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Escape of Abrikosov vortices in current-loaded nanostructured superconductors with extended 1D columnar defects

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Extended one-dimensional (1D) columnar defects in high-T_c superconductors (HTS), are known to be strong pinning sites for Abrikosov vortices, preventing their motion and related energy dissipation [1,2]. In the present work some theoretical aspects of single vortex depinning and its subsequent dynamics under the Lorentz force action in HTS materials with extended *c*-oriented linear defects loaded with transport current in the presence of external magnetic field inclined to the specimen surface are explored. We consider Abrikosov vortices as an elastic vortex strings in the pinning potential well of linear defects exerted to the Lorentz force action. The latter is caused by the transport current flow as well as the shielding current, induced by the tangent component H_t of applied magnetic field. These currents are considered as a surface Meissner currents with densities: $j_{tr}(z) = j_{tr,0}\, cosh(z/\lambda)$ and $j_H(z) = j_{H,0}\, sinh(z/\lambda)$ respectively, inhomogeneously distributed over the superconductor plate thickness d ($d > \lambda$; λ- is the London penetration depth).The explored model is based on the classical mechanics description for behavior of an elastic vortex string which is settled in the potential well of linear defect $U_p(s)$ ($s = s(z)$ - is the vortex line displacement from the defect axis) and exerted to the Lorentz force $F_L(z) = \phi_0\, j(z)$, where $j(z)= j_{tr}(z)+ j_H(z)$ ($\phi_0 = hc/2e$ - is the flux quanta). $F_L(z)$ is maximal near one of the film surfaces at $z = \pm d/2$. Solution of the stability problem gives conditions for the onset of vortex escape from linear defect, which approximately can be written as: $\phi_0 j(z = \pm d/2) = j_{c0} \cong \max\, (dU_p/ds)$, and thus determines the depinning critical current, its thickness and magnetic field orientation dependencies at low magnetic field and temperature values, which are of great interest for applied superconductivity [1,2].

1.Maiorov B., Baily S. A., Zhou H., Ugurlu O., Kennison J. A., Dowden P. C., Holesinger T. G., Foltyn S. R., Civale L. Synergetic combination of different types of defect to optimize pinning landscape using $BaZrO_3$-doped $YBa_2Cu_3O_7$ // Nature Mater.- 2009.- **8**.- P. 398– 404.
2.*Gurevich A. Challenges and Opportunities for Applications of Unconventional Superconductors //*Annu. Rev. Condens. Matter Phys. – 2014. - **5**. – P. 35-56.