Maplesoft + ANSYS: the best solution to the chainsaw kickback problem

Emak Technologies is a renowned Italian company for professionals and hobbyists in lawn and garden maintenance. Emak was established in 1992, from the merger of two major companies specializing in the production of gardening and forestry machines: Oleo-Mac and Efco, both of which had been active since the '70s in Northern Italy's burgeoning enterprise sector.

The Emak Group operates worldwide, handling distribution in Italy and in another ten foreign markets - USA, France, Germany, UK, Spain, Poland, Ukraine, China, South Africa, Chile and Brazil - through subsidiary companies, offering a vast assortment of products with recognized brands and addressing a highly diversified customer target group.
Emak products address gardening and forestry duties and agriculture such as brushcutters, lawnmowers, garden tractors, chainsaws, rotary tillers and motor hoes. Emak also produce diaphragm pumps for the agricultural sector (irrigation and spraying), piston pumps for the industrial sector, professional high-pressure washers, hydrodynamic units, and urban cleaning machines.
The Emak Group concentrates its efforts on achieving customer satisfaction with an offering of advanced technological solutions and services characterized by impeccable standards of reliability and innovation and the creation of value to benefit all its stakeholders. In order to achieve its goals the Group bases its activity on specific critical success factors.

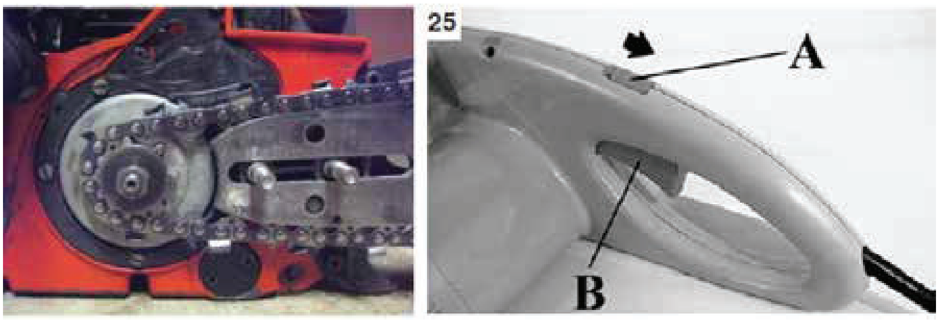

Figure 1 Chainsaw chain brake

The Chainsaw kickback problem

Chainsaws is one of the flagship products from Emak.. It incorporates numerous safety features common to many engine-driven power tools. Manufacturers have introduced numerous design features to improve safety. Some features have become de factor standards, and others are legal requirements in particular jurisdictions.

Best practice dictates that an operator should inspect the saw before starting work and only operate the saw if all the safety features are properly functional.
Additional safety features provide a significant commercial advantage to chainsaw producers. Most chainsaw safety features are focused on the kickback problem, and seek to either avoid it (chain and bar design), or to reduce the risk of injury should it occur (chain brakes).
Especially, the chain brake ensures maximum safety in using the chainsaw. It protects the operator from dangerous kickbacks which can occur during working phases. It is actuated, with consequent instant locking of the chain, when the operator presses the lever or automatically by inertia when the protection is pushed forward in the event of sudden kickback.

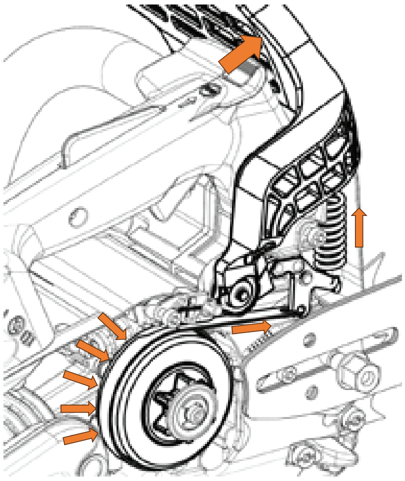

Figure 2 - Chain brake in detail

Modeling and optimization using Maplesoft + ANSYS
The main challenges can be summarized into three main questions that Emak want to answer:

1. How to get more accurate analyses?
2. How to improve post-processing analyses?
3. How to validate analyses experimentally?

To answer questions 1 and 2, the Emak team needed a software solution that could provide an advanced system level modeling to maximize system performance, detect performance issues at an early stage, handle multiple engineering domains and improve

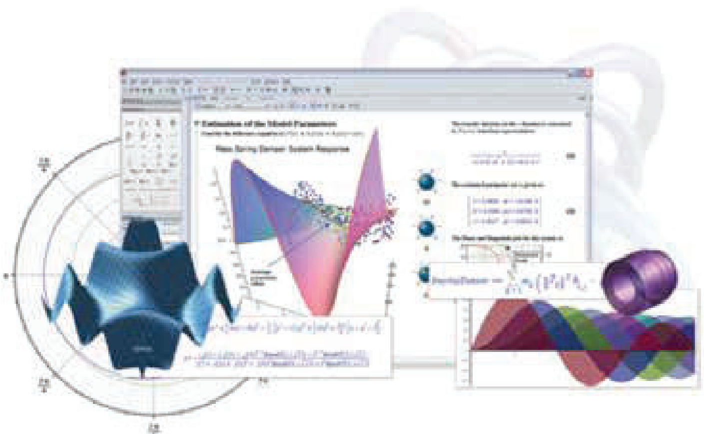

Figure 3 - Maple: the technical computing software for engineers and researchers

pre and post processing analyses. Emak discovered in MapleSoft products, Maple and MapleSim, the perfect pairing to perform these tasks.

Maple is a math software that combines the world's most powerful math engine with an interface that makes it extremely easy to analyze, explore, visualize, and solve mathematical problems.

Maple can:

- solve math problems easily and accurately
- provide insight into a problem, solution, data, or concept using a huge variety of customizable 2-D and 3-D plots and animations
- keep problems, solutions, visualizations, and explanations all together in a single, easy-to-follow document, to avoid wasting time reconstructing thought processes
- create interactive applications for colleagues easily and share them over the web

MapleSim, instead, is a Modelica®-based system-level modeling and simulation tool that applies modern techniques to dramatically reduce model development time, provide greater insight into system behavior, and produce fast, high-fidelity simulations.

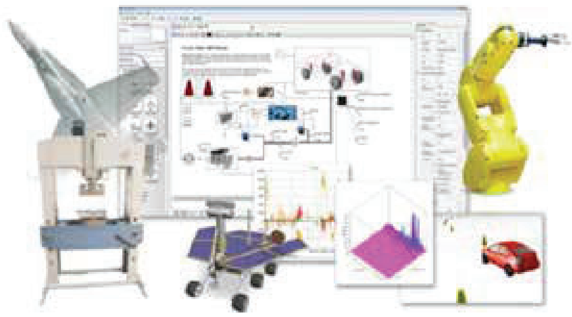

Figure 4 - MapleSim: the Modelica-based, multi-domain modeling and simulation tool

MapleSim can:

- verify a design before building a prototype, by creating a high fidelity virtual prototype of your entire system in a multidomain modeling environment
- simplify model development with model diagrams that closely resemble the system diagram, making them easier to construct and verify visually
- refine and optimize your designs with an extensive collection of powerful analysis tools and the ability to customize and extend these tools to suit your project
- quickly meet your specialized modeling needs, with easy-to-create equation-based custom components, access to specialized Modelica libraries, and customizable components
- reduce late stage changes by identifying unexpected subsystem interactions and other design problems early in the development cycle
- achieve extremely fast simulation code without sacrificing model fidelity, with highly optimized model code suitable for real-time and in-the-loop testing

- enhance customer toolchain without adding overhead, with easy connectivity to Simulink®, FMI-compliant modeling tools, CAD tools, and more

To answer to question 3, ANSYS Mechanical Workbench 18 has been used for structural analysis, including linear, nonlinear and dynamic studies.

The Emak Workflow Description

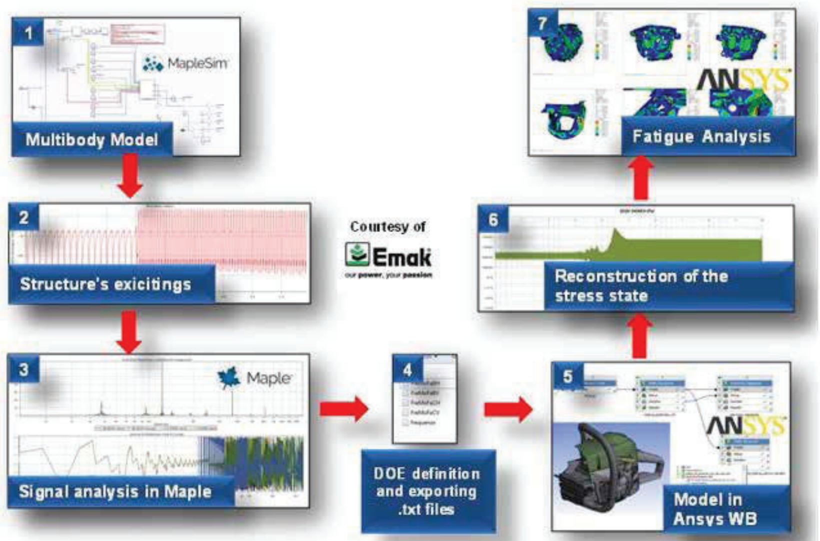

Figure 5 - The Emak Workflow Description

1. Multibody model

A single cylinder gasoline engine model has been created to predict engine performance in MapleSim, providing the first step of the workflow. The model describes the piston, cylinder, connecting rod and crankshaft behaviour.

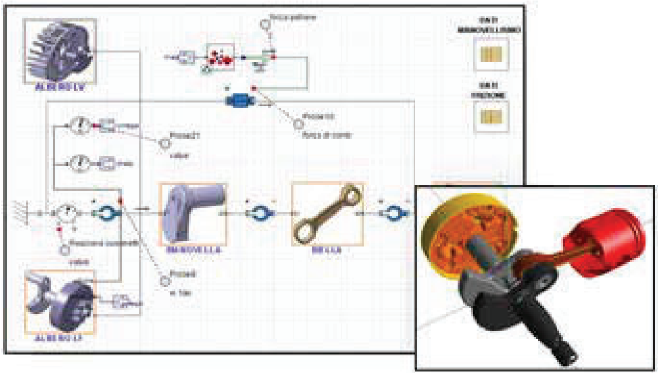
Figure 6 - Engine Model in MapleSim and Model in ANSYS WB

Every physical modeling or physics-based modeling in MapleSim, incorporates mathematics and physics laws to describe the behavior of an engineering component or a system of interconnected components. In addition, for every block imported in MapleSim its properties can be specified: for example, the revolution joint used in the previous schema has some properties like angular velocity, initial angle, spring constant and so on. Beside these, also related system units can be selected. Once connected, all MapleSim blocks, useful to design the model, generate a system of equations which is automatically resolved to get all physical quantities required.

The chain brake connected to the crankshaft has also been modeled in MapleSim in order to optimize the stop time and calculate forces on the quadrilateral. Chain brakes prevent movement of the saw's cutting chain by applying a steel brake band around the driven clutch drum. Clamping force for the brake band is provided by a powerful spring. The chain brake has two purposes. First, it can be used to secure the chain when changing position, moving between cuts or starting a cold saw, which requires a partly open throttle. This would otherwise lead to uncontrolled chain movement, a major hazard in older saws. Secondly, the chain brake can activate under kickback conditions to prevent the operator from being struck by a running chain.

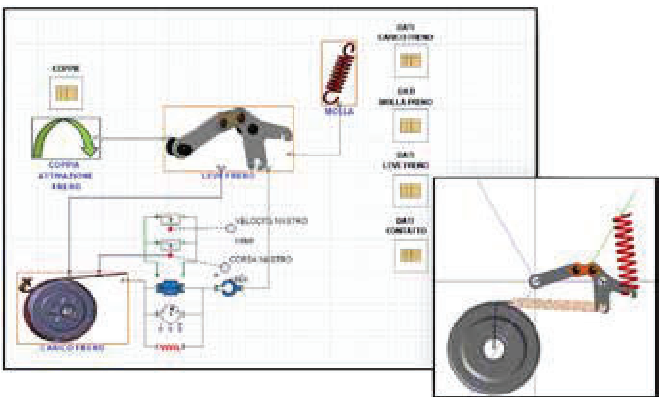
Figure 7 - Brake Model

2. Structure excitings

After the single cylinder engine model in MapleSim, the structure forces excitings obtained from bench experiments are extracted and imported into Maple. This task is supported by customizable and animated plots available in Maple.

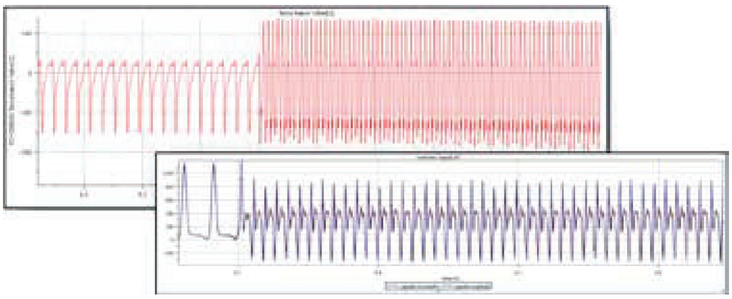
Figure 8 - Engine's Excitings

3. Signal analysis in Maple

As a third step, a custom template for signal processing has been implemented in Maple: the exciting forces were collected and then analyzed to reduce the frequency content through a Discrete Fourier Transform study. In particular, time histories were analyzed in order to extract the coefficients of the Fourier series that represent them, so to identify the dominant frequency inputs of the input signals, and use them for subsequent analyses. This allows for the frequency content to be decreased for post processing fatigue analyses that was executed later in ANSYS WorkBench 18.

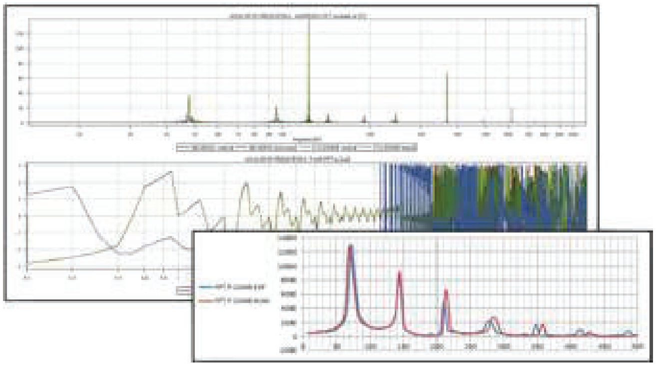

Figure 9 - Signal processing

4. DOE implementation in Maple and results export

Furthermore, a DOE with a graphical interface has been prepared in Maple: graphical Maple components were imported and connected to a Maple code to carry out a time reconstruction and to verify that the new signal was consistent with the original one, exporting it to the properformat. After this step, all results are exported into text files.

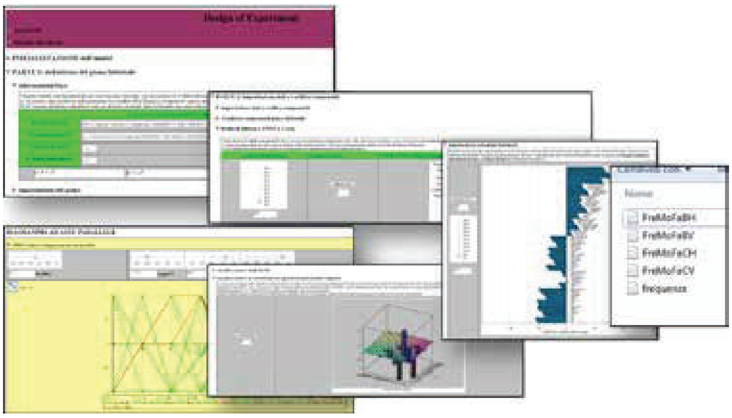

Figure 10 - DOE in Maple

5-6-7. Experimental validation

A model of the machine was implemented in ANSYS WorkBench and a related fatigue analysis is executed to validate experimentally all of its aspects (modal shapes, rigidity, damping). The reconstructed signal is imported through text files into WorkBench using the Imported Load block.

The procedure requires, as a starting point, the resolution of the harmonic analysis taking into account all the frequency components for the reconstruction of the input load cycle. Frequency contributions were reduced and the results are used to perform harmonic simulations (one for each frequency contribution), crucial for time reconstruction of system regime response. Even for these harmonic simulations, the harmonics are pre-stressed by a previous static condition that represents the tightening of the bolts. Following the harmonic simulations, the time history of the stress history in points of interest for the duration of the cycle progresses, in particular to get the temporal history of signed Von Mises. This time history is decomposed into a history of peaks and valleys, useful for counting load cycles through the Rainflow Algorithm. Once the current load cycles are known in the temporal history of signed Von Mises in terms of average and alternating voltage and their number, the alternating voltage is corrected taking into account the average value, according to Soderberg's theory. With these values the S-N curves are plotted to calculate the number of breaking cycles of each contribution and thus the total damage and fatigue life.

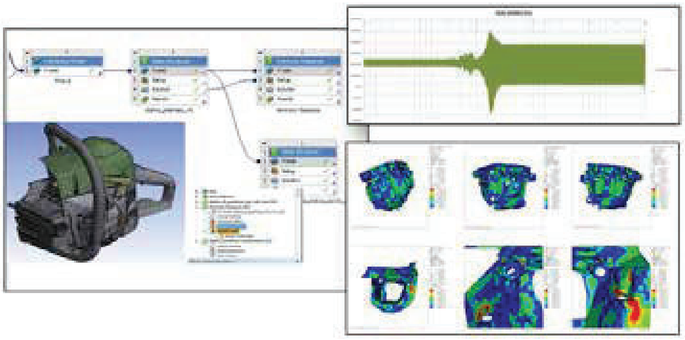

Figure 11 - Fatigue Analyses in ANSYS 18

Conclusion

By coupling Maplesoft products with ANSYS WorkBench 18, EMAK achieved high computational accuracy. In particular, by using Maple, the Emak engineers were able to drastically reduce the time typically spent on multiple trials and fine-tuning. Moreover, Maple's graphical interface makes reading the data far easier. On the other side, MapleSim, allows to create models quickly, and the mathematical analysis tools enable to really understand what is going on the chainsaw's single cylinder engine and brake, and how to optimize them, exploiting the best in class capabilities of ANSYS WorkBench 18.

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