EDITORIAL

Verbal Analogies in Noise And Vibration Control

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At times, common sense verbal analogies rather than mathematics may help explain noise and vibration control issues to managers, designers, and industrial engineers. Even if complex systems are discussed, most CEOs and clients often like that the appropriate language is English, not mathematical equations. It is noteworthy that specialists in acoustics and vibration among engineers and managers are much less abundant than those proficient in mathematics. This sends vibro-acoustic engineers or consultants in search of adequate verbal analogies to produce effective presentations and explanations. On the other hand, some common-sense analogies turn out to be misleading, and projects based on such 'ideas' fail. Several case stories are discussed here.

Experimental Error and Employment. This story, while being not related directly to acoustics or vibration, is a good introduction to the subject. In 1921, young Russian physicist Pyotr Kapitsa (a future Nobel prize winner) was sent by the Soviet government to study experimental skills at the Cavendish Laboratory of Cambridsge University. It was the best European physics lab and was led by Ernest Rutherford, who established the nuclear theory of the atom. Rutherford first refused to accept the young Russian because of his general prejudice against communists (even if Kapitsa himself was not a member of the Communist party), but explained his decision by saying that he had enough staff support. Kapitsa did not give up and asked him what experimental error is tolerated at the Cavendish laboratory. "Just 3%," replied Rutherford proudly. "Very good, sir," said Kapitsa. "Your present staff is about 30 people. So, you can hire me because I will be just an experimental error of 3%." Rutherford laughed and hired Kapitsa as a research scientist.

Octave Frequency Bands and Rainbow Colors. Eight octave frequency bands with center frequencies of 63, 125, 250, 500, 1000, 2000, 4000, and 8000 Hz are often applied to acoustical noise evaluations. Although many people are familiar with the "law of octaves" in musical notation, the concept can be a bit unclear. For a colorful explanation, one could use a verbal analogy with the basic light spectrum. There are seven main rainbow colors: red, orange, yellow, green, blue, indigo, and violet. Such a similarity is quite illustrative but conceptually limited; because a mix of two colors makes another color, and two different tones do not merge into one. For example, combining indigo and orange colors results in a visual sensation of green. But a combination of octave bands with center frequencies of 125 and 2000 Hz does not create audible perception of a single octave band with a center frequency of 500 Hz (both original components can be markedly heard). Generally speaking, an analogy pushed too far goes astray.

Decibels and Percentages. A plant manager was not satisfied with a predicted noise reduction of 17 dBA: "I wish the noise were slashed by 95%!" After my explanation that "cutting the sound intensity by 95% results in a sound level reduction of 13 dB," he told me of a company that claimed its active control device could reduce the noise energy by 80% (that is, by 7 dB). Probably, the sales agent found the two-digit number to look more impressive than just one digit. This misled and confused my customer even though he had heard something about decibels. It is not easy to get accustomed to units that are not summed in traditional terms (for example, 47 dB + 53 dB = 54 dB and not 100 dB). Using percentages and decibel scaling simultaneously is a bad practice. Here, a psychologically perceived loudness may be helpful in getting accustomed to decibels – if a sound level is increased (or reduced) by 10 dB, the human ear perceives it as a doubling (or halving) of loudness.

Sound Insulation vs. Thermal Insulation in Single Partitions. One client believed that lightweight, single partitions made of plastic or plywood can effectively shield acoustical noise just because they provide sufficient thermal isolation. He used a thin plywood wall in his house for noise control, but his dream did not come true. The original "common-sense" analogy proved wrong. To scientifically explain the failure, he suggested that plywood-like material is a good conductor for sound (like copper for electricity). I briefly introduced him to the "mass law" using Newton's second law (the lower the mass, the higher the acceleration for the force given), but he wanted a common-sense explanation. Then I convinced him with the following verbal analogy "Your bed blanket can protect you from a morning cold but not from the clanging of your alarm-clock." This happened to be a good correlation with his everyday experience.

Sound Insulation vs. Thermal Insulation in Double Partitions. Some people believe that good sound insulation afforded by double partitions is mainly enhanced by the air gap between leaves. However, the transmission loss of a double window at low frequencies can be much lower than that provided by a single window of the same surface density (mass per unit area). The reason is a so-called mass-spring-mass resonance, where the panes play the role of mass, and the air gap operates like a spring. However even at high frequencies, a notable increase in the transmission loss cannot be achieved with no sound absorption in the air gap. Consider the air gap to be thick (larger than the sound wavelength) and the partition leaves similar and infinite in size. Each time a sound wave hits the solid wall, only a small percentage of the sound energy passes through; some percentage is absorbed by the wall and converted into heat, and most is reflected from the wall.

Consider the ideal case of no sound absorption. After the initial sound wave propagates from outside via the first partition leaf, it undergoes multiple sound reflections within the air gap. The wave hits each leaf over and over again, getting weaker and weaker with time, but gradually transports all the energy through both leaves. Nearly half the energy passes through the second leaf, and the other half propagates back through the first. So, the transmission loss of the double wall without any sound absorption in the gap equals the transmission loss of one leaf plus only $10 \log (1/0.5) = 3$ dB. However, the more sound energy absorbed on the leaf surfaces or in the sound-attenuating layers (fiberglass, mineral wool, etc., and located inside the gap), the less energy transmitted outside through the leaves, and the sound transmission loss may increase significantly. For instance, lightweight double gypsum partitions with internal sound absorbing layers provide approximately the same sound insulation as 4-6 in. solid concrete walls.

"Sword-and-Shield" Synergy. The synergy of sound insulation and sound absorption in double walls may be compared to the traditional synergy of the shield and sword. If an ax-armed enemy had attacked a medieval soldier, his shield might have protected him from several cleaving blows. But if the soldier had not slashed the enemy with his sword on time, the ax would have finally cleaved the soldier's shield and skull. So, the sound absorption, playing the role of sword, is as important as the sound insulation (the shield). In any synergy, the whole effect is greater than the sum of the partial effects. Here, this is also true. As noted above, the double wall partition with no sound absorption in the gap is not very effective in shielding acoustical noise. On the other hand, a fiberglass layer with no walls around is just a blanket. So, the shield and sword cooperation is a comprehensible verbal analogy for the synergy of sound insulation and sound absorption.

Even a Bad Verbal Analogy Can be Useful. The newcomer at the Cavendish Laboratory was a type of individual that Rutherford had never met before. He was a man of enormous charm, generosity, and attractiveness. He soon became Rutherford's best friend. Rutherford liked him, but for a long time he was not aware of the strange nickname Kapitsa had given him. The moniker 'Crocodile' even became popular with all the Cavendish laboratory members. Indeed, Rutherford earned this nickname because he often looked angry. When Rutherford found out, Kapitsa explained to him that in Russian folklore, the crocodile never turns back (not actually true) and symbolized Rutherford's penetrating mind and his desire to move forward. Rutherford liked this analogy so much that the side of the Mond Laboratory in central Cambridge now carries an engraving of the crocodile. SV

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