

"The Emperor's New Clothes" of Modern Theory of Strength and Destruction And Reliability Assessments Methods

"You can fool all the people some of the time and some of the people all the time, but you cannot fool all the people all the time."
Abraham Lincoln

Dear reader!

I assume that you are not an expert in the theory of strength and destruction; and reliability assessment methods and you are forced to trust specialists and convinced that they know this theory and methods when they write articles in scientific journals. If you have finished school and you have certain knowledge in physics and mathematics, then you certainly know that it is impossible to answer the question: what is greater the two feet or two pounds? I understand that you were surprised by my question, for you probably know that only physical parameters having the same dimension can be compared. Sort of "apples to apples..."

Ok, just please bare with me - it gets interesting...



The picture here is from a scientific magazine (M.D. Chapetti, J.L. Otegui, J. Motylci: *Fatigue Assessment of an Electrical Resistance Welded Pipeline*, Int. J. of Fatigue, 2002, **24**, 21-28).

It shows a 20-year old oil pipeline API 5L X46 (Argentina), which had ruptured and created a large crack of 4.8 meters (15.84 feet).

The two sections were cut out for research of the causes of such rupture and prevent similar catastrophes in a future.

The pieces of pipeline were stretched and bent; the cracks were measured, the number of cycles was counted and the researchers were using PERIS-ERDOGAN EQUATION in the process:

$$\frac{da}{dN} = C \Delta K^m \quad (1),$$

Where da - crack elongation (m); dN - increase of number of cycles of impact (stretching, compressing and/or bending), C - coefficient of proportionality (m/cycle), m - exponent, $\Delta K = K_{max} - K_{min}$ stress intensity factor (SIF). The ratio da/dN is called **Velocity of Crack Propagation**.

The results of these calculations: $m=6$, $C=3.818 \cdot 10^{-15}$ m/cycle.

Please note that the size of atomic nucleus is $\sim 10^{-15}$ m; the closest distance between atoms of iron is $2.48 \text{ \AA} = 2.48 \cdot 10^{-10}$ m.

So, the mathematical extrapolation above is incorrect from the physics point of view and can be refuted experimentally, since a crack formation has a sporadic nature indicating energy accumulation periods.

Modern experimental methods allow to control individual atoms, determine the distance between them to the fractions of *angstrom* ([unit of length](#) equal to 10^{-10} m). In this regard, it is meaningless to write about a crack, the size of which is smaller than the size of an atom and comparable with the size of the atomic nucleus. The number $3.818 \cdot 10^{-15}$ m does not mean that the measurements were carried out with such accuracy. ***This value is obtained by dividing one number by another.***

The dimension of the left part of the formula is meter, dimension C is also meter. Therefore, $\Delta K = K_{\max} - K_{\min}$ is dimensionless. At the same time, G. Irwin, proposing such a new parameter in 1957, offered a formula $K = \text{MPa}\sqrt{m}$ where m has the dimension of a meter. Thus, the dimension SIF— $\text{Pa}\cdot\text{m}^{1/2}$, i.e., ***these two formulas contradict each other.***

Now let's review a second equation, called NASGRO. Office of Aviation Research Washington, D.C. 20591 Fatigue Crack Growth Database for Damage Tolerance Analysis (DOT/FAA/AR-05/15) by Office of Aviation Research Washington, D.C. 20591 states that “The **NASGRO** equation is unique among crack growth rate models in that it fits the asymptotes in both the threshold and critical crack growth regions, accounting for the influence of on the fatigue threshold and considering the effects of crack closure.”

[“NASGRO is the most widely used fracture mechanics and fatigue crack growth software in the world today.”](#) – says NASGRO® Fracture Mechanics & Fatigue Crack Growth Analysis Software brochure by Southwest Research Institute (SWRI.ORG).

$$\frac{da}{dN} = C \left[\left(\frac{1-f}{1-R} \right) \Delta K \right]^n \frac{\left(1 - \frac{\Delta K_{th}}{\Delta K} \right)^p}{\left(1 - \frac{K_{\max}}{K_c} \right)^q} \quad (2)$$

NASGRO equation включает четыре вида of Stress Intensity Factor - SIF ($\Delta K, \Delta K_{th}, \Delta K_{\max}, \Delta K_{crit}$) и пять безразмерных коэффициентов (f, R, m, p, q), для вычисления которых предлагаются различные процедуры расчета. Для этого авторы формул вводят новые параметры.

The NASGRO equation includes four types of Stress Intensity Factors (SIF) - ($\Delta K, \Delta K_{th}, \Delta K_{\max}, \Delta K_{crit}$) and five dimensionless coefficients (f, R, m, p, q), for the calculation of which various calculation procedures are proposed. The authors of the formulas introduce new parameters for this purposes.

We will not analyze these additional equations, since they are only different by one parameter of the material, the thickness. Note that the members of the right side of the equation in parentheses do not have dimensions. Consequently, the NASGRO equation differs from the Paris-Erdogan equation only by a multiplier.

There is a very popular [NASGRO software](https://www.nasgro.com/) that is being used everywhere. Although the software can only process what mathematical model tells it to process based on the *data* entered. Richard Feynman once said and it became a rule of thumb in computer world: "GIGO: Garbage In – Garbage Out!" (<https://www.dictionary.com/browse/gigo>), meaning that faulty *data* leads to faulty results.

Thus, modern methods of reliability assessment of technical structures components (BTW: all over the world, since the whole world has copied the US technology) rely on two basic equations, are devoid of physical meaning, in other words - meaningless. This absurdity in the formulas described above should have been noticed by a school student and exclaim: "Nonsense! The Emperor has no clothes! ". However, this does not happen, perhaps because in schools these formulas are not shown to naive students, but by the time students become engineers and scientists, their minds are blinded by the bright light of magical formulas; and therefore reliability assessments continue to make conclusions devoid of physical meaning, that is, of any useful meaning. The biggest "Elephant in the room" of modern reliability assessment methods is that while using the equipment that is based on principals of *quantum mechanics* they are drawing conclusions based on classical mechanics.

Assessment of reliability is not just some kind of unrelated scientific experience - it is something very concrete, like the investigation of cracks in the fuselage of the aircrafts on which we are flying. Error in calculating reliability assessment is a game of "Russian roulette" with the lives of people both on board and on the ground.

Now you know...and I hope that now it troubles you not less than me.

The Question is: what will we do about it?