



# LX. Considerations on permanent magnetism

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LX. *Considerations on Permanent Magnetism.**By* M. F. OSMOND\*.

IRON possesses at least two molecular states,  $\alpha$  and  $\beta$ .  $\alpha$  is soft iron, that is iron which has been annealed and cooled slowly. It changes into  $\beta$  during heating, at a certain critical temperature, and in part preserves this state during cooling, the more so the quicker the cooling and the larger the proportion of carbon, manganese, and tungsten that it contains. Some  $\beta$  iron is also produced during cold hammering. Iron deposited electrically is also of the  $\beta$  variety.

A bar of steel, allowance being made for the carburets and other compounds simply in mixture, can then be looked upon as an intimate mixture of  $\alpha$  iron and  $\beta$  iron in relative proportions, which can change from point to point but are determinate at any point. That being so, let us consider  $\beta$  as forming in a steel bar a porous framework, not changing under the influence of currents and of magnets. On the other hand, let us look upon  $\alpha$  as composed of particles polarizable under such influences. (The actual mobility of such particles, admitted by Hughes, appears from the sounds and changes of volume which take place during magnetization.) The particles  $\alpha$  so polarized will form so many small elementary magnets, which the magnetizing force has displaced from their former normal position of equilibrium, and which tend to take up this position again so soon as the external force ceases to act.

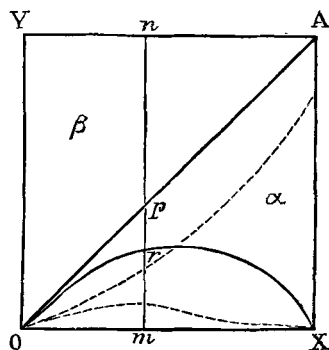
But in presence of the rigid network of iron  $\beta$  these polarized particles  $\alpha$  are conceived as catching in the pores of the  $\beta$  structure, and immovable in this position, thus resulting in a permanent magnet. The temporary magnetism and the permanent magnetism determined by the action of a certain magnetizing force at a point of a bar will be therefore a function of the relation  $\frac{\alpha}{\beta}$  at this point.

As an attempt to represent these ideas graphically, let there be a square, O A X Y, of which the side represents 100 parts. Every line  $m n$  parallel to the axis of Y meeting in  $p$  the diagonal O A represents a steel containing  $\frac{mp}{100}$  of iron  $\alpha$ ,  $\frac{np}{100}$  of iron  $\beta$ .

At saturation the temporary magnetism, or rather the sum

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of the polarized particles, will be exactly equal to the whole of the iron  $\alpha$ , *i. e.* to  $mp$ .  $\alpha$  varying from 0 to  $\frac{100}{100}$ , the temporary magnetism will be represented by the diagonal O A.



As to the permanent magnetism, in regarding it as the relative number of particles of  $\alpha$  which remain polarized after the cessation of the magnetizing force, it will be a fraction of  $mp$ , all the greater as  $\frac{\alpha}{\beta}$  is smaller for the steel under consideration. In other words, the polarized particles  $\alpha$  will be more immovable the closer the network  $\beta$ .

Under the supposition that the quantity  $mr$  of the particles  $\alpha$  which remain polarized after the interruption of the magnetizing force (that is to say, the permanent magnetism as defined) is proportional to the percentage of iron  $\beta$ ,  $\frac{np}{100}$ , we can write

$$mr = mp \times K \frac{np}{100},$$

$K$  being a numerical coefficient equal to or less than unity.

Since

$$mp = mO = x,$$

$$np = 100 - mp = 100 - mO,$$

$$= 100 - x,$$

$$y = x \times K \frac{100 - x}{100},$$

$$= K \left\{ x - \frac{x^2}{100} \right\}.$$

Accordingly the permanent magnetism is represented by a portion of a parabola whose axis is parallel to that of Y. It

vanishes for  $\alpha=0$ ,  $\beta=0$  (as could be foreseen from the properties of the irons  $\alpha$  and  $\beta$ , which have served as the grounds of the argument), and is a maximum for  $\alpha=\beta$ .

The number of the particles capable of remaining polarized after the interruption of the magnetizing force will at most form a quarter of the whole mass of the iron.

If the magnetizing force be too feeble to produce saturation, the lines  $OA$ ,  $Ox$  will take up a position indicated approximately by the dotted lines.

These considerations agree fairly well with many observed facts.

Thus all causes which tend to open, even temporarily or only in certain directions, the network of the iron  $\beta$  (expansion, shocks, vibrations) set at liberty some of the polarized particles of  $\alpha$ , and diminish the permanent magnetism.

The greater the proportion of  $\beta$  iron the more difficult becomes the polarization of  $\alpha$ , in the diminished pores, and the greater must the magnetizing force be to produce saturation.

When the proportion of carbon or of manganese is so great that the whole of the iron on quenching or even without this takes up the state  $\beta$ , a substance will result which is incapable of taking up magnetism; for example Spiegel-iron containing 25 per cent. of manganese and upwards, and Hadfield's steel. Since hardening takes place more energetically at the surface than in the interior of a bar, the relation  $\frac{\alpha}{\beta}$  will always be smaller there. The permanent magnetism remaining after saturation will therefore be stronger at the surface if  $\alpha > \beta$ , which is the common case. It would be more feeble if  $\beta > \alpha$ .

Magnets formed of laminæ are in general more powerful than those of the same volume in a single piece, because the laminæ are more hardened. But the contrary should be the case with metals in too hard a condition.

It is difficult after a bar has been magnetized to saturation in one direction to bring it to a moment of the same value in an opposite direction, because certain particles of the  $\alpha$  metal being held immovably cannot be displaced, &c.

The iron  $\beta$  can also be looked upon as a medium whose viscosity increases as its percentage in the mixture is greater.

We can compare these ideas with the experiment of Hughes, who has obtained permanent magnets by mixing iron filings and wax and melting the latter, which in setting held fixed the polarized portions of iron.