# Mechanical Impedance

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Webster's definition of impedance is "to interfere with or slow the progress of…" A scientific definition is "impedance is a form of resistance that will accelerate or decelerate." There is friction between an item and the surface. Where the object starts and where it stops is the impedance. When the object first begins to move is called "break-away" – the change from a static to a moving state. Once the object gets moving it is easier to keep it going. The impedance factor of a car is where it is at the start and where it is once it gets moving. Another definition is "a measure of how much a structure resists motion." Inertia is a force related to the weight and the speed. Impedance is a ratio of force to speed.

In a piano, let's assume we have a string that starts vibrating. In a wave form, it goes up, and then down. Impedance comes into play at the point where the note accelerates and decelerates, at the top of the wave. Impedance itself is also like saying "up" or "down." It is a reference point. The interaction of two solid pieces of metal is hard to define. Electrical parts are well-defined, but mechanical parts are difficult to define. The term "ohms" is sometimes used in mechanical descriptions. With objects, what is the unit of a table or a chair, other than hard or soft?

There are two things going on with impedance. There is the initial energy with a wave form. The second part is the circuit, or that part that is reacting with the initial energy. We need to know the up point, the down point, and the frequency.

A ball rolling down a hill hits a brick wall. The speed and weight of the ball determines the impedance. A brick wall has no resilience; other surfaces might have resilience. When the ball hits the brick wall, it quickly decelerates; at this point there is impedance. The point is that which is moving and that which it contacts. What is the length of time the object takes to stop? A low impedance circuit would be a ball hitting something soft, so it takes longer to slow down. High impedance would be if the ball is made of steel and hits a brick or steel wall and rolls towards it at a very fast rate.

Roger placed a weight on a torque scale. When pressure is first applied to a spring, the resiliency or deflection is quite great at the beginning. As more weight is added, the deflection is not proportional. On a graph, increased pressure does not create resistance in a straight line, but in a curved line. Notice all flatbed trucks have a curvature in the middle. If the bed were flat, every time the truck hits a bump, the center goes down at a slow frequency. If the truck bed is crowned, the flex is less.

In pianos, we have two different forces to deal with: the attack and the decay. The greater amount of flex, the more of that sound will be absorbed. "Thud, thud" represents the attack in a high impedance board. The decay is long or short depending on the impedance. A soundboard with a high amount of flexibility will absorb more of the sound.

A low-impedance surface can be demonstrated with swinging steel balls. Drop the ball on one end and the ball at the other end will bounce out at about the same distance that the first ball moved. The dropped ball does not bounce back. Drop the ball from a short distance to see impedance at its lowest point. To demonstrate high impedance, hold the ball still at one end with a solid weight, drop the first ball, and count how many times it bounces. To demonstrate low impedance, hold the ball at the other end with felted block and count the bounces: there will be fewer.

What kind of soundboard would have little or no resiliency? It would be an old board. With a flat board, weight will flex it quite a bit, but to flex it more requires increasingly more weight or force. Because the board moves so much, it doesn't send much energy back. The board now vibrates back and forth in a zero-tension zone, which sucks up a lot of energy, and the resonant frequency of the board is quite low. The board vibrates at a very low frequency. A board with no crown sucks up and absorbs the energy. In contrast, a board with a crown will reflect a lot back and will provide a lot of return on the string.

Percussion instruments focus on the initial contact sound, and the resonance of the sound that carries on afterward is secondary. Just by listening to different pianos one can hear the difference between variations in crowns. The crowns in soundboards sometimes begin deteriorating within five years. Sony has the top recording engineers on the planet; when they record, they use pianos that are less than five years old. They don't want hammer noise, and they want a lot of sustain. Roger has a Steinway D that is 20 years old, and he can tell that the soundboard has deteriorated.

On an upright, the notch at the treble strut between tenor and treble produces an explosive sound. Move away from that point and there is more sustain and less attack. Although Chickering put a cut at that point, most grand pianos do not have a cut there. Howard Hughes made the Spruce Goose; he flew it 30 miles and never again. He chose spruce because it has the highest strength ratio and the lightest weight. We use spruce for soundboards because of their resilience, their strength, and their even grain.

A soundboard made of a hard material would suck up a high frequency very well. Keep in mind that the rate that energy accelerates and decelerates is related to impedance. The key to soundboard building is that there must be much higher impedance at the string to send the impact down to the bridge. A stiff board with low impedance is a ratio of speed and weight; there would be little sustain.

Impedance is a wave form increasing and decreasing in proportion to speed, time, and weight. One Newton is the force it takes to accelerate 1 kg mass by 1 meter/s/s. To move something quicker takes more force. If you are waiting at a stop light next to a cement truck and a car hit that truck, the truck will not move very far, whereas if that car hit your car, your car would go through the intersection. However, if another cement truck hit the stopped truck, it would move farther than when the car hit it. If a cement truck hit your car, you would go much farther than everybody else went.

Impedance is the ratio of speed to weight in mechanics. In electricity it is the ratio of the voltage to the current. If you rub your feet on a carpet and touch the TV, you will get a shock. That is a high impedance circuit, like a very small car travelling very fast. A low impedance would be a car battery short-circuited with a screwdriver: it will get hot and burn but will not shock. With hardly any current, signals are sent very far into space; this is high impedance. A telephone would be low impedance. Mechanical engineers deal with noise, vibrations, engines, rockets, and their goal is to reduce vibrations. With pianos, we want to increase vibrations.

We can see bass strings going up and down. Treble string distances would be hard to measure because they are so small. In the treble we have a very small area and the bridge is large in proportion. The weight of the bridge then goes down the middle, and by the bass, the bridge is small in relationship to the board. Riblitz makes a short rib that is glued to a portion of the soundboard to restore a section of the crown, and it adds mass.

Routing the board around the rim would increase the flexibility of the board, but this would lower the impedance. This might suck up more energy. Some pianos have such a stiff board that there is hardly any sustain or energy out of the string. Mason Hamlin has a tension resonator, to tune the soundboard, and the manufacturers state not to change or adjust it.

Low impedance is a lower wave that takes a longer time. High impedance is a sign wave that is taller and closer together. Think of how ocean waves hit a cliff: 100% of the energy comes back. The big waves in Hawaii are long and travel a far distance, so that when they finally hit the beach there is hardly any motion left. Take a tennis ball and squeeze it in your hand. We can put a piece of wood in a vice and compress the wood, but we cannot squeeze water. When water hits a cliff, the impedance is so high that all the water goes directly back into the ocean.

Sound speakers have strong magnets inside. As the electrical energy comes into the cone, the magnet puts a lot of tension in the coil. What frequency is the speaker at 8 ohms? It's 1000 cycles. Measure a microwave transmission, it would be in megacycles, like a million ohms. To measure impedance, we must weigh it, check the resiliency, etc.

The piano hammer has an impedance factor as it contacts the string. Voicing the hammer by needling or lacquering changes the impedance. Hard hammers will bounce off the string so fast there will be no sound. Ed's light hammers are soft. Pianos deal with impedance more than any other mechanical field; we are trying to get proper sound instead of trying to eliminate sounds.

*"The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object: Force= Mass x Acceleration."*

*"Mechanical impedance is a measure of how much a structure resists motion when subjected to a harmonic force. It relates forces with velocities acting on a mechanical system. The mechanical impedance of a point on a structure is the ratio of the force applied at a point to the resulting velocity at that point."*

*"Mechanical impedance is the inverse of mechanical admittance or mobility. The mechanical impedance is a function of the frequency of the applied force and can vary greatly over frequency. At resonant frequencies, the mechanical impedance will be lower, meaning less force is needed to cause a structure to move at a given velocity. A simple example of this is pushing a child on a swing. For the greatest swing amplitude, the frequency of the pushes must be near the resonant frequency of the system."*