On the Static Work

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Abstract

The shortcomings of the notation of work in physics are discussed and introduction of the concept of static work is suggested. The phenomenon of permanent magnets is discussed. Connection between these two phenomena is proposed.

Introduction

There is one notation in physics that puzzles many people but remains unsolved due to many years of neglect of existent discrepancy. This is notation of work as dot product of force vector and displacement direction vector(1).

This notation is quite satisfactory in many instances of life except when human beings or other animals fulfill work of carrying a load on their shoulders or in arms. This case describes a work done when there is an angle between force and direction of displacement. This becomes even more striking when the angle is close or equal to 90^o. So the force is applied and displacement exists but no work is done. It means that there should not be any energy consumption, but why people feel tired if they don't do any work? More striking example: a person lifts a heavy stone in his arms and holds it for a long time. According to the basic physics principles he does not fulfill any work as far as there is no a displacement of the load except the initial heave. But why people prefer using carts to move a heavy load?

This problem becomes more subtle when a heavy load is set on a table, or a shelf, or other supporting setup. There is force applied to a shelf that is equal to mass times gravity acceleration ($F = mg$), but the shelf does not fulfill any work. More puzzling example, when a magnet is attached to a refrigerator door. Magnetic field holds a heavy magnet suspended in the air but does not fulfill any work. Even more interesting is the levitation of one magnet over another, with symmetrical magnetic fields of opposing directions.

It seems obvious: solid objects do not do any work; they can only transmit it on in case of engines. But this explanation is not satisfactory. Both, a heavy load, lying on the shelf, and the magnet hanging on the refrigerator door or levitating over another magnet, have a potential energy that can be easily converted into mechanical work, if they are released and allowed to fall, but there are forces that hang them and they also do the work.

It's the time to raise the question of the limits of applicability of the accepted definition of work. We often forget that there is no such thing as a closed thermodynamic system in nature. Trying to simplify the calculations, we usually consider idealized systems. This tradition began nearly two centuries ago, when a notation of work was introduced by French mathematician Gaspard Coriolis. Macro-systems have been isolated from the microstructure and since then, we believe that if the force acts on a solid and does not cause any displacement of the macro-system, no work is done. But this is not the case, since the internal structure of the system experiences external influence and reacts. Although thermodynamics was developed nearly two centuries ago, and is well developed at present, in practical applications macro-and microstructure of the system go side by side in our minds without interaction.

In reality, whenever an external force acts on a rigid body, the system meets the change in the internal energy. This means that each exchange of interaction between two systems does work.

Qualitative description of this change in the case of rigid objects influencing one another is beyond the scope of this publication, since it's a separate task to calculate change of trajectories of all particles in the bodies. However, this separation of macro-systems and their internal structure can be reduced by introducing the definition of "static work", giving a better description of the interaction of matter at the micro-level. The work done by a conservative force can be described as the sum of static and dynamic work in its current definition: $W = W_s + W_d$, and in many cases of life we should pay attention to the question of the value of the static work.

It seems that objects made of solid materials can perform static work indefinitely without any external source of energy, which makes these objects a "Perpetuum mobile" for static operation. But these solid materials are not "Perpetuum mobile" It is well known that the solid materials used in machinery, cannot last forever. Their life is limited. This phenomenon is called material fatigue. Microscopic cracks begin to form on the loaded surface over time. What does this mean? Intermolecular bonds between particles experiencing a load can be broken in the long run. Obviously, there is no "Perpetuum mobile" even for static work.

Why bother puzzling over such strange questions? This seems redundant, since centuries of technological development have shown that the current designation of the work is quite satisfactory. The first thing to say that people have always understood that they use the energy of their body, when holding a load, but physics does not describe this, and, moreover, does not pay attention, convincing people that they are not doing any work. However, it is clear that there is no static balance in this case. Constrained muscle requires an influx of new energy sources, and the body responds with increased blood flow. But why not bother, for example, which pose make it easier to keep a load suspended, and how much work is done by the muscles, and what part is taken by the bone skeleton. Is this really unimportant? Indian culture uses static exercises very widely to keep body in a good shape and maintain health, but Western culture denies static work.

Roughly the static work done by the muscles can be estimated by the formula $W_s = |\mathbf{F}|d_x$ that represents the product of the modulus of the force and the projection of the distance from the center of mass of the load till the center of mass of the skeleton in equipoise on a plane perpendicular to the force vector. This notation coincides with the modulus of torque, having units of work.

Phenomenon of permanent magnets

This notation can be applied to a permanent magnet suspended on a vertical wall made of a ferrous metal. Since we assume that the wall is vertical the static work fulfilled by the magnet can be calculated by the formula: $W_s = m*g_o*d_x$; where: m – the mass of the magnet; g_o – standard gravity; d_x – distance between the wall and the center mass of the magnet.

What does cause this work to be done? Magnetic materials (Ferro magnets) have domain structure, as was proposed by Pierre-Ernest Weiss in 1906. The strongest magnets, known up to now is alloy of sintered $Nd_2Fe_{14}B$, which can have the density of magnetic energy (BH_{max}) up to 440 kJ/m^3 (see table 1.)[(2)]

Magnet	M_r (T)	H_{ci} (kA/m)	BH_{max} (kJ/m^3)	T_C (°C)
$Nd_2Fe_{14}B$ (sintered)	1.0–1.4	750–2000	200–440	310–400

Table.1

There should be some interaction between domains and as a result internal energy of the structure can be changed. As it was described for solid materials, magnets also may feel fatigue after some (rather long) time of interaction and turning internal energy into static work. What happens there?

Energy equation for domains of magnetic material is described by Landau-Lifshitz energy, E, which is the sum of energy terms:[3]

$$E = E_{ex} + E_D + E_\lambda + E_k + E_H$$

Where: E_{ex} is energy exchange; E_D is magnetostatic energy; E_λ is magnetoelastic anisotropy energy; E_k is magnetocrystalline anisotropy energy; E_H is Zeeman energy.

In this equation, magnetostatic energy and Zeeman energy are related to the interaction between the magnetic material and an externally applied magnetic field. Interaction of magnetic fields also causes such affects as magnetostriction that influences magnetoelastic anisotropy energy. Crystal structure of material resists turning of magnetic dipoles under influence of external magnetic fields – the process known as coercivity. It means that processes in ferromagnetic materials may be energized from inner structure of the material that contributes to long acting of magnetic "Perpetuum mobile" which certainly cannot be perpetual, due to material fatigue.

Conclusion

Both, static work effect in case of physical work by people, and permanent magnets effect deserve more precise attention since physics is a strict science and requires that all small effects are counted for. Discrepancy in notation of work in basic physics can be solved by introducing notation of static work. And there is a remarkable room for experimental studies and many interesting experimental setups revealing the processes. Attracting attention to these problems is the major objective of the publication.

References:

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