Fatigue Life Calculator for Ansys Workbench using ACT/PYTHON

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Abstract:- **The traditional HCF/LCF life evaluation is manual process of recording/probing the alternating stress and mean stress for each node in FEA model, followed by using Goodman diagram to calculate the life. The process is time consuming for evaluating the entire model fatigue life. Automating the manual process in CAE is of utmost importance for error-free calculation, productivity improvement, reliable, and reduced design cycle time. The above objectives were met by developing fatigue life calculator tool. The tool carries out high cycle and low cycle fatigue life calculations based on Goodman failure theory. The fatigue life calculator is automated process of calculating the HCF/LCF life. The tool extracts the stress for all nodes from alternating stress and mean stress FEA models. The tool also supports the solution combination operations for various load case result sets. The ACT extension "HCF/LCF Fatigue Life Calculator" is developed for ANSYS Workbench. The tool is developed using ANSYS Workbench API, XML, Microsoft visual studio VB, and Python. The tool also contains several .NET forms for user information and guidance. The ACT extension creates seven submenus under "Life Calculator" menu. First, the tool extracts the mean stresses and alternating stresses. The tool created ANSYS Workbench journal for mapping the results from harmonic analysis FE model to mean stress FE model i.e., tool supports the different mesh between mean and alternating stress FE models known as location-based evaluation. Then, user choice for solution combination will be taken using additional tool developed in Microsoft visual studio VB application. Once user choice is taken, the ACT extension performs solution combination and fatigue life calculations for entire FE model. The tool also supports the displaying the results in Ansys mechanical. The tool plots the life contour on FE model in ANSYS mechanical.**

Key Words: - High Cycle Fatigue (HCF), Low Cycle Fatigue (LCF), Fatigue Calculations. ACT/Python, ANSYS Workbench and Automation, Python Extensions. MS Visual Studio, ACT Extension

INTRODUCTION

The traditional HCF/LCF life evaluation is manual process of recording/probing the stress for each node in alternating stress FEA model & mean stress FEA model. The Goodman diagram is used to calculate the life of area of interest/node/location. The traditional method is cumbersome, when iteration involves more nodes or location-based evaluation is required (FE models are different between $\square_{alt}$ $\square$ $\square_{mean}$). The HCF/LCF Fatigue Life Calculator will help the CAE engineers to evaluate the HCF/LCF life faster and with accuracy. It makes the calculations reliable and eases the review. The HCF/LCF Fatigue Life Calculator is an Ansys Workbench ACT Extension developed using Python software.

The Ansys workbench extension can be installed with the help of the Ansys Workbench Extension Installer. The tool extracts the stress for all nodes from alternating stress & mean stress FEA models. The tool supports the solution combination operations based on user input. The tool uses Goodman criteria for life evaluation. The tool is developed in "ANSYS Workbench ACT/Python software". The tool calculates & plot the life for all nodes as contour plot in ANSYS mechanical. The tool supports location-based evaluation for mapping the results between two different FE models i.e., $\square_{alt}$ $\square$ $\square_{mean}$. Developments in automation tools posed the requirement of faster and reliable methods. HCF/LCF fatigue life calculator fulfilling these requirements, became the first choice for many industries.

ANSYS WORKBENCH ACT/PYTHON

Ansys ACT provides an intuitive and guided set of tools that helps to generate reusable scripts for customization. In addition, Ansys provides a full set of supporting resources to help with application development. ANSYS ACT Reference and Developer's guide [1] provide detailed API descriptions and comprehensive feature overviews. ACT's standard XML and IronPython/Python [2] approach for all Ansys products makes app creation easy to learn irrespective of the Ansys products planned to customize. ACT can apply the same consistent framework and APIs to meet customization objectives and workflows. Advanced users can also take advantage of the opportunities of .NET integration and support provided by IronPython/Python. For users interested in specific members or code methods, the ACT console is a convenient tool to interactively navigate the APIs through robust auto-completion.

MICROSOFT VISUAL STUDIO

Microsoft Visual Studio is an integrated development environment (IDE) from Microsoft [3]. It is used to develop computer programs, as well as websites, web apps, web services and mobile apps. Visual Studio uses Microsoft software development platforms such as Windows API, Windows Forms, Windows Presentation Foundation, Windows Store and Microsoft Silver light. It can produce both native code and managed code. Visual Studio supports 36 different programming languages and allows the code editor and debugger to support (to varying degrees) nearly

any programming language, provided a language-specific service exists. The Fatigue Life Calculator is developed in VB .NET [3] and it is used in getting the user inputs for performing the mean stress & alternating stress solution combination operation.

STRESS-LIFE (S-N) BASED FATIGUE ANALYSIS

In materials science, fatigue is the weakening of a material caused by cyclic loading that results in progressive and localized structural damage and the growth of cracks. Fatigue has traditionally been associated with the failure of metal components which led to the term metal fatigue. If the loads are above a certain threshold, microscopic cracks will begin to initiate at stress concentrations such as holes, persistent slip bands (PSBs), composite interfaces or grain boundaries in metals [4]. The nominal maximum stress values that cause such damage may be much less than the strength of the material, typically quoted as the ultimate tensile strength, or the yield strength.

The American Society for Testing and Materials defines fatigue life, N_f, as the number of stress cycles of a specified character that a specimen sustains before failure of a specified nature occurs. For some materials, notably steel and titanium, there is a theoretical value for stress amplitude below which the material will not fail for any number of cycles, called a fatigue limit or endurance limit.

Engineers have used several methods to determine the fatigue life of a material [4]:

- The stress-life method,
- The strain-life method,
- The crack growth method and
- Probabilistic methods, which can be based on either life or crack growth methods.

Materials fatigue performance is commonly characterized by an S-N curve, also known as a Wohler curve. This is often plotted with the cyclic stress (S) against the cycles to failure (N) on a logarithmic scale. The progression of the S-N curve can be influenced by many factors such as stress ratio, loading frequency, temperature, corrosion, residual stresses, and the presence of notches. A constant fatigue life (CFL) diagram [5] is useful for the study of stress ratio effect. The Goodman line is a method used to estimate the influence of the mean stress on the fatigue strength. A Constant Fatigue Life (CFL) diagram is useful for stress ratio effect on S-N curve [6]. Also, in the presence of a steady stress superimposed on the cyclic loading, the Goodman relation can be used to estimate a failure condition. It plots stress amplitude against mean stress with the fatigue limit and the ultimate tensile strength of the material as the two extremes.

FATIGUE LIFE CALCULATION AUTOMATION

The Fatigue Life Calculator is automated process of calculating the HCF/LCF life. The tool extracts the stresses for all nodes from alternating stress & mean stress FEA

models. To accomplish the stress extraction, tool has two toolbars as shown in Figure 1.
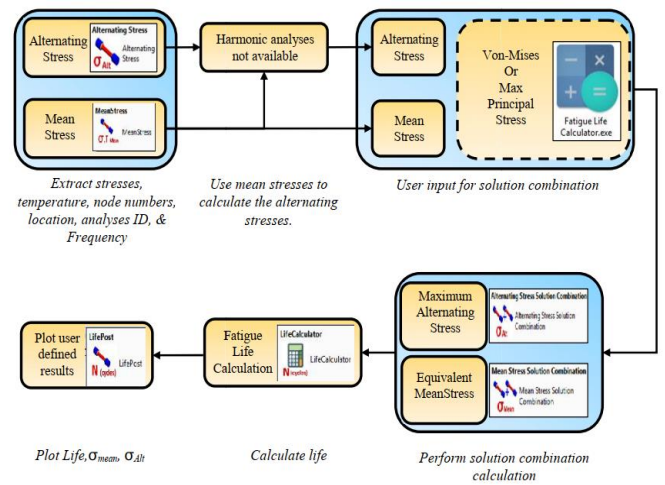

Figure 1. Fatigue Life Calculator flowchart

If in case Harmonic analysis results are not available, tool also supports deriving the alternating stresses based on the mean stress load cases. Once the stress extraction is complete, the tool performs solution combination operations as per user input provided for scale factor, von-Mises/maximum principal stress type & load case combination. User will input the S-N curve and ultimate tensile strength material properties in ANSYS WB and tool calculates life with respect to elevated temperature.

The tool has a capability to display the user calculated results or any user defined results as a contour plot on the FE model. The concept used to calculate the fatigue life is based on Goodman diagram. ANSYS Workbench/Python/Microsoft Visual Studio applications are used in developing the tool. Fatigue life calculator consists of six sub menus/toolbar to perform fatigue life calculation & help toolbar under "Fatigue Life" as shown in Figure 2. The first 4 sub-menus extract the stress and performs solution combination operations based on user input. The *Life Calculator* will calculate the life for all nodes. *Plot results* will plot the life of all nodes in ANSYS workbench.
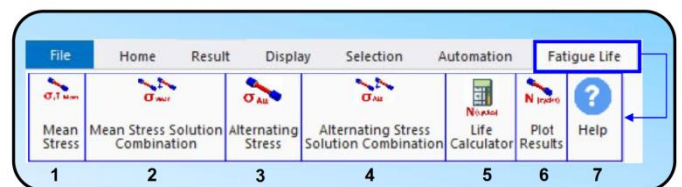

Figure 2. Fatigue Life sub-menu in ANSYS WB

The tool capabilities are as listed below:

- *HCF Life Calculator* can be used for any FE model size with faster turnaround time.
- *HCF Life Calculator* can be customized very quickly.
- *HCF Life Calculator* engineering tool suite can used across several domains including aerospace, automotive, energy etc.

Fatigue life calculator contains six ANSYS Python toolbar menus and one application to carry out the HCF/LCF life calculation.
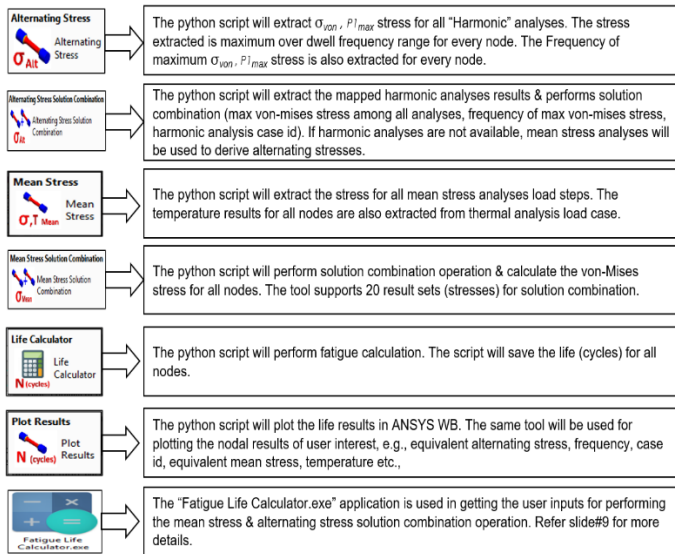

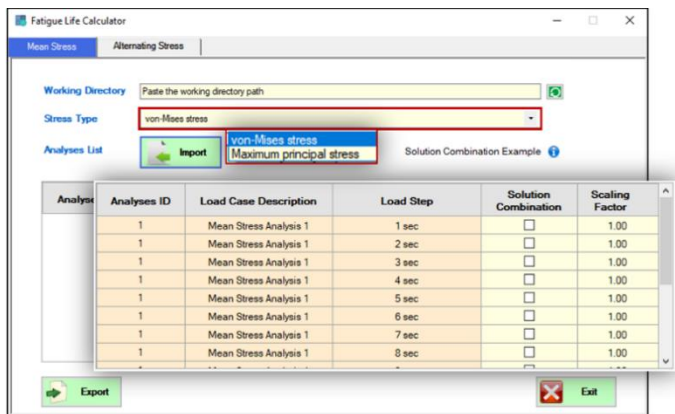Figure 3. Fatigue Life Calculator sub-menus description

Figure 4. Fatigue Life Calcualtor.exe "Mean Stress" menu tab

Fatigue Life calculator executable application is used to receive user choice to perform solution combination. There are 2 menu tabs available as shown in Figure 4 & 5. The mean stress analyses user input in first menu & alternating stress analyses input in second menu. The application usage instructions are:
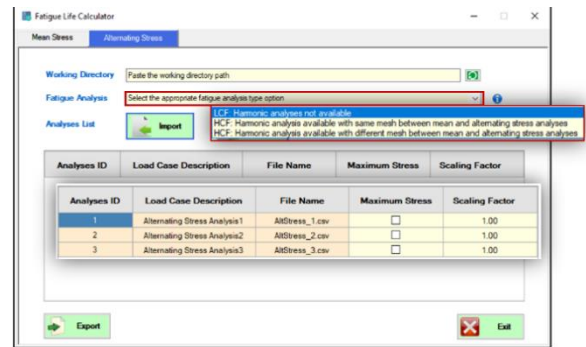

Figure 5. Fatigue Life Calcualtor.exe
"Alternating Stress" menu tab

- *User will input the ANSYS WB project user_files working directory path.*
- *The mean/alternating analyses list will be populated when "Import" button is pressed.*
- *All the FE analyses available in the user_files folder will be populated.*
- *User will provide appropriate choice/inputs.*
- *The user choices & scale factors will be written to "User Input" files by running "Export" macro.*

CONCLUSION

Automation has become an essential part of a successful design and development process. HCF Life Calculator helps increase the productivity and meet the short development cycle. Reliability of the tool is high, thus meeting the first time right. HCF Life Calculator can be used in different domains, onsite and offshore (e.g., aerospace, automobile, industrial) and other multi-disciplinary fields.

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