Critical current in thin flat superconductors with Bean-Livingston and geometrical barriers

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Dependence of the critical current I_c on the applied magnetic field H_a is theoretically studied for a thin superconducting strip of a rectangular cross section, taking an interplay between the Bean-Livingston and the geometric barriers in the sample into account. It is assumed that bulk vortex pinning is negligible, and the London penetration depth λ is essentially less than the thickness d of the strip. As is known, the Bean-Livingston barrier results from the attraction of vortices to the sample surface at distances of the order of λ, while the geometrical barrier is due to the shape of superconductors, and it develops on the scale of the order of d. In the familiar approach to the calculation of $I_c(H_a)$ [1], the sample is considered as an infinitely thin strip, and the barriers are modelled by the condition that the Lorentz force at the distance ~ d from the edge of the strip should reach a certain critical value for vortices to penetrate into the sample. However, to investigate the effect of these barriers on I_c more rigorously, one cannot neglect the thickness of the strip. In the present work a two-dimensional distribution of the current over the cross section of the sample is found under the assumption that a vortex dome exists in the strip. In obtaining this result the approach of [2] is exploited which is based on the methods of conformal mappings. With this distribution the dependence $I_c(H_a)$ is calculated. This dependence is determined by the ratio $p \equiv (\lambda/d)^{1/3}\kappa/\ln(\kappa)$, where κ is the Ginsburg-Landau parameter. If p exceeds a critical value, the critical current is mainly determined by the Bean-Livingston barrier, otherwise the geometrical barrier prevails at low H_a. In the latter case a crossover between the two types of the dependences $I_c(H_a)$ occurs with increasing magnetic field.

References

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