Thesis proposal

Theme: Determination of the stress concentration factor for multiple stress concentrators using the finite element method for elements in three dimensions.

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Here, it can be demonstrated that the formula to calculate the theoretical average normal stresses is $\sigma = F/A$. According to Saint-Venant's principle, it can be assumed that the normal stresses distribution on an element with axial loads is uniform, except in the vicinity of where that load is applied. Therefore, it is valid to assume that the distribution is uniform when the force is applied on the centroid of the cross section. This doesn't mean that the distribution is always uniform, for example for axially load members with an eccentrically applied load.

If instead of applying the load axially it is applied perpendicularly to the axis, a different inner force is produced. This is known as shearing force. If this is divided over the area of the section, it will result in the average shearing stress. Therefore, $\sigma = V/A$. Here, it can also be assumed that the stresses are uniformly distributed over the entire section. In reality, this distribution isn't uniform, because it varies from the surface of the element, where it is zero, until it reaches a maximum value, which can be located where the cross section is not constant.

Analyzing the formulas described before, it can be said that they can only be applied for elements with an uniform cross section, or with a gradual change in its geometry. Nowadays, because of the more and more advanced applications in engineering, there aren't a lot of elements with these characteristics, and if we consider three dimensional elements, we'll find very few cases. For example, when a shaft is designed, roundings, key seats, retaining rings grooves, etc. are included, and they generate big stress concentrations. Generally, when discontinuities are presented in certain elements, there's where the bigger stresses are generated.

In order to have a clearer idea about how stress distributions are and behave in three dimensional elements, there are analyses made by the photoelastic method. This method serves only to have an idea of how the stress concentrations are, but it does not tell you if they are going to make the element fail. Trying to develop a method for an easier and simpler analysis, stress concentration tables have been created. These tables include data that is independent of the size or type of material used, and they just depend on simple relationships according to the type of geometry. However, most of these tables are for two-dimensional elements.

What a designer is interested in is in obtaining the maximum given stress in a specific section, in order to be able to determine if that stress overpasses the allowable stress. That is why this relationship has been developed:

$$K_t = \frac{\sigma_{\max}}{\sigma_{aver}}$$

This indicates a factor which is the ratio between the maximum stress and the average stress generated in the critical section of the discontinuity. This factor is known as stress concentration factor.

Values obtained by this formula are theoretical values. To be able to obtain more precise results, an analysis with the same precision has to be made. Here arises, as a limitation of the problem, that the analysis of each element is only valid for that particular element, because if more discontinuities, key seats, section changes, etc. are added, it will generate a totally different stress distribution, and also a different stress concentration.

To make this analysis easier, a tool known as the finite element method can be used, which not only simplifies the problem, but it provides a better and clearer idea of what is happening in each particular element. To increase the precision in the data obtained, it has been developed the computer assisted finite element analysis. As an example of this software there is ALGOR®, which allows manipulating the stress concentrations according to the designer's criteria. Also, using parametrical software as Pro-E, the designer can create the model of an element by CAD, and then simulate it in ALGOR®, and based in this analysis, make a diagnostic of how the element is going to behave. If the analysis gives as a result a high stress concentration in a certain area, the designer can modify the element according to his criteria in the parametric software, and make the computer assisted finite element analysis as many times as it is necessary, until reaching an optimum result. Here is important to say that even if this analysis is closer to reality, there are still some points to consider, because the software is not capable of identifying external factors such as material failures, impurities, thermal treatments, etc. Nonetheless, ALGOR® represents a very useful tool to elaborate tables for three-dimensional elements.

General objective:

To estimate the stress concentration factor for a shaft (three dimensional element) with one or more stress concentrators in diverse geometrical arrangements subjected to tension and compression loads applying the finite element method by using the software ALGOR® to be able to find the way to modify the stress concentration factor (Kt) in order to increase the number of cycles that a shaft can support.

Specific objectives:

- Take models from the literature, and subject them to proper analysis in ALGOR®, in order to demonstrate that the recommendations of the literature are based merely in experience, but not in real experiments.
- Create the model of the shafts with stress concentrators subjected to tension-compression, torsion and bending loads in Pro-E, and then analyze them in ALGOR®.
- Determinate the maximum stress for each previously modeled case.
- Determinate the stress concentration factor for shafts with multiple stress concentrators placed in series.

Limitations:

In this investigation, the maximum stress and the stress concentration factor will be determined for three dimensional elements using tools like ALGOR®, without using another computer analysis or by any other method.

Charts will be elaborated to have a better idea of the stress concentrations in certain specific geometries, utilizing as a basis only the data obtained by ALGOR®, and trying to make a comparison of the obtained data with the actual existing data.

For each proposed model, charts will be elaborated according to the results obtained. In the same way, stress concentration factor results will be delivered with its respective chart, and also the maximum stress obtained and the nominal stress, together with some recommendations to optimize the design.

Because of the great variety of models that can exist for three dimensional elements, this thesis will try to take into account the most common, so that these models can be taken as basis for elements with a similar geometry.

Methods and techniques:

- Review the basic concepts of stress, stress concentrations and factors that can have certain influence on them.
- Review the finite elements method, applications and mathematical tools as matrixes.
- Solid modeling in Pro-E® and AutoCAD2002®.
- Use of ALGOR14®.
- Use of tools as Microsoft Office®.