CHEMICAL INTERACTION OF THE PARTICLES BEAM WITH THE TARGET MATERIAL[*]

E.S. PARFENOVA[1], *A.G. KNYAZEVA*[1,2]

[1]*Institute of Strength Physics and Materials Science of Siberian Branch of Russian Academy of Sciences, Tomsk, Russia*
[2]*Tomsk Polytechnic University, Tomsk, Russia*

The different methods of surface treatment of metals with charged particle beams are widely used in order to improve hardness, wear resistance and resistance to chemical attack. Various physical and chemical processes arise after the interaction of particles beam with the target. And these phenomena interact with each other and influence the final result. For example, heating, stress field formation, composition changes, defect generation and migration, formation of new compounds and phases and etc. Only theoretical research allows us to study each such process separately from the others. It is impossible to do it experimentally.

The purpose of this work consists in numerical investigation the co-propagation of elastic mechanical waves and implanted particles, taking into account their chemical interaction with the treated material. The mathematical model takes into account the finite relaxation times of the heat and mass fluxes. Also the thermal conductivity equation and balance equation for the introduced component take into account the heat source/loss due to the chemical reaction and the impurity loss due to the formation of the chemical compound, respectively.

The process of interaction of the charged particle beam with the target surface can be described within the framework of the thermoelastic diffusion theory, taking into account the nonlinear effects associated with the dependence of the diffusion coefficient and the chemical reaction rate on the composition and temperature. In addition, the model is modified for the different number of reactions occurring in the surface layer during processing. We assume that the deformations, velocities and accelerations are small. We consider the particle beam to be uniformly distributed along the treated surface, so we can limit the study by a one-dimensional problem. The case of uniaxial loading under the experimental conditions is realized. The detailed derivation of the equations can be found in [1, 2].

The example of the problem solution for different time moments is shown in Figure 1. The target material is Ni, the introduced material is Al. Time of action of a single sinusoidal pulse is 0.05. Figure 1 shows the distributions for times comparable to the pulse action time.

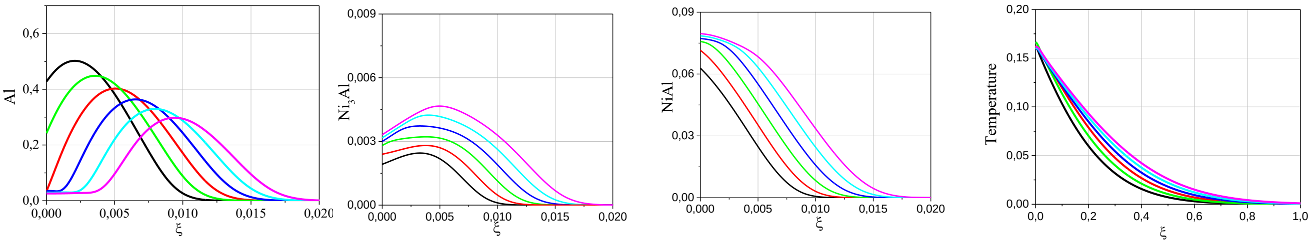

Fig.1. The results of solving a coupled problem: distribution of introduced material concentration (Al), mass content of the first reaction product (Ni_3Al), mass content of the second reaction product (NiAl) and temperature. Time moments are: 1 – 0.04; 2 – 0.045; 3 – 0.05; 4 – 0.055; 5 – 0.06; 6 – 0.65.

It can be seen that diffusion waves propagate much slower than heat wave. The rate of the chemical reaction increases obviously due to an increase in temperature and concentration of the introduced material. Chemical reactions also occur at times longer than the pulse time. As the temperature and implanted material concentration allow its. Because reactions with heat release are considered, then after the pulse stops, the temperature at the left boundary does not decrease and increases for a time.

REFERENCES

[1] A.G. Knyazeva, E.S. Parfenova, “Nonlinear coupled model of surface treatment by a particle beam taking into account the formation of a new phase”, J. Appl. Mech. Tech. Phys., vol. 62, no. 4, pp. 633–641, 2021. DOI: 10.1134/S002189442104012X.

[2] E.S. Parfenova, A.G. Knyazeva, “The influence of chemical reaction parameters on the interaction of thermal, diffusion and mechanical waves under surface treatment by a particle beam”, Comp. Continuum Mech., vol. 14, no. 1, pp. 77-90, 2021. DOI:10.7242/1999-6691/2021.14.1.7.

---

[*] The work was supported by the Russian Foundation for Basic Research and the Rosatom state corporation (Grant No. 20-21-00064 Rosatom).