The University of Jordan
School of Engineering

Department	Course Name	Course Number	Semester
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Safety factor: How do I calculate that?

How do I know if the design of my part is « safe » enough?
That's a difficult question that many designers asked themselves.
One of the potential answers involves the measure of the **safety factor**.

***Important note**: This article talks mainly about "stress-based" safety factors, but you should know that there are different definitions of "safety factor" margins, which are not all necessarily related to the state of stress. Additionally, stress definitions can vary… there is Von Mises Stress, but also Tresca, etc.….*

Getting safe designs

First of all, I think it is not too much to remind that one of the purpose of simulation is to get safe designs…

When a part fails, it involves of course a **risk for the life of people**, but also a **huge financial loss for the company** who created this part (just think about the explosive Samsung batteries and you will understand what I am talking about)

FEA simulation helps to understands **why a design fails**, **where it failed** and **how to improve it**.

That's why FEA is so important for companies who design products. To assess the safety of a design, designers need a simple factor which will help in understanding if a design is safe enough. This factor is called the safety factor.

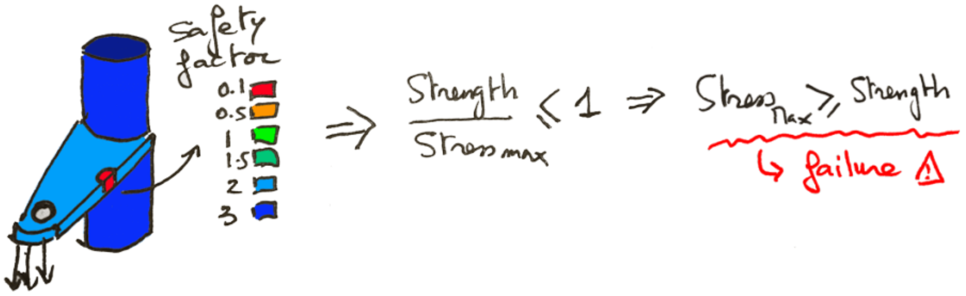
How is the safety factor calculated

The definition of the safety factor is simple. It is defined as the ratio between the strength of the material and the maximum stress in the part.

$$\text{Safety Factor } n = \frac{\text{Strength}}{\text{Stress}_{max}}$$

When the stress in a specific position becomes superior to the strength of the material, the safety factor ratio becomes inferior to 1, this when there is danger

What it tells us basically is that in a specific area of the model, the stress is higher than the strength the material can bear.



When the stress in the model remains much inferior to the strength of the material, the safety factor stays superior to 1 and the model is « safe ».

Keep in mind that if the safety factor is way superior to 1 everywhere in your model, this is also indicating that your part may be over-engineered. In this case, this is not desirable either, because you are just wasting material resources and increasing the cost.
Now, let's talk about the 2 important values that you need to calculate this safety factor: Stress and Strength

What is stress?

If you still have some doubts about that, no shame, it's not a concept easy to grasp for beginners, but it is an essential one.

In short, stress is a value that measure the inner pressure inside a solid which is cause by an external loading. If stress is too high inside a part, the part may fail.

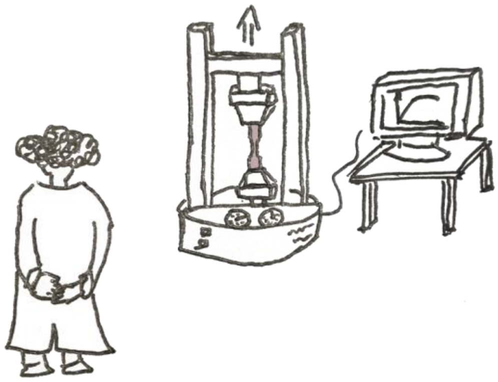
The notion of stress is not so different with what we experience every day at work… When we receive a load of work, we become stressed. If we are too stressed, we may experience a nervous breakdown and many health problems.

What is the strength of a material?

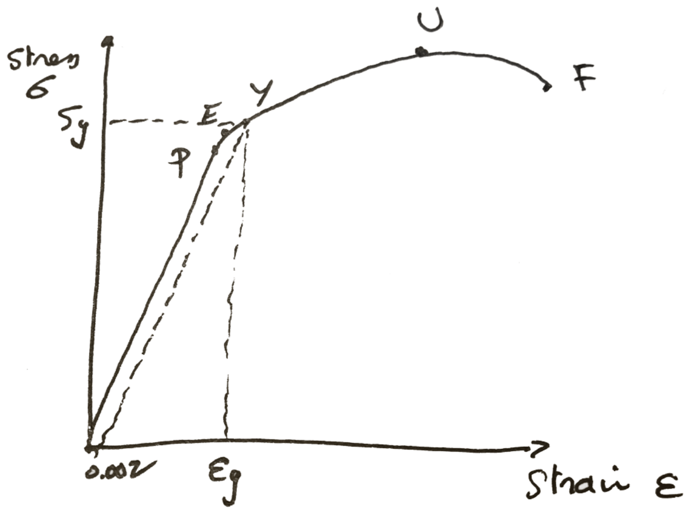
Stress and Strength are different and that's where many people don't get it.

Stress in a body is always a function of the applied loading and cross-section, whereas strength is an inherent property of the body's material/ manufacturing process.

Strength is obtained similarly to other material properties, by doing for example a standard tensile test which subjects a sample bar to uniaxial stress. Then we can draw the material stress-strain curve by extracting the deformation data and plotting it in function of the load data.



Note that if you need some high accuracy, the test should be performed under conditions similar to the operating conditions of the part or the system (Temperature, strain rate, material grain, flow direction,…)



There are several important points to understand on this curve:

- The point P is the proportional limit, it limits the portion of the curve which governed by Hooke's law
- The point E is the elastic limit. The material will continue to behave elastically up to point E, but stress and strain won't be proportional anymore.
- The point Y is the yield point which corresponds to the yield strength of the material
- The point U indicates the maximum stress that can be achieved by the material. It corresponds to its ultimate or tensile strength.
- The point F is the fracture point.

Note that the points E and Y may coincide for some types of materials such as ferrous materials.

The yield point is not necessarily very clear, and it is generally obtained by an offset method:
Y is considered to be the intersection of an offset line, parallel to the linear portion of the stress-strain curve typically at 0.002 axial strain, and the plastic portion of the curve.

As you read, there are several material strength values: the yield strength, the ultimate strength and the fracture strength.
The safety factor is calculated with the yield strength so this is the parameter you need to know in priority.

Is this ratio a perfect indicator of a model safety?

I'd like to say that nothing is really perfect… As engineers, we have to learn to live with errors ;-)
Errors are everywhere:

- In the testing process that will provide you with the stress-strain material curve and the yield strength used to calculate the safety factor
- In the FE model that you build, it is probable that the boundary conditions and/or the meshing will cause a certain amount of error

- In the FEA software itself and the algorithms it uses, error is included (and hopefully controlled)

That’s why it’s always better to consider a safety factor which is not exactly 1, but maybe a little higher (2-3) depending on the hypothesis you take.

Additional note: The safety factor only describe material failure. In some designs, it is sufficient, but if you are designing a slender element some form of stability failure (i.e. buckling) may occur. Such safety factor do not take that into account since buckling can happen when stress is much smaller than limit stress of the material.