

RomaxNVH

The complete simulation environment
for noise, vibration and harshness
of transmission systems



Quieter design, quicker solution

With pressure to reduce costs and development times, the need to access NVH information at every step of the design process has never been greater. Now there is a solution that enables you to accurately and quickly assess the effects of design changes before the design freeze and move away from expensive physical prototyping and testing. With RomaxNVH's fast model-building interface and rapid solution times a quiet design is available to you and your customers quicker than ever before.

Reduce number and length of design cycles

It is now possible to reduce the number and length of design cycles by considering transmission NVH alongside functionality and durability right from the concept stage. RomaxNVH offers you a single integrated solution for transmission NVH modelling and analysis giving you the opportunity to capture any problems before they become real and to optimise refinement from the start.

Make design changes and accurately assess their effects

Whether you are comparing simple concept designs or evaluating a fully detailed model, you can now access NVH information at every step to allow you to make design changes and quickly assess their effects. With RomaxNVH, you can analyse interactions between individual components at a whole system level to accurately represent the complex vibration path, saving you time and money.

Automotive

- Design quieter transmissions, driveline, axles and engines
- Perform NVH analysis early in the design cycle
- Calculate and compare the NVH of new transmission concepts such as AMT, DCT, Hybrid, CVT, etc
- Ensure NVH and durability targets are achieved simultaneously
- Reduce the demands on the interior sound package
- Identify root causes of transmission and driveline noise
- Determine rattle sensitivity and the requirements for dual mass flywheel
- Predict NVH of a design against different manufacturing process capabilities
- Create system level models and set component level targets for NVH improvement
- Reduce axle beam weight while maintaining NVH targets
- Analyse engine geartrains for rattle and whine performance
- Create quiet and durable geartrains for interior drive mechanisms

Wind turbine

- Understand and benchmark dynamic failure modes
- Design gearboxes to meet noise and vibration targets throughout the warranty period
- Analyse the behaviour of complex planetary systems
- Reduce weight and cost without increasing vibration levels
- Minimise noise pollution caused by transmission and driveline vibrations
- Produce technical documentation for certification

Aerospace

- Reduce transmission vibration levels through full system dynamic analyses
- Analyse high speed dynamic effects for gears and bearings
- Optimise gearbox weight

Off-highway

- Design heavy duty hydrostatic and powershift transmissions
- Minimise multi-mesh geartrain whine and rattle
- Optimise gearbox NVH performance without compromising durability
- Reduce transmission and driveline low-frequency vibration levels
- Improve cabin comfort by reducing noise from engine, drivetrain and auxiliary drive systems
- Analyse engine geartrain dynamics to improve durability and reduce noise

Industrial equipment

- Design for reduced vibration and noise in process machinery, material handling, power take-offs, speed reducers and production line equipment
- Improve accuracy of high precision machinery by understanding system dynamic effects
- Reduce fatigue failures in gears, bearings and shafts due to vibration
- Meet strict environmental noise targets

Consumer and office appliance

- Optimise noise and vibration characteristics of power tools, food processors, washing machines, printers and photocopiers
- Improve product quality by reducing gear noise and vibration levels
- Predict changes in noise and vibration over a product's life
- Create high precision, low noise geartrains for printers and photocopiers
- Design casings and enclosures to minimise radiated noise

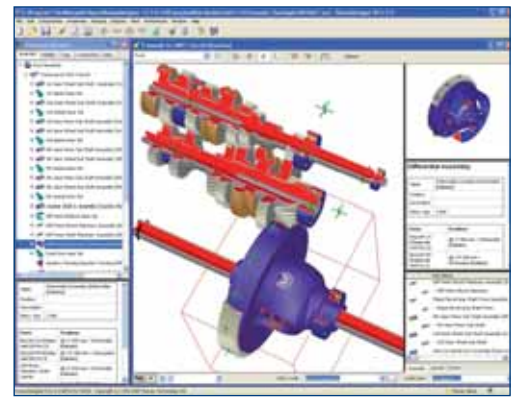
The RomaxNVH Solution

The RomaxNVH software suite is a single environment which covers all your requirements for the modelling, simulation and analysis of geared transmission systems. Whether you are calculating the expected life of a bearing in a wind turbine or investigating the vibration characteristics of a whole vehicle driveline, with RomaxNVH you are provided with all the necessary tools to give you confidence in the noise and vibration performance of your designs. The intuitive graphical interface allows you to quickly build up a full system model using component-based construction yielding results in a fraction of the time of traditional methods.

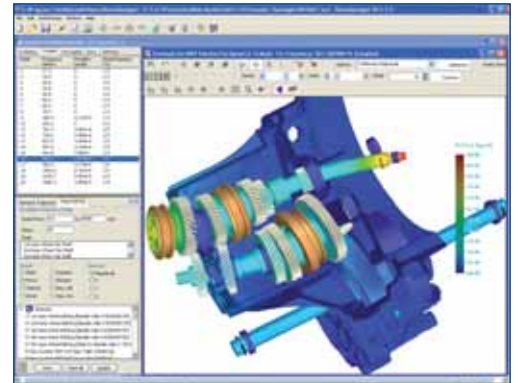
Whether your product design is in the development stage or you are refining the details of your product, RomaxNVH can still give you a full range of analysis options. Gears, shafts, bearings, clutches and so on, can all be defined as 'concept' or 'detailed' components. Standard bearing types can be picked from built-in custom and manufacturer catalogues. Complex rotating and non-rotating components such as differentials and housings can be imported from standard FE pre-processors and included in the analysis using RomaxNVH's built-in model FE solver modules.

Graphical representation and HTML reporting allow you to evaluate and present your analysis results quickly and easily. You can also integrate RomaxNVH with your other applications through the XML interface option. With the Design of Experiments module you can take advantage of RomaxNVH's ultra-fast solution times to perform automated parametric studies which until now would have been impractically slow.

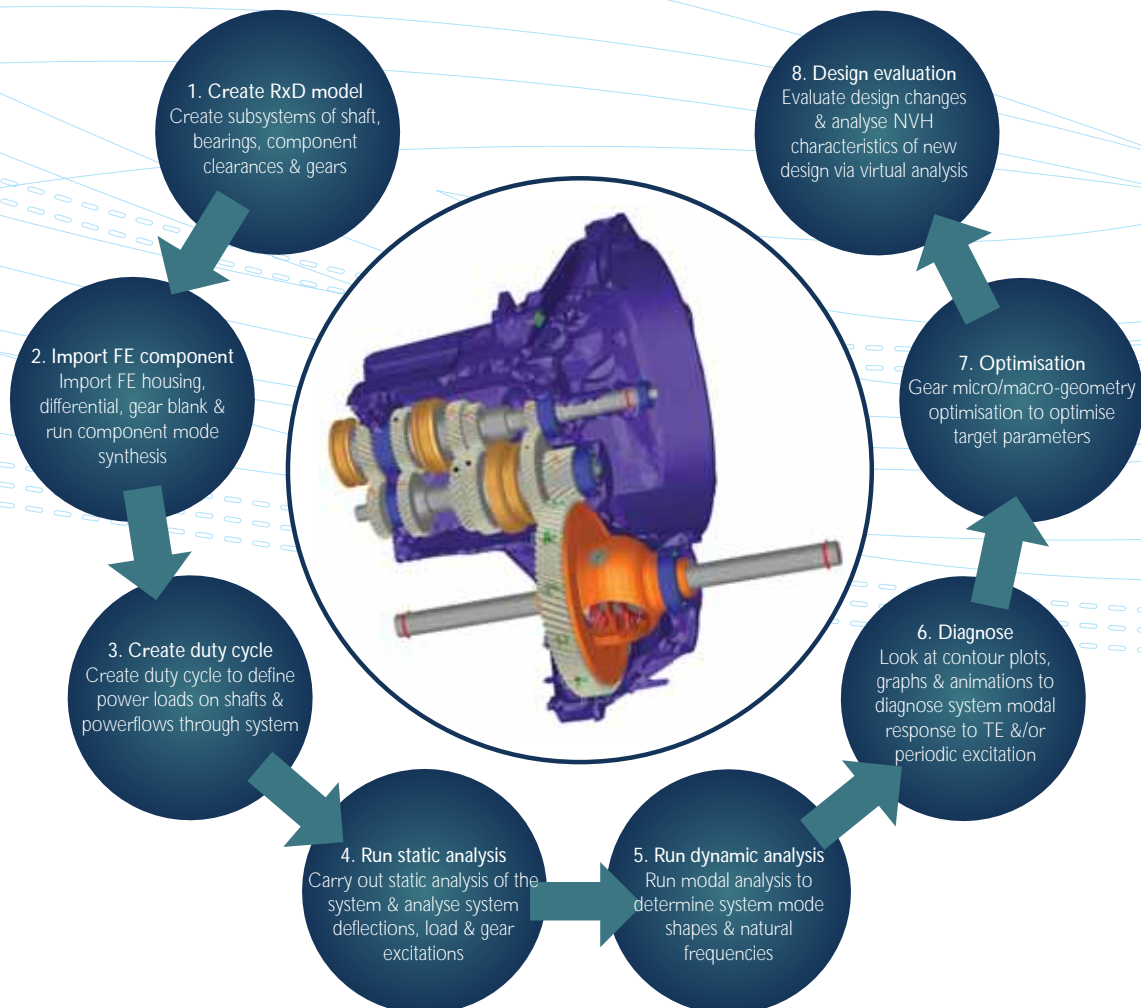
The integrated RomaxNVH environment means that your design, analysis, durability and NVH teams will all be speaking the same language; streamlining and improving your processes and delivering customer requirements faster and better than ever before.



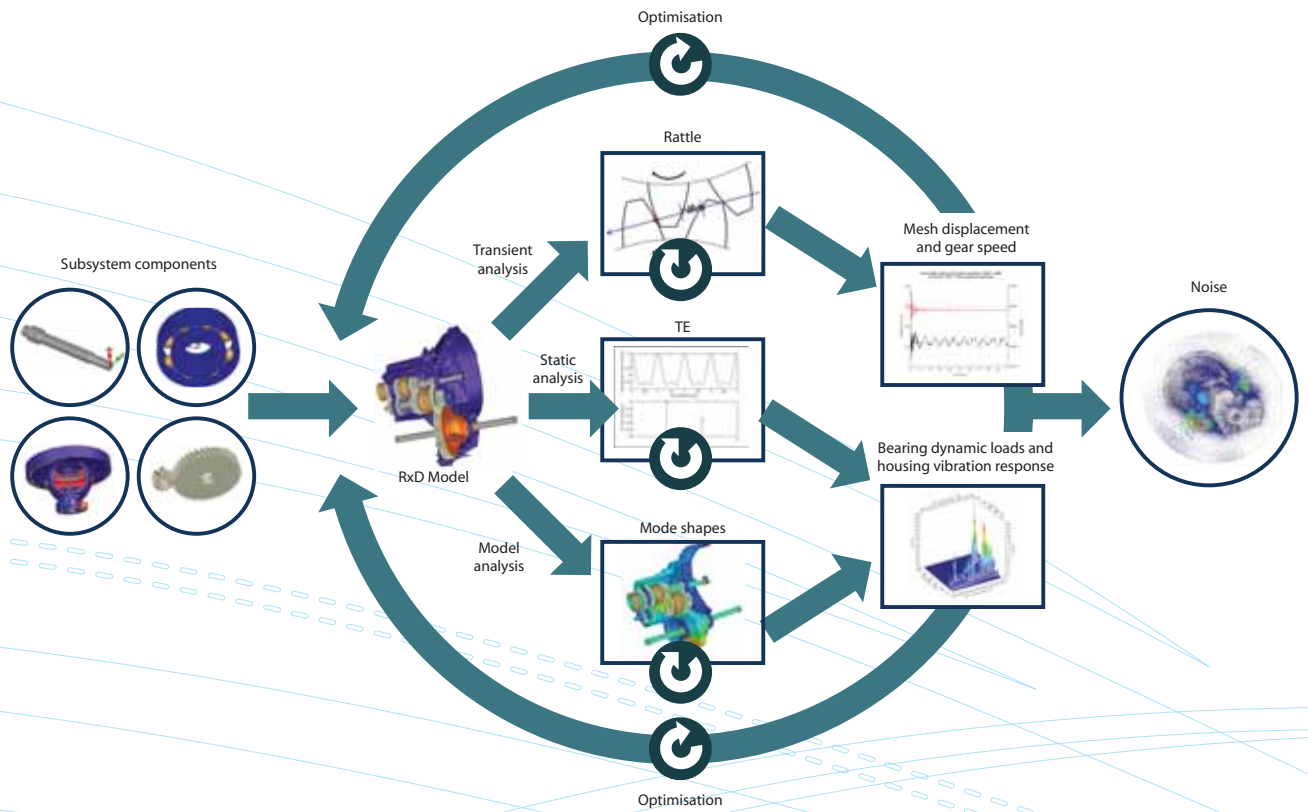
Gearbox design layout window



RomaxNVH 3D mode shape display window



A Complete NVH Analysis Tool for Transmission and Driveline



RomaxNVH Case Study: 5-Speed Transaxle - Low Noise Design Optimised for Manufacturability

The issue

A significant gear whine noise issue with a 5-speed manual transmission for a small front wheel drive passenger car. This occurred across the range of manufacturing tolerances and the client was considering substantial investments in their gear manufacturing facility to solve the problem.

The solution

RomaxNVH was used to create a validated dynamic model of the transmission. DoE analysis revealed the micro-geometry to be particularly sensitive to variations in manufacturing. A robust micro-geometry optimisation was performed based on the existing manufacturing capability. The customer was spared the cost of substantial investment.

Design optimisation

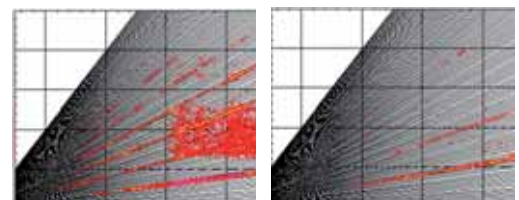
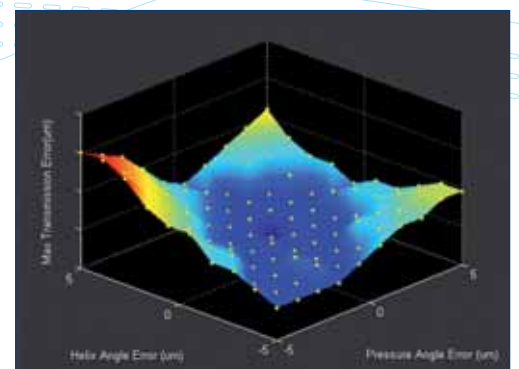
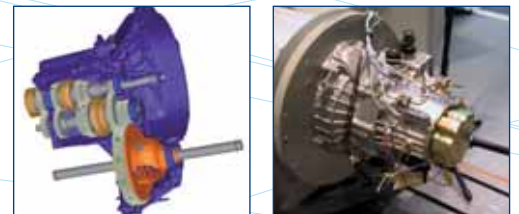
- Robust micro-geometry optimisation was carried out to reduce TE and hence vibration
- The customer's manufacturing tolerance capability was taken into account
- Gear durability was not compromised

Validation by test

- New prototypes built to RomaxNVH optimised design
- TE, housing vibration and radiated noise measured on original and optimised designs with nominal and worst case tolerances

Design evaluation

- Gear whine considerably improved on optimised design
- End-of-line variability in vibration due to manufacturing tolerances reduced by robust optimisation
- RomaxNVH optimised design put into full production by customer



Original design

RomaxNVH optimised design

Gear Whine Analysis

Transmission error (TE) is the fundamental source of gear whine noise. RomaxNVH calculates static deflections of the system under a given loading condition. The resulting gear mesh misalignments are used, along with gear micro-geometry to predict the TE in each loaded gear mesh. The vibration response of the entire system to the TE excitation is obtained from an automatically generated dynamic model. The relative phase of the TE excitations can be critical and so is included in all analysis. A number of tools are available which allow the user to interrogate the data.

Capabilities

- Full system vibration response and dynamic behaviour analyses
- The results from the NVH gear whine analysis include:

Mode shapes

Mode shapes can be displayed as an x-y plot or fully animated 3D schematic images and fully rendered 3D mode shapes.

Transfer functions

Allows the user to generate FRFs and transmissibility functions between any two points in the RomaxNVH model. These can be compared with test data for dynamic model validation.

Modal flexibility

Modal flexibility shows the potential of each system mode to be excited by transmission error at a particular gear mesh.

Modal energy

The kinetic and strain energy of each component in the gearbox can be calculated for an individual mode to show components contributing most to the dynamic behaviour.

System general excitation

A general excitation (force or moment) can be applied to any point in the model. The excitation can be of fixed frequency or related to the rotational speed of any component in the model.

Uncoupled analysis

Dynamic analysis can be run without specified gear meshes included. The system compliances on either side of the mesh can then be examined to aid gear blank tuning.

Harmonic response

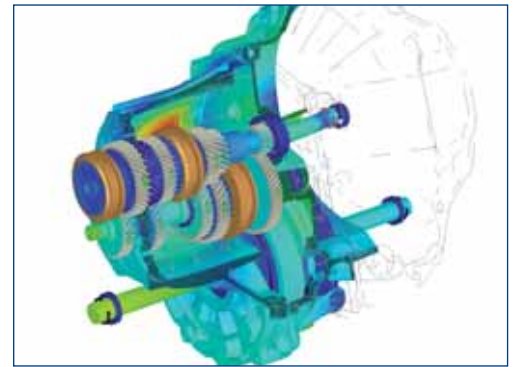
The vibration response of any part of the model to calculated or measured TE excitation can be determined. This includes the forces and responses across bearings.

Waterfall plots

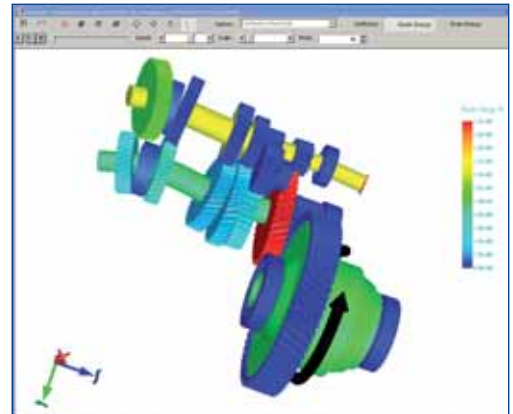
Waterfall plots show the interaction between tooth-passing orders and system resonances.

Benefits

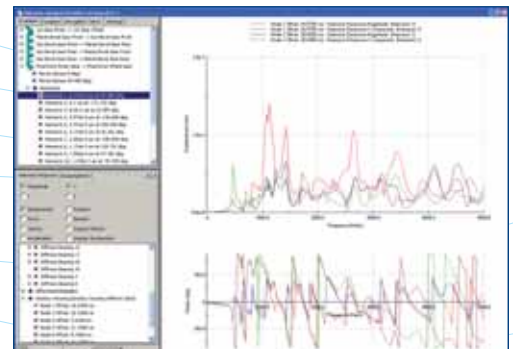
- Integrated within the Romax modelling environment – single environment for static and dynamic analysis
- Fast analysis time
- Ideal for NVH problem solving and investigation
- Correlation of test data with RomaxNVH calculated data
- Design evaluation of NVH characteristics in the early development stage
- Avoid NVH problems from the start
- Diagnose and resolve whine problems in existing designs



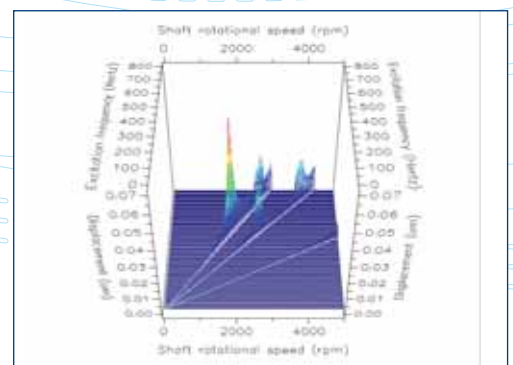
Animated 3D mode shapes with FE cutaway



Mode shape component energy contribution



Bearing dynamic force response



Waterfall plot of harmonic response showing gear tooth related meshing orders

Micro-geometry Robust Optimisation

In any gearbox, it is impossible to avoid variations in mesh misalignment, since the gearbox experiences different speeds and different torques. However, it is possible to modify the gear geometry to minimise the transmission error over its range of operating conditions. Gear macro-geometry can be modified to maximise the contact ratio in gears, thereby improving the noise characteristics of the gear. However, micro-geometry modifications are also necessary since the gear undergoes elastic deflection and must be able to accommodate variations in mesh misalignment.

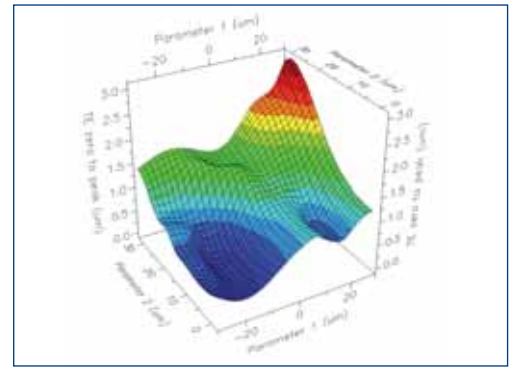
The micro-geometry optimiser within RomaxNVH uses an evolutionary optimisation process to quickly and easily analyse gear mesh micro-geometry and predict the transmission error as well as gear contact patterns and loads. After using the optimiser to determine the ideal micro-geometry design, it can also be used to investigate the sensitivity of the design to manufacturing errors and tolerances.

Capabilities

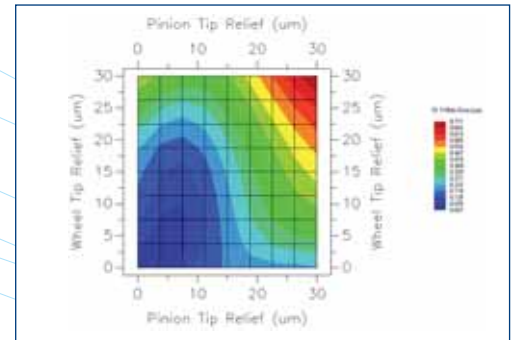
- Robust macro and micro-geometry optimisation to reduce gear whine noise without compromising the durability of the gears
- The automated intelligent gear optimiser can check the whole design space to rapidly determine the optimal detailed geometry of a gear pair
- Target parameters can be easily set and the importance of each to the design are controlled via different weighting

Benefits

- Quickly analyse a large number of design candidates in just a few minutes
- Increase durability and reduce gear whine across operating conditions through the generation of optimal micro-geometry
- Reduce gear TE sensitivity to manufacturing tolerance variation



Surface plot of an objective function in an optimisation problem



TE sensitivity to tip relief manufacturing errors to nominal design

System Sensitivity Analysis (DOE)

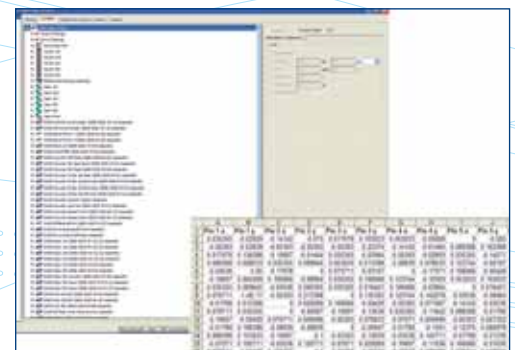
Statistical analysis of the design provides the missing link between the simulation environment and the realities of the manufacturing and build process. The Design of Experiments (DoE) capability provides tools for performing a systematic and efficient analysis of the design space to assess the impact of the many design variables on the NVH characteristics, and to identify significant interactions among them. With the RomaxNVH DoE capability, manufacturing variability can be considered for each design iteration so that the final design has a high tolerance to this.

Capabilities

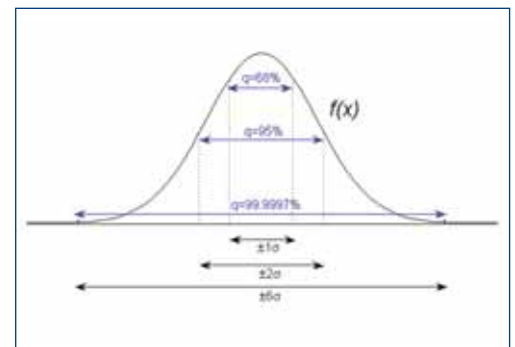
- Study multiple product design and/or manufacturing process variables at the same time
- Evaluate hundreds of potential combinations of numerous variables for the best overall combination
- Statistical analysis to give a more realistic study of the effects of manufacturing tolerances on gearbox NVH behaviour

Benefits

- Quickly and efficiently generate reproducible results through running multiple sets of variables from a single model
- Identify hard-to-find solutions to ongoing quality problems
- Faster development time and cost effective
- Increased quality, reliability and understanding of the whole system



RomaxNVH DoE set up interface with DoE design matrix



Random permutations of variables using the six-sigma normal distribution

Gear Rattle Analysis

Transmission designers are increasingly turning to virtual simulation solutions to address the challenges of noise caused by gear meshes. In many applications both gear whine and rattle noise problems occur simultaneously and often only become apparent when complete transmission prototypes are built and tested which often leads to product launch delays and considerable additional expense.

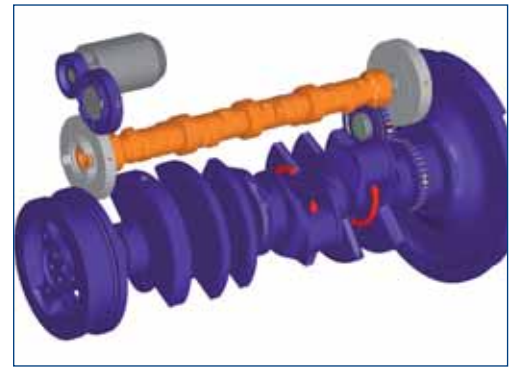
RomaxNVH enables you to perform gear whine and rattle analysis in a single environment and on the same virtual model. Rattle problems can then be addressed in parallel with whine issues at an early development stage with consequent savings of time and resources. Concept designs can have their potential susceptibility to rattle behaviour quantified and remedied before any metal is cut. Unlike typical analysis software, RomaxNVH takes into account the detailed non-linear behaviour of the tooth contact caused by gear misalignment and micro-geometry effects giving you the accurate data you need to make critical design decisions.

Capabilities

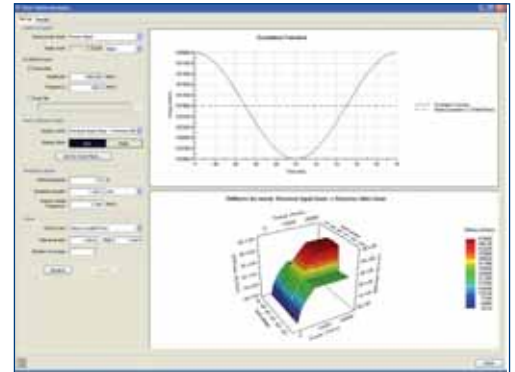
- Perform a torsional multi-body dynamic simulation of gear rattle behaviour directly from a RomaxNVH model
- Use the full system flexibility and detailed component definitions automatically from the RomaxNVH model
- Six types of non-linear gear mesh models available
- Gear meshes accurately account for misalignments and micro-geometry effects

Benefits

- Save time and cost through using just one virtual model for whine and rattle analysis
- Identify the key factors controlling gear rattle and predict the onset of gear rattle for specific inputs
- Perform sensitivity analysis for gear rattle



Engine geartrain, including crankshaft and camshaft



Gear rattle analysis set up pane showing the sinusoidal dynamic torque excitation and the non-linear gear mesh stiffness

Gearbox Transmission Error (GBTE)

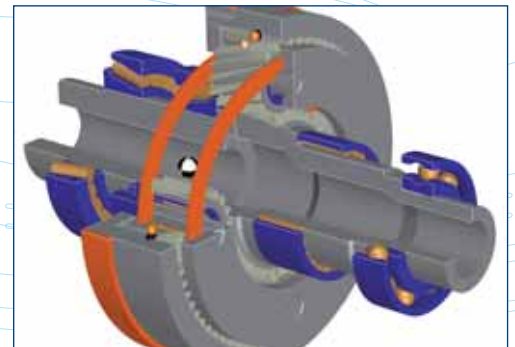
Successful analysis of transmission error for an isolated gear pair can be carried out if the system meets certain criteria. The assumptions of constant torque, constant load point position across the face width and constant mesh misalignment are reasonable for the analysis of an isolated gear pair in non-load sharing transmission. However, these assumptions needed for the analysis of an isolated gear pair are seen to be invalid in the case of planetary systems because the torque sharing of the planets will cycle with each planet rotation. The stiffness of the planetary carrier would also vary as the carrier rotates, and this variation is significant for a non-symmetric carrier model. Hence, GBTE is the ideal tool as it eliminates the inherent assumptions and captures the overall transmission errors caused by all of the loaded gear-meshes, by performing a time-stepped quasi-static analysis of the whole system.

Capabilities

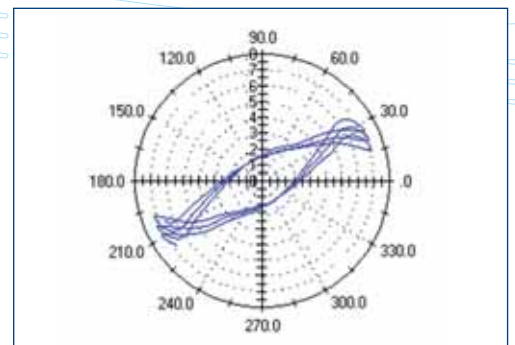
- Rotation-stepping static analysis of planetary system to predict the varying loads and misalignments in each gear mesh
- Total TE between the input and output of the gearbox can be calculated and compared with TE measurements
- Captures simultaneous TE and relative phasing of all the gear meshes
- Considers the full system affects of shaft, bearings, housing, carrier and ring gear deflection, as well as variation of gear tooth stiffness through the mesh cycle

Benefits

- Improve alignment and tooth contact analysis for gears with flexible mountings
- Accurate TE prediction for planetary or other load sharing systems
- Understand the affect of pin spacing tolerances on noise
- Predict whirling of sun, planet and carrier through the mesh cycle



Planetary gear range changer system



Displacement of sun gear due to circumferential errors in planet pin positions



RomaxDesigner is the complete simulation environment for transmission and driveline engineering. The software suite encompasses a variety of configurations focused on industries and applications, including:

- noise, vibration and harshness
- transmission design and durability
- design automation and optimisation
- advanced bearing simulation
- wind turbine solutions

UK Head Office

Rutherford House
Nottingham Science & Technology Park
Nottingham
NG7 2PZ
+44 (0) 115 951 8800
sales@romaxtech.com

China

Romax Technology (Hangzhou) Ltd
10-05 Building 1 Huarui Centre
66 Jianshe Yi Road
Xiaoshan
Hangzhou 311215
+86 (0) 571 8378 6230
romaxchina@romaxtech.com

India

302, Third Floor
Sai Capital
Senapati Bapat Road
Pune
411016
+91 (0) 20 6720 1800
sales_in@romaxtech.com

France

13 rue Louis Gibert
13004
Marseille
+33 (0) 6 80 91 82 80
sales_eu@romaxtech.com

Japan

Romax Technology Tokyo Business Center
2F Taikai Building
3-23-13 Minami-Ooi
Shinagawa-ku
Tokyo
140-0013
+81 (0) 3 5767 9400

South Korea

2F Jae-yoon Building
75-3 Yangjae-dong
Seocho-gu
Seoul
137-889
+82 (0) 70 7580 6210
sales_kr@romaxtech.com

North America

Romax Technology Inc
Suite 380 Columbia Center I
201 West Big Beaver Road
Troy
Michigan 48084
+1 (0) 248 250 7691
sales_us@romaxtech.com

www.romaxtech.com

About Romax Technology

Romax Technology offers integrated solutions for noise, vibration, harshness [NVH] and bearings analysis through software tools, process, training and engineering services to major OEM and Tier 1 suppliers in the automotive, aerospace, wind energy, industrial equipment, rail and marine industries around the world.

Romax Technology's pioneering full-system flexibility and integrated software package encompasses 20 years of development and benchmarking in partnership with major OEMs and extensive research in conjunction with top academic establishments. Romax's customised and 'off-the-shelf' software provides customers with the tools for 'right-first-time' transmissions and driveline design and analysis.

Romax Technology's engineering teams are integrated with its advanced transmission software development which encompasses 20 years of expertise and benchmarking. Service offerings include benchmarking, concepts generation, issue investigation and resolution, analysis and detail design through to production. Romax offers agile issue resolution with a flexible team approach dedicated to individual projects with execution available remotely in the UK or locally with the customer. Local co-ordination of engineering programs is undertaken through offices in USA, Korea, Japan, China, India, Germany and the UK.

"AISIN AW engineers are very pleased to be using such advanced and convenient software from Romax Technology. This agreement will help the further development of simulation tools that will enable AISIN AW to examine many kinds of NVH matters at the early development phase."

AISIN AW NVH Manager