In this paper a theory of the coercive force of ferromagnetic materials, caused by the motion of domain walls, is developed. The equilibrium positions of the wall are studied by taking stray field free curvatures into account. The interaction potentials of the obstacles with a wall are assumed to be additive and to have a range of force which is short compared to the mean distance between obstacles. For calculation of the coercive force, a random distribution of obstacles is assumed. A new treatment is proposed for the statistical method of Néel, called the polygon method. It is shown that the curvatures of the walls are very important and that the displacement resulting from this curvature is mostly not small compared to the distances of obstacles.

1. Introduction

The coercive force is one of the most important parameters of ferromagnetic materials and, therefore, there are a great many papers on this problem. The books by Bozorth [1] and KneUer [2] and the paper by Brenner [3] give a
full bibliography on this subject, and we do not need any discussion in this paper about the earlier works.

In this paper we consider the case in which the coercive force is caused by the motion of domain walls. The motion of a wall under the pressure of an external magnetic field is restrained on the one hand by lattice defects or precipitations and on the other hand by the connectivity of the whole domain wall structure requiring an increase in the wall area. However, if we do not consider extremely soft magnetic materials we can neglect the second influence.

This motion of the wall goes on partially reversibly and partially by more or less large jumps. Then, the coercive force is that field at which these jumps have the order of magnitude of the domain diameter.

In order to calculate the coercive force we must first know the interaction energy between the wall and a single defect or precipitation. In the present paper we do not consider this interaction more closely, but we only assume some general properties about it: The interaction potentials are additive, and the range of forces caused by this interaction is small in comparison with the average distance between the defects.

The next point is the assumption about the distribution of the defects. We consider in this paper a completely random distribution of defects, and, moreover, we assume that we have a great number of such defects in each domain.

Now, the first problem is the calculation of the equilibrium condition of one wall at given external field and given distribution of the defects. In this we shall pay attention to the cylindrical curvature of the wall which is possible without the creation of any magnetic field. The curvatures with creation of magnetic field are very small because of the high field energy, and therefore we can neglect them. This was pointed out more exactly by Néel [4] in his paper about a general theory of coercive force.

In the theory of magnetism [2] one defines the coercive force in the following way: For a given distribution of defects one looks for the greatest external field at which the wall will remain in its equilibrium position. Then the average of this field, taking all possible distribution of defects, is identified with the coercive force. However, it seems impossible to perform this method mathematically. Instead of this one uses generally the “polygon method” which was developed by Néel [4, 5]; we shall discuss it in detail in a later part of this paper. Brenner [3] criticized this method and we shall try to process the problem in another way, of course without finding an exact solution.

This program for calculation of the coercive force is similar in many points to that by Néel [4] but the procedure is quite different from it.

2. Energy and equilibrium of the wall

We consider a wall which separates two domains with the magnetizations $J_1$ and $J_2$; the magnitude of these magnetizations is equal to the saturation magnetization $J_s$. To avoid creation of a magnetic field, the normal of the wall surface must be perpendicular to the vector $J_1 - J_s$ (Fig. 1), and we take the $x$-axis parallel to this vector. We describe the whole region which the motion of the wall can cover as a box with the edge lengths $L_x$, $L_y$, $L_z$, and the $z$-axis is the mean direction of motion of the wall.