EDITORIAL

The Vibroacoustics Engineer on a Product Development Team

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The quality and reliability of a new product used to be implemented in the design stage because any later design iterations consume time and money. In the worst case, no design correction can help, and the project has to be started from scratch. The human factor is very important if special skills are needed.

Intellectuals solve problems, geniuses prevent them.
– Albert Einstein

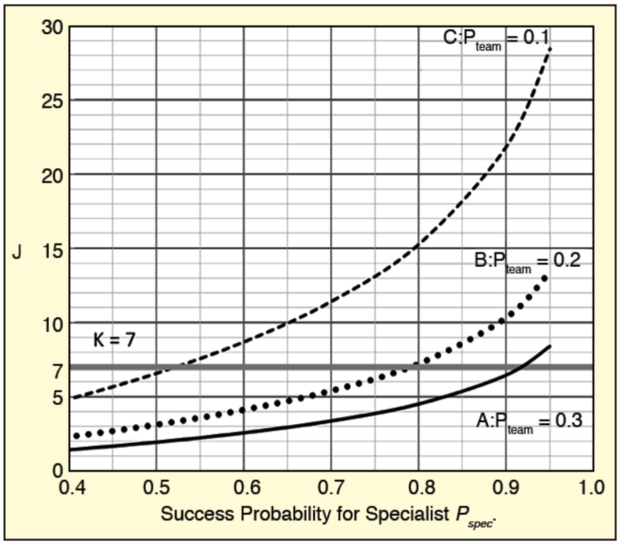

Figure 1. Critical Number J for three levels of team expertise: A B, and C; bold horizontal line indicates the average number K = 7 of active team players.

Once upon time, a project team of K engineers was to design a new product within a year. The acoustic noise, vibration, and fatigue issues were of great importance, so the project leader suggested hiring a full-time vibroacoustic engineer. He knew that such specialists (NVH engineers) do great work for automotive and aerospace companies. But his manager was reluctant: why spend more money if every engineer in the team must have at least some knowledge in sound and vibration? Indeed, many people believe in the power of teamwork rather than the "myths" of a lone genius.[1]

However, if a task can be performed by one highly skilled professional, it is not wise to delegate this duty to a group of low-skilled individuals. "A great engineer is worth 100 average engineers," says Facebook CEO Mark Zuckerberg.[2] Generally, the dilemma "to hire or not to hire" a special expert is of practical interest. The following statistical approach may help estimate the risks and make the right decision.

Estimatiing the "success" probabilities for high-level specialists and ordinary team members. One of my university professors used to say that everybody could win the Nobel Prize, but it could take 20 years for the talents and 200 years for ordinary people. If the probability distribution is uniform (the chances are distributed equally in time), the probability of winning the Nobel Prize within 16 years is calculated as 16/20 = 0.80 for a talent and 16/200 = 0.08 for every "ordinary" person. Such a simplified view of the "success" probability quantifies both personal belief and logical rationality.

Assume that a high-level specialist and each ordinary team member can resolve the vibroacoustics issues for the same time with the "success" probabilities P_{spec} and P_{team} (where $P_{spec} > P_{team}$). Their "failure" probabilities can be expressed as $F_{spec} = 1 - P_{spec}$ and $F_{team} = 1 - P_{team}$, respectively. Introduce three typical levels of the team expertise in vibroacoustics: A (advanced) with $P_{team} = 0.3$, B (middle) with $P_{team} = 0.2$, and C (basic) with $P_{team} = 0.1$.

The critical number of ordinary team members to match a high-level specialist. The team level depends on both individual skills of each member and collaboration between the members. To simplify the simulation, let's neglect any interaction between the team members, but incorporate the benefits of team collaboration in the value P_{team} (for example, the "success" probability may be 0.15 and 0.20 for a single engineer and a team player, respectively). So all the team members fail with the probability that is equal to the product of their "fail" probabilities: $F_{all} = (F_{team})^k$.[3] The team can overdo the high-level specialist if $F_{all} < F_{spec}$, or $(1 - P_{team})^K < 1 - P_{spec}$; taking natural logarithms of both parts of this inequality, obtain:

$$K > J = \frac{\ln(1 - P_{spec})}{\ln(1 - P_{team})} \qquad (1)$$

were, J is the critical (minimum) size of a team performing better than a high-level specialist in his professional areas. The number J infinitely grows for $P_{spec} \to 1$ and $P_{team} \to 0$, but these two critical cases are not practical. In particular, it is reasonable to suggest that $P_{spec} < 1$, since nobody can guarantee complete success. The reason is at least twofold: (1) the project time is relatively short, (2) the recommendations of a vibroacoustics specialist may not be accepted if they negatively affect other qualities of the product.

Table 1. Number of players for typical sport teams.

Sport	Number of Players
Beach Volleyball	2
Basketball	5
Ice Hockey	6
Volleyball	6
Water Polo	7
Handball	7
Soccer	11
American Football	11
Mean	**6.9**

Using Equation 1, calculate and plot the critical number J for three levels of team expertise: advanced (A), middle (B), and basic (C). Note that such relationships can work for various applications. For example, one of my friends happened to subjugate four ruffians who attacked him in a dark street for the sake of his wallet. He was a heavy-weight expert in Greco-Roman wrestling but never won an Olympic medal and did not serve in the army, so let's estimate his martial performance by the "success" probability $P_{spec} = 0.8$. The bullies were physically strong but they were not professional wrestlers, so their "success" probability may be approximated as $P_{team} = 0.3$. For this case, Plot A in Figure 1 is used to evaluate the critical number: $J \approx 5$. My friend had also admitted that five thugs might have been too much for him.

General recommendations to the "hire or not hire" issue. Let's estimate the average number of the most active members in typical engineering project teams. Commonly, it is between two and 12, with an average of seven, which is the fictional team size in movies like *The Magnificent Seven*, *Seven Samurai*, *Snow White and the Seven Dwarfs*, *Seven Brides for Seven Brothers*; you get the idea. The number seven is also close to the average number of the field players in typical sports teams (see Table 1).

In Figure 1, the intersections of the horizontal line matching $K = 7$ with the three curves signify the minimum "success" probabilities for the specialist to perform better than the team in his professional field: $P_{spec} \approx 0.9$, 0.8, and 0.5 in cases A, B, and C, respectively. As seen, the advanced Team A may not need a full-time vibroacoustics engineer, but such a specialist could be helpful on a short-time consulting basis. The basic-level Team C is strongly recommended to hire a full-time vibroacoustics engineer. The middle-level Team B could hire either a full-time vibroacoustics engineer, or a part-time consultant.

Special Skills of a Vibroacoustics Engineer. There was a joke: if an engineer is always nice to his superiors, his great professional performance is just a plus for his career. But I still prefer to concentrate on the special skills in order of importance.

Theory and mathematical modeling. A vibroacoustics engineer must know the classical theory of sound propagation, absorption, and radiation, and be proficient in mathematical simulation of the sound fields in air volumes (rooms, layers, and waveguides) and of vibration in solid structures (lumped mechanical systems, membranes, rods, and plates). A good understanding of resonance and anti-resonance effects, spectral analysis, and theory of measurements is also of special importance.

His/her mathematical skills should be sufficient to apply the known equations, deduce new equations, and interpret the trends and interaction of the parameters. Note that some simple formulae are semi-empirical (developed using both theoretical and experimental results). For instance, if the wheel speed N in a blower switches from N_1 to N_2 : (a) the sound level of a broad-band noise L changes by $\Delta L = 50 \log (N_2/N_1)$ for aerodynamic noise and $\Delta L = 20 \log (N_2/N_1)$ for mechanical noise, (b) the air pressure changes from p_1 to $p_2 = p_1 (N_2/N_1)^2$, and the air flow rate changes from Q_1 to $Q_2 = Q_1 (N_2/N_1)$. Therefore, reducing the wheel speed by 25% will lower the broad-band aerodynamic noise by 5 dB (which is good), but the air pressure and flow rate will drop by 44% and 25%, respectively (which may not be acceptable). Generally, it is helpful to perform simple comparative calculations, where possible, instead of using complicated models to obtain the absolute values. The model should not be too cumbersome or extremely simplified. In the first possible case, extra resources and time are spent to produce a straightforward solution. In the second case, the solution may be not adequate.

Make everything as simple as possible, but not simpler.

– Albert Einstein

Experimental modeling and testing. Normally, the conformance of a final design to the regulatory, technical and safety requirements is verified experimentally, not theoretically. Experimental modeling and testing starts as soon as a physical prototype of the product is made. The goal is to reveal, fix, and improve the quality and performance of the product as early as possible. The design should be optimized experimentally by changing the prototype parameters and comparing the relevant acoustic or vibration spectra. Even simple listening and visual observation can help.

The knowledge of theory is very important to interpret the experimental results and develop effective improvement proposals. Ideally, the vibroacoustic laboratory includes a hemi-anechoic room for acoustic tests, shaker room for vibration and durability tests, and all the measurement equipment: microphones, accelerometers, laser-vibrometers, signal analyzers, conditioners, calibrators, shaker with its controller, and (if needed) strain gages, load cells, and speakers. The vibroacoustics engineer is to use and maintain the measurement equipment, know the typical standards, and train the laboratory technicians for the routine tests. If the company cannot purchase expensive facilities for vibroacoustic measurements, they can be rented. But a simple reverberant room can be arranged within the company for acoustic noise testing, and a hammer impact set may partly replace a shaker for vibration modal testing.

Computer knowledge and modeling. As some people believe, with the recent progress in computer modeling, the product can be designed and optimized with no need for a physical prototype and labor and time-consuming experimental studies. Moreover, with finite-element analysis (FEA) and computational fluid dynamics (CFD) software, many engineers neglect the mathematical models used before computers became so widespread. Indeed, FEA and CFD produce illustrative graphical and animation results (vivid pictures of vibration modes or sound pressure distributions), but at least now and in the near future the software modules cannot fully replace the experimental and analytical methods.

First of all, even a computer model is just an approximation of the real object.

All theory is gray, my friend. But forever green is the tree of life.

– Johann von Goethe, "Faust"

So the experimental simulation is still of importance. Besides, the analytical knowledge remains essential for interpreting computational data too. The other reasons are both subjective (user errors in setting the dimensions, material parameters, and boundary conditions, etc.) and objective (the software does not estimate all the physical effects or takes much time for accurate computation).

Collaboration with the design and industrial engineers. Because of multi-functional requirements to the product, all team members must discuss any design correction before it is implemented. Otherwise, the "correction" may improve one and degrade other parameters of the product. This puts more limitations for each member of a project team, particularly for the vibroacoustcs engineer, because the product cost and performance are commonly more important than the noise and vibration problems. It is noteworthy that a vibroacoustics engineer should collaborate with the industrial engineers too, in particular, to develop industrial on-line testers for the quality control of mass production.

Conclusion. It is not easy equally to get a good job and to find the right specialist to do it. Hopefully, my suggestions might help; at least for vibroacoustic applications.

1. Keith Sawyer, *Group Genius: The Creative Power of Collaboration*, Gildan Audio, 2008.
2. Jeff Stibel, *Why a Great Individual Is Better Than a Good Team*, https://www.scribd.com/document/61607367/Why-a-Great-Individual-is-Better-Than-a-Good-Team
3. A. A. Sveshnikov, *Problems in Probability Theory, Mathematical Statistics and Theory of Random Functions*, Dover Publications, NY, 1978.

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