EDITORIAL

Thinking *is* Required!!!

***Peter Avitabile**, Contributing Editor*

Typically, I am not one to get on the soap box and preach my beliefs. (Who am I kidding – I have just written this editorial!) Anyway . . .

In recent years, I have become more and more frustrated with the lack of basic engineering thought processes in trying to solve basic vibration problems. Rather than thinking about how to solve a problem or apply basic theoretical concepts, today everyone wants a push button answer. The basic motive is to get an answer or get a problem fixed rather than understanding how the problem occurs so that future designs will avoid the root cause.

Burger King Mentality. I worry about this because it appears that no one wants to think anymore. We want to make massive analytical models that will supposedly solve every possible problem that needs to be addressed. The model is developed from some CAD database with the push of a button. Somehow loads are applied, boundary conditions are applied, stress/strain/modes, etc. are computed – and then either a *red* light or a *green* light magically appears on the computer screen notifying the user whether the design is acceptable or not. At least that is what we would like to see. Of course, we don't just see red or green but rather a myriad of beautiful colors appears on the screen for our viewing pleasure. But at some point, someone needs to interpret all these colors to determine if the design is acceptable or not.

What most companies want is a 'process' for the design sequence. Some predetermined, well-defined sequence of steps or events that are performed in order to design every piece of equipment. I call this the "Burger King Mentality." Basically, the process becomes a push button approach stated simply as: "Burger, fries, coke, $3.28 total, $5.00 received, $1.72 change." Bingo – no thinking required whatsoever. (And heaven forbid you give them that 3 cents extra *after* they hit the button because you know they will have to call a manager to figure out what to do. And, of course, I'm not sure the manager won't break out into a cold sweat and offer your lunch for free to avoid the simple math.) I am terrified that eventually the same will happen with our engineering skills.

Generally, what happens is that 'habits' are developed when the same types of structures are tested (as in a particular industry such as disk drives or automotive structures, etc.). Since the overall effort is to streamline the process to efficiently move products out the door, there is insufficient time (and many times money or desire) to train the next person to take over the function (as people move upward or away) – so the 'habit' becomes a 'procedure.' The original thought process gets lost in the shuffle. This is also true for generic industry standards for vibration testing, shock testing, etc. Most people really don't know *why* they have to perform the procedural steps in a certain fashion, they just know that they *have to* follow those steps in order to *certify* certain equipment for certain applications. Without knowing *why* certain steps were created in a standard or procedure, a test engineer is at a loss when a test anomaly occurs and requires intervention (and thinking).

It is a bad state of affairs when there are many people conducting important tests and analyses who have picked up "rules of thumb" that are totally void of any real technical substance. The common expressions include:

- "This is the way we always do it."
- "That's what they told me to do."
- "I'm just following the procedure."

What happens is that these people working in a certain industry *learn* these 'habits' and don't understand *how* and *why* the 'habit' was developed. As they move on to different industries as more 'experienced' engineers (with younger inexperienced engineers below them), they then apply those 'habits' to different problems where the 'habits' they learned may not be applicable – there are many "war stories" that could be cited here!

These are people who are blindly following a set of rules with no real understanding of their basis, approach or procedure. I worry because people need to be able to think and make decisions about the data they collect or the analyses they perform.

Chimpification. It would be wonderful if all of our engineering design and analysis functions could be put into simple procedures. At some companies, the objective is to put every analysis or test into a 'process' – a fool proof set of instructions so that no one ever has to think. Wouldn't that be great? (But realize that when this happens, there won't be a need for the highly trained/paid engineer!) At one company, I have recently heard this referred to as 'Chimpification' – trying to make a standard process that a monkey could successfully perform. Then all that would be necessary is a "Noise & Vibration Processing Person." I have a very hard time envisioning a near-term point in time where vibration problems are so mundane that they can be relegated to a nontechnical individual.

The problem with this approach is that we are expecting everything will go as planned or expected. A checklist of tasks and expected results is all that occurs. But what if an unexpected result occurs? Will the "Processing Person" ever have enough understanding and training to be able to realize that a problem exists and flag a potential problem? Unfortunately, if a certain anomaly has not been anticipated, the "Processing Person" may not even think twice that there is a potential problem. I remember one day in the supermarket, trying to explain that a particular package of chicken had an incorrect price per pound. It was marked as more expensive than the best steaks! All the clerks were dumbfounded and didn't know what to do. Obviously, the person who weighed and labeled the chicken didn't pay attention to the fact that $25 for 3 pounds of chicken is very overpriced!

People get complacent when their job becomes a simple procedure. They don't know how to think anymore and don't have a basic understanding of what they are doing. This is inherently bad as far as I am concerned. People have a hard time getting a 'ballpark' or "order of magnitude" answer to a problem. In the old days of slide rules, we inherently had to think in our heads what the resulting number or answer would be and make sure we had the right magnitude. Now everyone punches numbers into a calculator rather than thinks about what the size of the numbers might be.

There is a great deal of time spent in the educational process to force engineers to think rather than just provide rote skills to solve specific problems. Students fall prey to this due to the manner in which we teach. All the material to solve a given problem at the end of the chapter is contained in that chapter. These problems are clearly defined with only the necessary information to solve the specific problem. Give the same problem on a test – but give extra unnecessary information not needed to solve the problem – and many students crumble since there is too much information provided. They have a hard time because they have been trained to solve the clear cut problems. They need to learn how to think! We struggle in education to force students to think so they can perform well with problems that are not well defined and require multiple tools to solve the problem. If we provide 'Chimpification' then all these young engineers will quickly forget all their basic knowledge since they won't have to think and will only be required to follow the rules of the process.

Rainman[1] Effect. The next problem I see is what I call the "Rainman Effect." Engineers immediately skip the basics like simplistic modeling or experimental approaches and jump right into a massive model or extensive array of measurements. I recently saw a modal test being set up with hundreds of measurement locations and no preliminary measurements acquired. Before a large detailed test is performed, it is always wise to take a few measurements to determine some of the basic characteristics prior to instrumenting the entire structure. Thoughts as to how many modes, what characteristic shapes, directional modes, transducer types, etc. all come into consideration here. What if the measurements are poor or the system is nonlinear? Why bother taking 300 measurements if the FRFs are going to be inadequate to obtain basic information? What effects do the test boundary conditions have on the extracted data? Should the structure be free or fixed? What effects does the fixturing have? And many more questions come to mind. But when given a task to perform a test, often the test engineer provides the specific data requested by the project engineer – whether or not the requested test makes any sense or not! A common statement typifies these situations: "That's what they wanted so I assume they knew what they needed."

And of course with today's technology, a finite element model can be generated at the snap of a finger with hundreds of thousands of elements that are generated to model a structure – but is the mesh refinement justified? Many times it is not. This step is skipped because there is not enough time or not enough disk space or not enough understanding. Many times the mesh 'appears' to be so completely refined that the analyst's answer is "How could you possibly think that the model hasn't converged? Over 250,000 elements were used for the analysis. That's the way we always model that part. Plus the disk drive can't handle a larger model so that's the best that can be done." So does that mean the model is correct??? What about taking the model with a mesh density that is half of the current model??? If the results are the same then a converged solution has been obtained. But if there is significant difference then there is no basis to think that the "so called" detailed model has converged.

These finite element models are an important part of many design processes. But what are the boundary conditions? What types of elements best describe the phenomena to be determined? What are the material properties? The list goes on and on. The natural frequencies can be reported with surprising numbers of significant digits, but what are the material properties, what are the actual boundary conditions, what are the real loads? Generally, a vague understanding of these basic parameters exists but they are critically important to the estimated parameters.

Experimental testing has also become a common effort in many companies today. But when asked about the setup or other aspects of a test, many times no one knows why the test is conducted a certain way. In free-free testing, a question always arises as to the dynamic coupling that might exist between the rigid body modes and lower flexible modes. There might be sufficient separation between the modes, but when asked *if* there *is* enough separation between these modes, there should be a good technical answer. The answer shouldn't be "Harry told us that 3 to 1 separation is good enough." This separation may be adequate for the structures that Harry has tested in the past, but the real question is "Is that separation adequate for the structure you are testing today?" Someone needs to *question assumptions*! (but please do so very cautiously and delicately if Harry is your boss)

In both the test and analysis scenarios above, what I refer to as the "Rainman[1] Effect" exists:

"What is the square root of 2343, Raymond?"

"48.404545241123792630003201 43."

"Did you model the structure to account for the local flexibility of the attachment points or did you model it free or constrained?"

"yeah . . ."

"Did you test the structure free-free or built-in?"

"yeah . . ."

Somehow we can report the natural frequency with many significant digits but have no idea what the Young's Modulus is for our material. And is it a nominal, maximum or minimum? And what is the variance? Most people don't know! We want to correlate models and adjust model parameters to reflect test data but don't know what the real loads are or what the boundary conditions are. What effects do the design tolerances have on the computed results? We can report answers in extreme detail but don't have a feel for what the basic real-world application means to the results. Many times, the computer solutions look so real due to the color and animation that we convince ourselves that the solution must be correct. The solutions obtained must make physical sense. (Otherwise a candy bar and a brand new shiny car will both cost $100 – at least according to the Rainman!)

Thinking is Not Optional! In order to solve engineering problems, engineers must think. If the problems are that simple and straight-forward, then they are not problems. We could then apply 'Chimpification' or the "Burger King Mentality" to the problem. And if we only need to apply excruciating detail to determine answers and do not need to know what the answers mean, then we can hire Rainman to solve our problems. (*definitely, definitely*!) Of course, with this approach, invariably there will be many problems that arise to which everyone will say "*uh oh*!" and might not know what to do. Thinking is required to solve the majority of problems we face. "The Burger King Mentality," 'Chimpification' and "The Rainman Effect" must always be avoided at all costs.

And remember next time you are at Burger King and you see the Chimpification process in progress, slip the clerk some extra change and see how long it takes for them to do the math in their heads – but you can't let them take too long since it is only 15 minutes to the Judge Wapner show! S/V

1. *Rainman*, starring Dustin Hoffman as Raymond.

The author can be contacted at: peter_avitabile@uml.edu.