mu_{lub}\gamma_{lub}\right)f_{lub,1}^o/\left(1+\mu_{lub}\right)\gamma_{lub};$$

$$f_{sol} = \left(1+\mu_{sol}\gamma_{sol}\right)f_{sol,2}^o/\left(1+\mu_{sol}\right) = \left(1+\mu_{sol}\gamma_{sol}\right)f_{sol,1}^o/\left(1+\mu_{sol}\right)\gamma_{sol};$$