For the mathematically minded

Kinetic Energy

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8.7.2.1.1.2 "The kinetic energy of the car door and the mechanical elements which are ridgidly connected to it, calculated or measured at the average closing speed shall not exceed 10j.

You almost need to be a mathematician to find this clause with its five levels of indenting! What does it mean?

We have all tried to measure the kinetic energy of doors using spring balances, often with mixed success. Would it be easier to calculate it? How can this energy be calculated?

There is a very simple relationship between kinetic energy (*KE*) and velocity (*v*), it is: $KE=\frac{1}{2}mv^2$. So if we know or can estimate the mass (*m*) of the mechanical elements then we can decide the average speed to suit.

But it is not as simple as this as we must consider the *inertial* energy in the rotating parts, ie: the door operator motor, belts, pulleys, chains, speed reducers, etc. These can represent about 25% of the total kinetic energy. The speed selected should therefore be for 8 Joules rather than 10 Joules.

What has been calculated is the kinetic energy at the average speed. It does not follow that passengers will only be hit by doors moving at the average speed. What is the maximum kinetic energy likely to be?

To answer this question we need to know the velocity profile of the doors. This will depend on the door control system, ie: sinusoidal, parabolic, trapezoidal, etc. Taking the sinusoidal case as the easiest to analyse. We know that the ratio of the rms value to maximum (peak) value of a sinewave is $\sqrt{2}$, ie: 1.414. We might also remember the form factor of a sinusoid, which is the ratio of the rms to the average value, is 1.1. This means the ratio of the average value to the maximum value for a sinusoid is 1.57. Thus although the average speed is x the maximum speed is $1.57x$. As we are considering kinetic energy ($\frac{1}{2}mv^2$) then the maximum energy at the maximum speed will be some 2.5 times (1.57x 1.57) the energy at the average speed, ie: 25 Joules. If a passenger is unfortunate to be hit by the doors, when they are moving at the maximum speed, they can be hurt and sometimes killed.

A full treatment of door dynamics can be found in "*Kinetic energy of passenger door systems*" by George Gibson, Elevator World, December 1989 and January 1990. Heikki Nykanen dealt with the bio-engineering (elasticity of body parts) aspects in "*Safety criteria for power operated doors*" in Elevator World, June 1986.

To put this into perspective what do you think 10 Joules feels like? Put a cushion on a firm table and lay your hand face down on it. Take a sealed 1 kg bag of sugar and hold it 1 m above your hand. Careful now! Let the bag fall.
That is 10J!

CAUTION

Use a cushion
Do not drop
hard objects