Transition of spring resonance and mechanical energy

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When a vibrating spring interferes with another spring and spring resonance takes place, it is not known how the mechanical energy changes between the two objects. The mechanical energy of a single vibrating object can be derived by determining the mass, frequency, and amplitude of the object. We decided to investigate the change in mechanical energy by graphing the change in the mechanical energy of two resonant springs. As a result, we found that the mechanical energy is transferred between the two objects mutually. In addition, we investigated whether the distance between the two resonating objects was related to the transition of the mechanical energy. As a result, it was also found that when spring resonance occurs, the oscillating object passes more energy from that object to the closer object.

1 Background

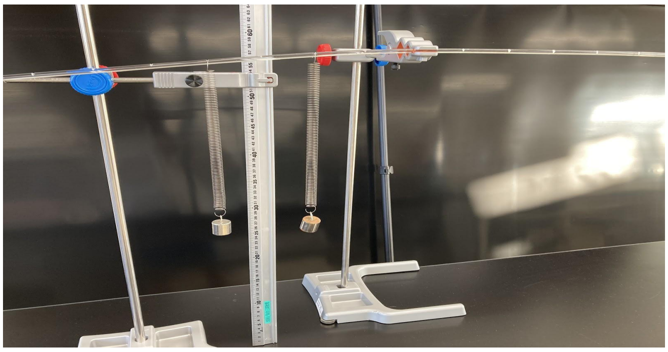
Resonance is when an object that is vibrating vibrates further in synchronization with an external vibration. Examples include earthquakes, in which vibrations in the ground are transmitted to a building and cause it to resonate, and resonance, in which one tuning fork transmits sound to another tuning fork. Among these, a spring vibrates singly when it resonates. When an object vibrates singly, the mechanical energy of the object can be derived by determining the mass, frequency, and amplitude of the object. Therefore, in this research, we decided to study the resonance of springs.

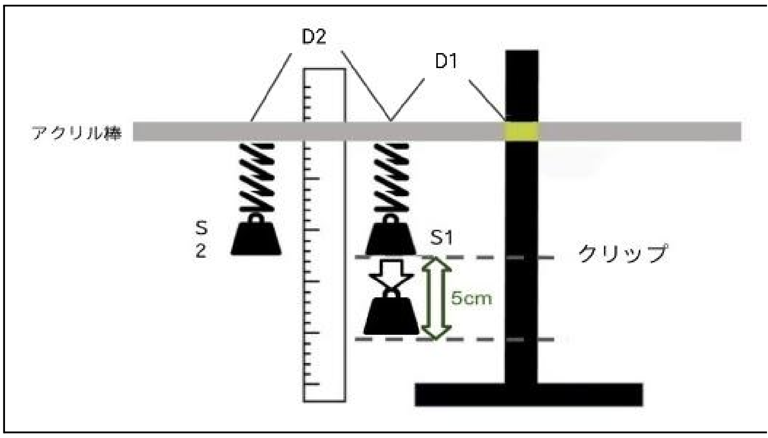
In 1940, the Tacoma Narrows Bridge in the United States was destroyed by wind resonance. The details of the mechanical energy at the time of resonance were not known. Since the details of the mechanical energy at the time of the resonance were not known, we decided to try to figure it out and started this experiment.

Resonance phenomena are used in various ways in our daily lives, such as when an object vibrating alone inside a machine resonates with another object to damage the inside of the machine, or in devices that resonate inside a machine to generate a certain period. Thus, by clarifying the relationship between the change in mechanical energy at resonance and the distance between each object, it is possible to share more energy and make resonance less likely to occur, thus making resonance generation easier to use. In addition, by suppressing the resonance inside the machine, we can solve the noise problem when driving the machine and reduce the deterioration of machine parts.

2 Materials and Methods

The following experimental setup was used in this study.





To prevent the spring from moving during vibration and resonance, we carved grooves every 5 cm in the acrylic rod and hung the spring there. I used acrylic rods for three reasons: they are inexpensive, strong, and flexible. Two springs are suspended from the acrylic rod, and each spring has a 50g weight attached to it. The spring closer to the stand is S1, and the one farther from the stand is S2. Let the distance from the stand to S1 be D1 (cm) and the distance between S1 and S2 be D2 (cm). In the experimental results, the values of D1 and D2 are denoted as (D1,D2). (e.g., (5,10) → D1 is 5cm, D2 is 10cm) The mechanical energy of the spring was calculated using the formula for single vibration (E=2π2mf2A2) where E is the mechanical energy (mJ), m is the mass of the weight (kg), f is the frequency (Hz), and A is the amplitude (mm).

The procedure of the experiment is as follows.
(1) Pull S1 about 5 cm to make it vibrate.
(2) Record the vibration and resonance of the two springs for five minutes from the moment when S1 is released from your hand as 0 second.
(3) From the recorded images, calculate the amplitude of the two springs every five seconds.
(4) Substitute the obtained amplitudes into the equation for a single vibration to obtain the mechanical energy of the springs every second, and make a graph with time (s) on the horizontal axis and mechanical energy (mj) on the vertical axis.
(5) From the approximate shape of the graph, examine the trend and regularity of the increase and decrease of the mechanical energy.
(6) Repeat this procedure, changing only the values of D1, the distance from the stand to S1, and D2, the distance between the springs. Then, the following four experiments were conducted.
(i) D1 was varied to 5 cm, D2 to 5 cm, 10 cm, and 15 cm.
(ii) D1 was changed to 10 cm and D2 to 5 cm and 10 cm.
(iii) D2 was 5 cm and D1 was changed to 5 cm, 10 cm, and 15 cm.
(iv) D2 is 10 cm and D1 has been changed to 5 cm and 10 cm.

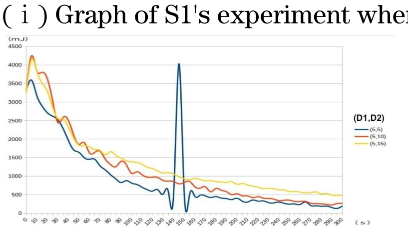
3 Hypothesis

We hypothesized that the graph of the transition of the mechanical energy would be a curve because it is proportional to the square of the amplitude and the square of the frequency. We further hypothesized that if two springs resonate and share energy, the energy of the two springs will eventually be almost the same. I also hypothesized that the shorter the distance between the two springs, the more energy each spring would have, so the shorter the distance between the springs, the smaller the decrease in the graph would be.

4 Results

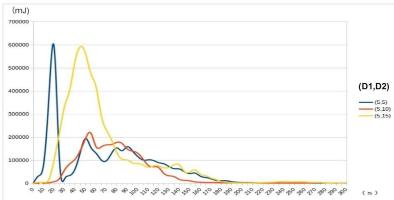
The obtained graphs are as follows.

(i) Graph of S1's experiment when D1=5



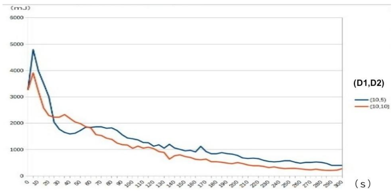
When the distance between the stand and the spring was fixed at D1=5cm, the mechanical energy in the graph of S1 repeatedly increased slightly and decreased significantly. Eventually, all the values of the graph approached zero. The distance D1 between the stand and the spring was fixed, and the distance D2 between the stand and the spring was changed to 5 cm, 10 cm, and 15 cm, but there was no significant change in the decrease in energy. There was an outlier in the graph of S1, but this experiment focused on the transition of the mechanical energy, and it was not a part of the overall trend. Since it was not seen, it was not taken into account.

(i) Graph of S2's experiment when D1=5



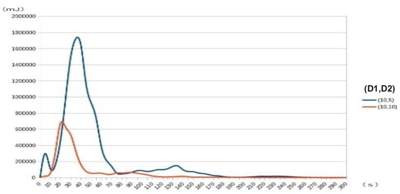
If we focus on the maximum value of the mechanical energy in each experiment in the graph of S2, we find that (D1,D2) = (5,5) ≈ (5,10) > (5,10).

(ii) Graph of S1's experiment when D1=10



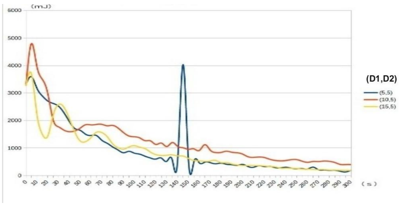
The distance between the stand and the spring, D1, was fixed at 10 cm, and the distance between the springs, D2, was changed to 10 cm and 15 cm, but there was no significant change compared to the case when the distance was fixed at 5 cm in (i). In this experiment as well, the graphs showed a slight increase and a large decrease repeatedly, and eventually all the graphs approached zero.

(ii)Graph of S2's experiment when D1=10



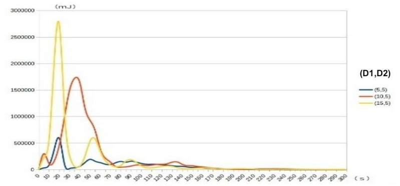
The relationship between the maximum values of the mechanical energy in each graph is (D1,D2) = (10,10) > (10,5). In this experiment, the shorter the distance D2 between the springs, the larger the maximum value of the mechanical energy.

(iii)Graph of S1's experiment when D2=5



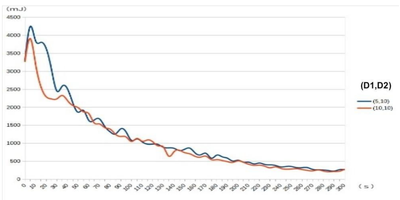
In this experiment, the distance D2 between the springs was fixed at 5 cm, and the distance D1 between the stand and the springs was changed to 5 cm, 10 cm, and 15 cm, but as in the experiments (1) and (2), the way the variable mechanical energy changed did not change.

(ⅲ)Graph of S2's experiment when D2=5



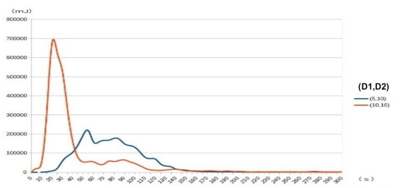
The relationship between the maximum values of mechanical energy in each graph is (D1,D2)=(15,5)>(10,5)>(5,5). In this experiment, the longer the distance D1 between the stand and the spring is, the larger the maximum value of mechanical energy is.

(iv) Graph of S1's experiment when D2=10



The distance D2 between the springs was fixed at 10 cm and the distance D1 between the stands was varied, but the way the mechanical energy changed did not change as in the experiments (ⅰ) to (ⅲ).

(ⅳ)Graph of S2's experiment when D2=10



The relationship between the maximum and minimum values of the mechanical energy was (D1,D2)=(10,10)>(5,10). In this experiment, as in (ⅲ), the longer the distance D1 between the stand and the spring, the larger the maximum value of the mechanical energy.

5 Discussion

From the graph of the mechanical energy of S1 and S2, the mechanical energy of the two springs repeatedly increased and decreased at resonance. It was found that the total amount of mechanical energy decreased and eventually approached zero.

S1 gave energy to S2 and S2 gave it back, the so-called energy transfer was taking place. It is thought that the shorter D2 is, the more energy is transferred.

The shorter D1 was, the smaller the maximum value of the mechanical energy was, which is thought to be because the stand absorbed the energy as a non-resonant object. This indicates that more energy is given to the object that is closer to the object that is vibrating at resonance. In other words, when spring resonance is taking place, the shorter the distance between springs and the longer the distance between springs and non-spring objects, the less mechanical energy is dispersed at resonance and the easier it is to resonate. And of course, the reverse is also true.

6 Conclusion and outlook

From the above, we have learned that it is necessary to increase the distance between vibrating objects in order to make resonance less likely to occur. Based on this, we can expect to be able to reduce the negative effects of mechanical vibration by improving the internal structure of the machine.

However, since the energy of the spring interferes with various things such as the stand, it was difficult to find the regularity of the period of mechanical energy increase and decrease. In the future, we would like to deepen our discussion by changing the conditions and the number of springs from various perspectives.

[References.

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