Name :

Partners

Period

Date

Car Crash Portfolio Sample

Technical Analysis of Crumple System

Mass Data

- Mass of wooden car "frame" = 0.82572 kg
- Mass of homemade car body = 0.1121 kg
- Mass of both passenger eggs combined = 0.11233 kg

Total mass of car body passenger system = 1.0502 kg

Crumple Zone Data

- Length of crumple zone before collision = 0.176 m
- Length of crumple zone after collision = 0.166 m

Change on crumple zone length = 0.010 m

Other

- Distance the car rolled down track = 1.60 m
- Angle of incline track = 40°

Theoretical (Idealized) Data Analysis

1. To get the vertical distance:

$$1.60 \sin 40° = \mathbf{1.03\ m}$$

$$Potential\ Energy = mgh$$
$$Potential\ Energy = 1.0502\ kg\ \left(9.80\frac{m}{s^2}\right)(1.03\ m)$$
$$Potential\ Energy = \mathbf{10.6\ J}$$

2. To get speed before it hit the brick wall: PE =KE (conservation of energy)

$$Kinetic\ Energy = \frac{1}{2}m(v)^2$$

$$10.6\,J = \frac{1}{2}(1.0502\ kg)(v)^2$$

$$v = \mathbf{4.49\ m/s}$$

a. This is not an accurate assumption of my car's speed because there actually was friction, and the ramp makes it so that car is not falling directly (vertically) to the ground. The true velocity would be slower, because friction would slow the car down and the ramp makes it so that there isn't actually 9.80 m/s^2 of acceleration.

3. To get the momentum before it hit the brick wall:

$$Momentum = m(v)$$

$$Momentum = (1.0502\ kg)4.49\ m/s$$

$$Momentum = \mathbf{4.72\ kg\ m/s}$$

*Change in momentum is the same as Impulse, so I can use that to get the force

$$Impulse = F(\Delta t)$$

$$4.72\ kg\ m/s = F\ (0.001\ seconds)$$

$$Stopping\ force = \mathbf{4,72\ N}$$

In order to allow the passenger and driver to survive in a crash, the crumple zone's purpose is to increase the time of impact. By doing this, you prolong the amount of time that the stopping force is felt on the car occupants.

4. According to the Work Energy Theorem, work = change in energy. So going off of this, the potential energy my car had at the top (10.6 J) is the kinetic energy it had right before it hit the end of the ramp. So…

$$W = \Delta E$$

$$W = \mathbf{10.6\,J}$$

Since our crumple zone reduced the force acting on the car and I now know the work done to bring the car to a stop… I can get the average force that stopped the car.

$$W = F(d)(\cos\theta)$$

$$10.6\,J = F(0.010m)(cos40°)$$

$$10.6\,J = F(0.007660444)$$

$$F = \mathbf{1,383\ N}$$

To get the theoretical minimum average force… it's the same thing expect I substitute my 0.010 m to 0.12 m

$$W = F(d)(cos\theta)$$

$$10.6\,J = F(0.12\,m)(cos40°)$$

$$10.6\,J = F(0.091925333)$$

$$F = \mathbf{115.3\ N}$$

If the 'perfectly ideal' crumple zone completely compressed the entire 12.0 cm, then the force required to stop the car would be A LOT less than it would with my crumple zone, which only compressed 1 cm, requiring a MUCH higher force to stop the car. With my crumple zone, it needed 1,383 N of force to stop the car, and with a perfect crumple zone, it would need 115.3 N of force to the stop the car (this crumple zone is much safer for the occupants, aka the eggs).

5. My impulse (or change in momentum) value comes #3 and my experimental force value comes from #4

$$Impulse = Force\ (\Delta t)$$
$$4.72\ kg\frac{m}{s} = 1{,}383\ N\ (\Delta t)$$
$$\Delta T = 0.003\ seconds$$

Yes, this is a reasonable time, because the time provided in #3 was 0.001 seconds, which is 0.002 seconds away from the time that I got.

6. If my car bounced then the time of impact would have decreased because it would have spent less time in contact with the end of the ramp. Therefore it the time of impact decreases then the force felt on the car increases, lessening the chances of survival for the eggs. This is why it is important to design a quality crumple zone that absorbs the energy and force that occurs at impact.
7. Well since the momentum equation is m(v) then the cars with the larger masses would have the larger momentum. Based off of this, I know that the change in momentum is the same as impulse, which means that the larger the mass, the larger the momentum, or larger the impulse, therefore the larger to force felt, increasing the chances of your egg cracking.

Real-time Sensor Data Analysis

8. On the velocity-time graph, the line peaks at about 0.80 seconds. I know that right before the car hits the bottom of the ramp, the velocity should be the highest. So on the table, the highest velocity is at the position of 0.80 seconds, where it is 4.007 m/s. I can use this to solve for momentum.

$$Momentum = m(v)$$

$$Momentum = 1.0502\ kg\ \left(4.007\frac{m}{s}\right)$$

$$Momentum = \mathbf{4.208\ kg\frac{m}{s}}$$

Under the Analyze, Statistics section for the maximum velocity before it hit the bottom was **0.792 m/s**

9. The impulse-momentum theorem basically says that the change in momentum is equal to the impulse, so the answer to number 8 is the answer to number 9.

$$Impulse = \mathbf{4.208\ kg\ m/s}$$

10.

$$Impulse = F\ (\Delta t)$$

$$4.208\ kg\frac{m}{s} = F\ (0.055\ seconds)$$

$$F = \mathbf{76.5\ N}$$

11. Under the Analyze, Statistics section the maximum force exerted between the crashing car and the barrier was **223.4 N.**

This force is much higher than the average force that I found in question #10. The reason that these forces don't match up is because the calculations don't account for "real world" factors, like how the car crashed, whether it bounced, or moved sideways, etc. The calculation in #10 tells me the ideal, "perfect" crash whereas the loggerpro value tells me the legitimate force exerted with the crashing car and the barrier at the bottom of the ramp.

12. Under the Analyze, Integral section of the Impulse graph, the total impulse the plate applied to the crashing car was **6.095 s(N)**.

The impulse that I calculated in #9 is much less than the one that loggerpro gives me.

$$Percent\ Error = \frac{Theoretical\ Value - Experimental\ Value}{Theoretical\ Value}\ x\ 100\ \%$$

$$Percent\ Error = \frac{4.208\ kg\ \left(\frac{m}{s}\right) - 6.095\ s(N)}{4.208\ kg\ (\frac{m}{s})}\ x\ 100\%$$

$$Percent\ Error = \mathbf{-44.8}\ \%$$

13. Each "rise and fall" point in my impulse graph indicates the split second that my crumple zone was "crumpling", or when the newspaper and tissue paper inside the hood of my car was absorbing the energy before it reaches the egg.
14. I do consider my car design to be a success; as long as both eggs survived the crash then I think it's a successful day. Commenting on the purpose, to design a vehicle that will allow two occupants (eggs) to "survive" a head-on crash with a concrete wall and to make vehicles constructed according to the specifications listed, and my score, a 24/25, then I could also say that our car design was great. Under specifications, Paulina and I made sure that our car fit all the requirements as follows; the dimensions of the cardboard fit onto the base easily (it actually fit perfectly), we had a front bumper that did not extend 12.0 cm from the front, we had doors and see-through windows, we had a trunk, we had a safe secure system of rubber bands with cotton around them, and we were sure to include other tiny details that kept the occupants protected to the best capability. All in all, a score of 24/25 on the live crash test day proves that we did what was necessary to design a successful, functional model-vehicle with properties that actual car designers would take into consideration when building legitimate vehicles in the real world.
15. The biggest recommendation(s) I would make is to pay *equal amount of attention* to the restraint system as to the crumple zone. Paulina and I spent a lot of time designing the crumple zone, only to realize that towards the last construction day that the restraint system plays an equal role to the protection of the eggs compared to the crumple zone. I would also HIGHLY recommend hot glue; this kept our cut out of the seat very secure against the side walls of our car, and ultimately secured the rubber band seat belts around the egg that kept them in place when our crumple zone made contact with the bottom of the ramp. If this were at a higher angle, I would have probably redesigned our crumple zone to be able to *compress* much more; that seemed to be the biggest success with other cars. I noticed that some groups used stacked Dixie cups with soft material on the bottoms of each, which seemed to be very effective. If we were to do this again I would have probably gone that route instead of the boxy front bumper route. All in all the biggest piece of advice is to take very careful measurements, this will make sure it fits the car body well, and will ultimately keep the built car frame as secure as possible, increasing the chances of the eggs surviving.