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MECHANICS OF NANO-COMPOSITE MATERIAL

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Abstract. Nano- material has just been exploited and employed recently. However, its extraordinary and marvelous characteristic opened a new and significal prospect in new material field. There have been numerous mechanical problems that should be taken into consider and being solved. In this article, we want to introduce the concept of nano-crystal, our new results in researching on the material, and problems posing on this industry.

As we have known, the physical and chemical characteristics of each kind of material are depend on the three following factors:

- The basic component which created the material.
- Structure, dimensions, and the component arrangement.
- Manufacturing technology.

The least change in those three factors will create new material with alternative characters. For examples, we can have a new material with two times higher in skid modulus value when the composite 1D becomes composite 3D although theirs components are the same. In fact, this cannot be achieved by changing the technology. In recent years, the method of creating new material which was exploited and employed widely is changing structure, dimensions, and arrangement. Lately, super-composite, the composite of composite material (its components are also composite), and nano-material, the size and dimensions among its seeds are extremely small, in nano-metre. Because of their outstanding advantages, composite and nano-composite are the only material which can apply for the strict demanding in modern-technology. So that, scientist called the twenty first century as the century of high technology and new composite material, and nano-material. That the new material with wanted characteristics can be made by changes in shapes, arrangement, size, and components is the most significant advantage of composite material and nano-material. It explains the wide concern and overwhelming development in the new material mechanics industry, mechanics of composite material and nano-material. Mechanics not only help to modelize material - structure into mathematical problems to be solved and calculated the stress and reforming state inside the material, but also help us to have the key in optimal design and exploit limiting prediction of the material. It also helps us to get through the flaw and break-down inside the material and structure scientifically. From mechanical results, equations are declared and relative techniques are posed such as testing, estimating the material and structure quality. These results are also applied in manufacturing machine and equipment which are used in making and testing new material. Moreover, new material and structure models are being built and searched by mechanics, such that posing new demands to the designer and manufacturer. This explains the important participation of mechanics in modern technology. In this article,

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we introduce some latest result attained in the study of nano-composite with reinforced pip as "crystal-nano".

Crystal-nano is a kind of material with crystal dimension (seed, pip) which is smaller than 100 nanometers. Crystal-nano's physicchemistric characteristic is far greater in comparison to conventional material without nano-structure with the same chemistry component, such as 2-3 time in plastic limit, and 1,5-8 times in material strength.

Crystal-nano has highly anti-vibrating character because nano-pips have various elastic modulus and the emission of elastic vibration on edge-layer is diffused and not homogeneous. Copper with 200 nanometers nucleus is 2-3 times higher in antvibrating compare to cast iron - the most antvibration material have ever known until recent.

Crystal-nano's private-resistance is higher than conventional one because electrons are highly diffusing on it's pip's edge. Copper, nickel, and steel crystal-nano with 100-200 nanometers pips has their private-resistance (in 20^0C) increased 15%, 35%, and 55% respectively. When copper-nano is as small as 7 nanometers, it's private-resistance immediately increases thousands times. Crystal-nano and conventional material are significantly different in physical property such as thermal conductivity, magnetism, etc. For example nano-copper which nucleus is 8 nanometers wide has its thermal stretching coefficient twice as high as conventional copper, and not only has nano-zincodioxide numerous advantages but it also "bakes" at 1250^0C, while Zincodioxide-terracotta "bakes" at 1600^0C saves the energy in manufacturing.

Nano material with super-minuscule pip has opened significant prospect in various industries such as machine manufacturing, national defense, and others sector in the national economy.

In crystal-nano, the ratio of surface layer of pips will increase rapidly when their size vary from 100 nanometers to 4-5 nanometers. Here we suppose that these pip are spheres, and surface layer is 1 nanometer deep, correlative to 2-3 nucleus layers of most metals, and have the interrelation between diameter and ratio of surface layer as follow:

Pip diameter, nanometer	100	50	25	20	10	6	4
Ratio of surface layer, %	6	12	24	30	60	100	150

Thus, in crystal-nano, the volume of surface-layer is larger than the crystal volume when the pip's diameter is equal to or smaller than 6 nanometers.

Currently, crystal nano is made from 3 main approaches:

- Treat 100 nanometers pips and smaller by using powder craft.
- Crystallize the alloy of amorphous metal in specific conditions.
- Crystallize alloys of deformable metal by using heat treating.

Crystal-Nano's physic and chemistric properties are determined by the three following basic factors:

1/ Pips' size

2/ property and ratio of surface-layer

3/ Reciprocation of components to surface -layer

Generally, nano-material is chosen basing on its most distinguished advantages. For example, composite, with baked-clay as foundation and was mix by nano-iron, is used to eliminate electromagnetic rays in the television-long-wave zone. The synthesization of iron pip with diameters range from 30 nanometers to 1-2 micrometer in lubricant is used to prolong the lifetime and recuperate parts of machine which are under highly abrasive condition in the machine.

Thus crystal nano material is often exploited and employed as the component in manufacturing new composite material. (*Composite which is synthesized from at least two different materials, is a new material that has preeminent properties than its initial components*). Composite with nano-material as its component is called super-composite, or nano-composite.

The objective of nano-material mechanics is solve its basic problems as: 1. Build the material model to set up mechanical problems

2. Define relation between stress and deformation, and from that define technical constancies of the material

3. Calculate, and pick the optimum design for the material

4. Establish and solve thermal problems

5. Establish and solve the problems of long-term deformation

6. Solve the lubricated elastic problems

7. Solve the plastic deformation problems

8. Define solid standards, establish and solve the problems of ruining

9. Promote solution to treat and make good the defects in material

10. Establish calculating basis, testing; place and solve problems for nano-material structure.

In the initial study of nano-composite, we built a model that basic component is mixed with sphere nano pips, Fig1. In this we define the model and stress, micro-deformation relation with reciprocation is taken in consider.

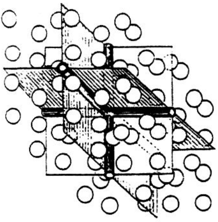

Fig 1. Model of nano- composite material 3D

Micro-stress in the material is define as:

$$\sigma_{ik} = \sigma_{ik}^{0} + \sigma_{ik}^{*} + \sigma_{ik}^{**} + \cdots , \qquad (1)$$

where, σ_{ik}^0 is homogenous stress, σ_{ik}^* is reciprocal stress among pips, σ_{ik}^{**} is stress among mostly adjacent pips, etc. In this article, we only consider the first two term in the equation 1.

Suppose that component material are elastic, homogeneous, and isotropic, then displace equation satisfy Lamer equation:

$$2(1-\nu)graddiv\vec{U} - (1-2\nu)rotrot\vec{U} = 0. \tag{2}$$

To examine micro stress problem, in the neighboring of the considering pip, we use local sphere coordinate that has its origin coincides with the pips' centers.

$$x_1 = r.\cos\theta, x_2 + ix_3 = r\sin\theta.e^{i\phi}, \tag{3}$$

boundary conditions of basic component are established as: $(r = a)$

$$\begin{aligned} &\sigma_r^+ = \sigma_r^-, \quad \sigma_{r\theta}^+ = \sigma_{r\theta}^-, \quad \sigma_{r\phi}^+ = \sigma_{r\phi}^-, \\ &U_r^+ = U_r^-, \quad U_\theta^+ = U_\theta^-, \quad U_\phi^+ = U_\phi^-. \end{aligned} \tag{4}$$

Elastic energy of nano-composite is defined by the following equation

$$\begin{aligned} U &= \frac{1}{2}\left(\hat{\sigma}_{11}\hat{\varepsilon}_{11} + \hat{\sigma}_{22}\hat{\varepsilon}_{22} + \hat{\sigma}_{33}\hat{\varepsilon}_{33} + \hat{\sigma}_{12}\hat{\varepsilon}_{12} + \hat{\sigma}_{13}\hat{\varepsilon}_{13} + \hat{\sigma}_{23}\hat{\varepsilon}_{23}\right) = \\ &= \frac{1}{2V}\oint_S \left(\sigma_r U_r + \sigma_{r\theta}U_\theta + \sigma_{r\phi}U_\phi\right) R_0^2 \sin\theta d\theta d\phi. \end{aligned} \tag{5}$$

Receive the equation to define the inter-material's micro-stress as:

$$\hat{\sigma}_{ik} = \frac{1}{2V}\oint_S (x_i\Omega_k + x_k\Omega_i) R_0^2 \sin\theta d\theta d\phi, \tag{6}$$

where:

$$\begin{aligned} \Omega_1 &= \sigma_r\cos\theta - \sigma_{r\theta}\sin\theta \\ \Omega_2 &= \sigma_r\sin\theta\sin\phi + \sigma_{r\theta}\cos\theta\cos\phi - \sigma_{r\phi}\sin\phi \\ \Omega_3 &= \sigma_r\sin\theta\sin\phi + \sigma_{r\theta}\cos\theta\sin\phi - \sigma_{r\phi}\cos\phi. \end{aligned}$$

In the compressing-stretching case, micro-stress satisfies the equation:

$$\sigma_{ij,j} = 0; \quad i = \overline{1,3}, j = \overline{1,3}. \tag{7}$$

Micro-stress of basic component is defined by:

$$\begin{aligned} \sigma_r &= R + 4G\frac{M}{r^3} + 2G\left(\frac{Q}{G} - \frac{20-4\nu}{r^3}N + \frac{12}{r^5}F\right)P_2(\theta) \\ \sigma_{r\theta} &= 2G\left(\frac{Q}{2G} + \frac{2(1+\nu)}{r^3}N - \frac{4F}{r^5}\right)\frac{dP_2(\theta)}{d\theta} \\ U_r &= \frac{R}{3K}r - \frac{M}{r^2} + \left(\frac{Q}{G}r + \frac{10-8\nu}{r^2}N - \frac{3F}{r^4}\right)P_2(\theta) \\ U_\theta &= \left(\frac{Qr}{2G} - \frac{2-4\nu}{r^2}N + \frac{F}{r^4}\right)\frac{dP_2(\theta)}{d\theta}. \end{aligned} \tag{8}$$

where:

$$P_2(\theta) = \frac{1}{2}(3\cos^2\theta - 1), \quad K = \frac{E}{3(1-2\nu)},$$
$$R = \frac{1}{3}(\sigma_{11}^0 + \sigma_{22}^0 + \sigma_{33}^0), \quad Q = \frac{1}{6}(2\sigma_{11}^0 - \sigma_{22}^0 - \sigma_{33}^0).$$

Responsive micro-stress in the nano-pip is of the form:

$$\sigma_{rc} = 2G\left\{-2(1+\nu_c)A_0 + \frac{2D_0}{r^3} + [-6\nu_c Ar^2 + 2B - 4(5-\nu_c)\frac{C}{r^3} + \frac{12D}{r^5}]P_2(\theta)\right\}$$
$$\sigma_{r\theta c} = 2G_c\left[(7-2\nu_c)Ar^2 + B + 2(1+\nu_c)\frac{C}{r^3} - \frac{4D}{r^5}\right]\frac{dP_2(\theta)}{d\theta} \qquad (9)$$

Received nano-material is elastic, homogeneous and isotropic material with 2 material constants. The ultimate result is below;

$$\hat{K} = K\frac{1+4\xi_c GL(3K)^{-1}}{1-\xi_c L}, \hat{G} = G\frac{1-\xi_c(7-5\nu)H}{1+\xi_c(8-10\nu)H}, \qquad (10)$$

where:

$$L = \frac{K_c - K}{K_c + 4G/3}, \quad H = -\frac{1-G/G_c}{8-10\nu+(7-5\nu)G/G_c}. \qquad (11)$$

Components with subscript index "c" are relevant to nano pips, and components without index are relevant to basic material. To illustrate, we took composite with basic polymer component and glass pip in consider. Modulus G received from equation (10) is a curve on figure 2.

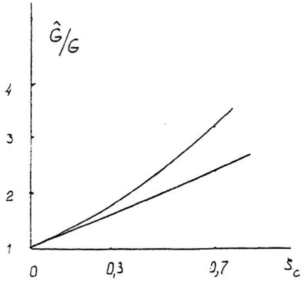

Fig. 2

Comparing the practiced results obtained to the calculating result for composite with padding pip and components stated in Esenpi equation we found that (fig. 2) when the portion of nano pip is small the two result is almost similar, but modulus G of nano-composite is higher than conventional composite when nano pips' proportion increases to 60%. Relative curve between elastic modulus and proportion of pips' volume is linear, and from our result with nano pip, considering reciprocal relation between basic component and pips, is parabolic curve.

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