

Magnetic Materials: Other Materials

There are various other types of magnetic phenomena and materials that are exploited commercially. This section will look at magnetostrictive and magnetoresistive materials.

Magnetostriction:

Most magnetic materials exhibit magnetostriction, which is a change in physical dimension as a result of magnetic ordering. There are two types of magnetostriction: spontaneous magnetostriction which arises from the magnetic ordering of atomic moments below the Curie temperature (usually causing a volume expansion) and field induced magnetostriction which arises from the alignment of magnetic domains on application of an applied field.

Spontaneous magnetostriction is exploited in the NiFe based alloy known as invar, which is noted for the fact that it shows zero thermal expansion up to its Curie temperature. As mentioned previously, the saturation magnetisation of a material decreases on heating towards the Curie temperature due to a decrease in the degree of alignment of the atomic magnetic moments.

As this alignment and the saturation magnetisation decreases then so does the volume expansion caused by the spontaneous magnetostriction and hence the material contracts. In the case of invar this contraction due to loss of spontaneous magnetostriction is equal to the expansion caused by normal thermal vibration processes, and hence the material shows no change in dimensions. However, above the Curie temperature there is no longer any magnetic ordering and thermal expansion occurs normally.

Field induced magnetostriction occurs when magnetic domains align and the dimension change caused by the ordering of the atomic magnetic moments all combine to give a dimensional change to the block of material.

The material that shows the largest useful magnetostriction is Terfenol, which is an alloy of Tb, Dy and Fe. Terfenol is used for position and field sensors, as well as mechanical actuators and speakers. Magnetostrictive position / load sensors work by the fact that when a magnetostrictive material experiences a strain then the magnetisation of the material will change.

Terfenol actuators usually have a rod of Terfenol which is placed under compression in order to align the magnetic domains perpendicular to the length of the rod. A coil around the rod can then apply a field to the rod that will align the domains along its length.

The schematic in figure 17 shows an actuator that has a permanent magnet to bias the Terfenol rod so that currents flowing in the coil in different directions will make the actuator decrease or increase in length. If the magnetic bias was not present then a current in either direction would cause the actuator to expand and if the actuator was being used as a loud speaker then the frequency of voltage applied to the coil would be doubled by the speaker.

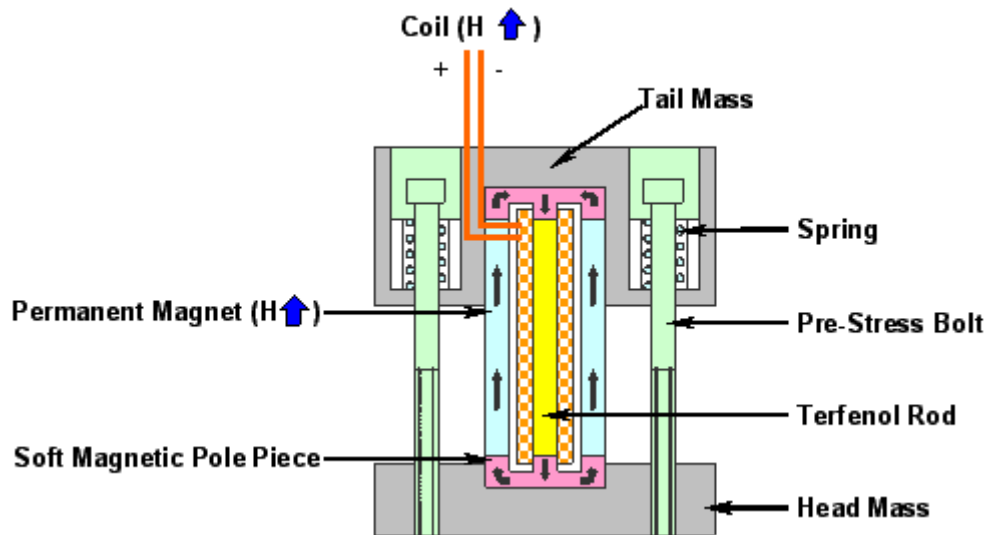


Figure 17: Schematic of a Terfenol actuator

Magnetostriction:

Magnetostriction (MR) is the effect by which the electrical resistance of a magnetic material changes depending on the relative direction of the current and the magnetisation. In most cases the electrical resistance is highest when the current and magnetisation are parallel and lowest when they are perpendicular.

The level of magnetostriction shown by a material is usually expressed in terms of the percentage change in resistance from the highest to the lowest resistance and is usually of the order of a few percent. The main application for MR sensors is in the read heads of hard disk drives.

A similar effect has been observed in magnetic multilayers, e.g. Fe/Cr, where the alternate ferromagnetic layers couple anti-parallel to each other. Under the influence a magnetic field the relative orientation of the magnetisation of the layers changes and the electrical resistance decreases to a minimum when the magnetisation directions of the layers are parallel. This effect gives rise to resistance changes of 50-80%, and the effect has been termed giant magnetostriction (GMR).