Re: Hydraulic Presses and Force

Source: http://sci.tech−archive.net/Archive/sci.physics/2006−06/msg02752.html

- *From*: "Dennis B" <Utopian@xxxxxxxx>
- *Date*: 30 Jun 2006 04:36:58 −0700

PD wrote:

> Dennis B wrote:
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>> A hydraulic press is supposedly capable of amplifying force. For example, 1 dyne of input force can supposedly be converted into 10 dynes or even 100 dynes of output force. In a hydraulic press the supposed increase of force is offset by a decrease in the distance the output piston travels. The output is dependent upon the (exposed) surface area of the piston (and input force). As the volume or capacity of the output piston chamber increases (and the exposed surface area of the piston as well), the distance which the output piston travels will decrease in response to the input force (presuming the input remains constant). Force is determined by measuring the displacement of a mass (as well as the time involved for the displacement to occur). Since the distance a piston travels is dependent upon the volume or capacity of the piston chamber (as well as input force), the distance travelled by two different (output) pistons as a result of a given input force (1 dyne for example) will not be the same if the volume or capacity of the output piston chambers are different (for example if the exposed piston surface area of one is 10 cm^2 and 100 cm^2 in the other). Yet, the total volume of fluid displaced (1 cm^3) is the same for both pistons. In other words, the amount of mass (i.e., the water) displaced in response to a given input force (1 dyne in this example) is the same. Thus, wouldn't the output force of both pistons be the same, considering that force is measured by the displacement (or acceleration) of a mass (such as the water inside the piston in this case)? Undeniably, the total energy remains the same (ignoring losses due to friction, etc.), although the energy density must decrease at the output for the same reason that the total energy density of a fluid accelerating through a tube of varying diameter changes, while the total energy remains the same (ignoring losses). The definition of force is that which causes acceleration of a body. Force would therefore appear to be synonymous with the definition of "energy". So, how is it that the input force increases while the input energy density decreases in the case of a hydraulic press? One may be inclined to argue that the energy density does not decrease as the volume/capacity

> of the output piston chamber (or circumference of the tubing) increases. Yet, the energy density does in fact decrease as the volume (capacity) of the piston chamber or circumference of the tubing decreases, for the energy must expand to occupy a larger volume of space. Thus, I would expect that the force would decrease as well, just as the ram pressure (and velocity) of an accelerating fluid decreases as the circumference of the tube in which it flows increases. To use an example, I would expect that a force of 1 dyne applied to a piston with an exposed surface area of 1 cm^2 would be converted into a force of .1 dyne cm^2 in an output piston with an exposed surface area of 10 cm^2.
>
> −Dennis B

You're a little confused. The *work* is the same, but the force is amplified.
This is much the same way that a pulley system amplifies force, though conserving work.
In a pulley system, like the gears on your bike or a block & tackle or the chain linkage that helps you raise a heavy door, lower force applied comes at the expense of requiring larger displacement. For example, you can raise a piano with a block and tackle by exerting only 1/5 the weight of the piano, but you have to pull 5 ft of rope through the pulley for every foot you want to raise the piano. You can lower the force by a factor of 3 by changing gears on your bike, but you have to crank three times as fast in the lower gear. In both cases, the work (force x displacement) is the same at the engine and at the load (ignoring friction), though the force may be changed quite a bit.

The same thing is true in a hydraulic system. At the engine, the force applied might be low (F1 = P * A1), but you'll have to push a long column of fluid (d1), compared to the large force applied at the load (F2 = P * A2), where a much shorter column of fluid comes out (d2). Note that the work done is identical at both engine and at load (P * A1 * d1 = P * A2 * d2). In this case, the volume of the fluid pushed is the same at the engine and at the load (A1 * d1 = A2 * d2).

PD

Force is defined as mass times acceleration. In other words, force is essentially a measure of the total energy it takes to move a certain mass a certain distance within a certain amount of time. Work is defined as force times distance and is essentially the same as force minus the measure of time. In other words, it is a measure of the total energy required to displace the mass a certain distance without regard to the time involved.

If the input piston (having an exposed surface area of 1 cm^2) travels 1 cm as a result of 1 dyne of force, and the output piston (having an exposed surface area of 10 cm^2) travels only .1 cm, then the force involved to displace 1 cm^3 of fluid (or water) is the same for both the input and the output because the same volume of fluid is displaced at either piston. If one takes into consideration the mass of the pistons, this also partially explains why the output piston traverses less distance than the input piston. It would take 10 times the input energy (or 10 dynes) to displace the output piston by 1 cm, using the body of water in between as a mediator of the applied force. An input force of 1 dyne can only displace the more massive output piston a distance of .1 cm. In other words, to reverse the situation, if 1 dyne of force were applied to the larger "output" piston, it would move it the same distance of .1 cm, and also displace the smaller "input" piston by 1 cm. Thus, the input and output force must be the same. Because work is a measure of force or energy, determined by the displacement of a mass without regard for the time involved, the work applied to the input piston must be the same as the work of the output piston.

A weight scale measures weight by the distance the scale plate traverses as a result of the gravitational force (or acceleration) between the earth and the mass being weighed (presuming the measurement is performed on Earth) according to the following equation:

$F = ma = mg = w$

Key:

F = force

m = mass

a = acceleration

g = gravitional acceleration

w = weight

....The greater the mass being measured, the greater the gravitational force between the mass and the Earth and therefore the greater the distance the scale's plate will traverse. Although weight is a measure of force, and force is defined as essentially an accelerating mass (or energy since energy and mass are equivalent, mass being made of energy)...the fact is that a scale measures the force of weight without measuring the acceleration or time involved to displace the mass. Rather, a weight scale measures only the WORK involved in displacing the scale plate. Yet, it does indeed measure the (total) force (or energy) which displaces the scale plate. Thus, implying the following equation:

$F = ma = mg = w = W$

Key:

W = work

Yet, if one uses a scale to measure the force at the output of a hydraulic press, the scale will actually measure less force or work as the volume of the output piston chamber increases, because the piston will traverse increasingly less distance as the volume of the output piston chamber expands.

Dennis B

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