CHAPTER 8

Resistance verifications

8.1 Introduction

Once the model has been validated, at least from the numerical point of view (as we have seen in Chapter 7), it is necessary to proceed with the structure resistance verification.

Substantially for each load condition, for each critical point, for each connection and/or connecting member it is necessary to evaluate the "safety factor" or its homologous "margin of safety"; we will see below that the difference between them is just a numerical one, while they substantially indicate the same thing: the capability, or the incapability, of the structure to withstand the applied loads.

Generally the minimum values of these coefficients vary depending on the structural engineer experience, on the type of structure being designed, on the level of uncertainity of the boundary conditions (i.e. loads known only approximatively or based on some imprecise estimations), on the uncertainity of the used materials behaviour; sometimes the minimum value is fixed by a Supply Specification.

Usually the safety factor (η) is calculated as the ratio between the allowable value and the stress applied to the member under examination: in the case of structure portions this will generally be a ratio between stresses, while for rivets, for example, it could be a ratio between forces. Anyway we can say that:

$$\eta = \frac{\text{Allowable}}{\text{Applied}}$$

The safety margin (S.M.) is calculated in the following way:

$$\text{S.M.} = \frac{\text{Allowable}}{\text{Applied}} - 1$$

It is also clear the equation that relates η to S.M.:

$$\text{S.M.} = \eta - 1$$

Traditionally in mechanical environments the safety factor is the most used one, while in aeronautic environments the most used is the safety margin.

As they are related by the seen equation, using either one or the other is completely indifferent, but it must be clear which of them is used; in fact when we talk about η the discriminant limit is 1 while for S.M. the limit is 0. How much is necessary to stay away from these limits depends on the factors seen above.

In both cases, anyway, when we are above the limits, the two coefficients indicate how big is the "reserve" that the structure has in that point before reaching the collapse (which can be the yielding or the rupture).

In the following paragraphs we will discuss both static and fatigue verifications, starting from the assumption that the data used are the ones given by a finite element calculation.

8.2 Static verification

8.2.1 Continuous structure portions

In structures constituted by homogeneous and isotropic material static verification today rarely represents a problem, because of the use of resistance criteria consolidated and frequently validated by experimental tests.

The most used criterion is the one based on the equivalent Von Mises stress σ_{VM}; this "number", as we have seen in Chapter 7, is a combination of principal stresses but it can also be obviously expressed as a function of all the stress tensor components. We can therefore have the following two equations valid for the σ_{VM} calculation:

$$\sigma_{VM} = \sqrt{\sigma_I^2 + \sigma_{II}^2 + \sigma_{III}^2 - \sigma_I \cdot \sigma_{II} - \sigma_{II} \cdot \sigma_{III} - \sigma_{III} \cdot \sigma_I}$$

$$\sigma_{VM} = \sqrt{\sigma_{xx}^2 + \sigma_{yy}^2 + \sigma_{zz}^2 + 3 \cdot \tau_{xy}^2 + 3 \cdot \tau_{yz}^2 + 3 \cdot \tau_{xz}^2 - \sigma_{xx} \cdot \sigma_{yy} - \sigma_{yy} \cdot \sigma_{zz} - \sigma_{zz} \cdot \sigma_{xx}}$$

Usually calculation codes can directly evaluate the σ_{VM}, while in other cases are the post-processors that, starting from the stress tensor, calculate the σ_{VM}.

Anyway, once the σ_{VM} is known, it is possible to calculate the safety factor (or margin) in all the points of the structure. The σ_{VM} will be the applied stress, while the allowable stress depends on the material used: generally the material yielding limit is assumed, because residual deformations, due to plasticization of some regions, are not allowed. Only in exceptional cases structure are designed to their ultimate strength (rupture) and mainly just to evaluate the margin with respect to their catastrophic collapse; in this case the use of σ_{VM} might not be indicated because it could be excessively conservative. However in most cases this way is followed and safety factor (or margin) are calculated with respect to material ultimate strength just using this value instead of the yielding one.

Rarely the Guest criterion is used because it is definitely more conservative than the Von Mises criterion; we just mention it, as it is seldom used, and for this reason only a