

Romax Bearing Design & Analysis

Total system approach to advanced bearing technology for manufacturers and end users



Quickly and accurately assess bearing performance

Bearing durability is a key factor for reliability in all driveline applications ranging from automotive transmissions to wind turbine gearboxes. The Romax Software Suite offers a system analysis tool for the whole transmission to quickly and accurately assess bearing performance under the influence of shaft and housing deflection. Bearing selection for a specific gearbox design can easily be carried out and assessed without the need for extensive prototyping and testing.

Identify and optimise problems early in the design process

With the Romax Software Suite, you can define bearing internal geometry for the majority of bearing types and adjust it according to the loading conditions. The interactions between individual components such as deformation and misalignment of the shafts and housings can be used to accurately predict loading within the bearing. Possible problems can be identified and optimisation carried out to refine performance at an early stage in the design process.

Solutions for all your bearing needs

As well as providing software, Romax Technology offers consultancy for any area of bearing technology. Such activities range from strategic consulting and technical due diligence, technology transfer on design and manufacturing, bearing selection for new gearbox designs, optimisation of internal raceway profiles, analysis of bearing failures and support on developing new or complex design arrangements.

Automotive

- Accurately predict bearing life under detailed duty cycles in the design concept phase
- Improve bearing choice by unique and accurate prediction of bearing behaviour
- Analyse and compare bearing arrangements for new transmission concepts
- Investigate influences of internal geometry, lubrication and housing design on bearing durability
- Benchmark and compare gearbox designs
- Reduce the risk of selecting alternate bearing suppliers for second source and cost down exercises
- Automate the design and analysis of integrated wheel hub bearing arrangements

Wind turbine

- Software tool for advanced analysis of bearing behaviour to identify undesired load conditions
- Improve bearing choice by accurate life prediction including flexible housings, carriers and shafts
- Design, analysis and manufacturing solutions for pitch, yaw, main shaft and gearbox bearings
- Gearbox bearing selection review and analysis
- Consultancy for obtaining wind turbine bearing certification
- Technical due diligence on component suppliers, such as bearings, gearboxes and mechanical systems
- Detailed investigation of wind turbine drivetrain failures, especially on gearboxes and bearings

Aerospace

- Predict bearing behaviour under extreme load and climate conditions
- Analyse high speed dynamic effects for gears and bearings
- Identify root causes for bearing failures during test or service
- User defined micro-geometry input for special bearing design
- Technical service for complex stress analysis on large size bearings and their mounting arrangements

Off-highway

- Bearing selection for heavy duty hydrostatic and powershift transmission
- Predict system and bearing behaviour under misuse conditions
- Compare the effects of different lubrication conditions on bearing life

Industrial equipment

- Design for improved bearing reliability in process machinery, material handling, power take offs, speed reducers and production line equipment
- Reduce failures in bearings due to precise prediction of misalignments
- Analyse influence on durability of bearings and shafts from vibration
- Design of casings to minimise influence on bearing life

Consumer and office appliance

- Select bearing types and design for power tools, food processors, washing machines, printers and photocopiers
- Simulation of complex shaft, gear and bearing arrangements to assess complete system durability

Railway

- Assessment of bearing performance and selection for transmission and final drive configurations
- Investigation and analysis of axle box bearings for new or in-service railway bogies

Romax Software Suite Overview

Whether you are calculating the expected life of a bearing in a wind turbine or optimising roller raceway profiles, with our bearing software you are provided with all the necessary tools which give you confidence that the bearings are suitable for testing and in-service. Realistic modelling and simulation provide you with the capabilities to assess bearing selection and internal geometry in much more detail than traditional analytical tools.

One key feature of the software not accounted for in most bearing software tools is the inclusion of the housing deflection influence. Complex components can be imported into the model from FE pre-processors for the housing design. The stiffness characteristics from this, combined with the bearing and shaft positions allow a complete analysis of the system deflection. The consideration of the housing deflection and shaft misalignments in this way show the significant influence these factors can have on bearing durability.

As well as a database of existing bearing catalogues, Romax Advanced Bearings modules allow the user to fully define any custom bearing, including internal and external geometry, roller and raceway profiles and load ratings. Should the exact bearing details not be known, the software will accurately estimate the internal details meaning conceptual designs can be quickly and easily modelled without the need for specialist information which is often hard to obtain.

When selecting a bearing, it is essential that the bearing life meets the requirements in relation to the operating conditions. A variety of mounting conditions and the radial internal clearance can be specified to account for assembly conditions, ensuring a truly accurate representation of real world performance. A simple yet comprehensive bearing report is provided after each durability analysis is conducted and raw data for graphs can be exported for further investigation.

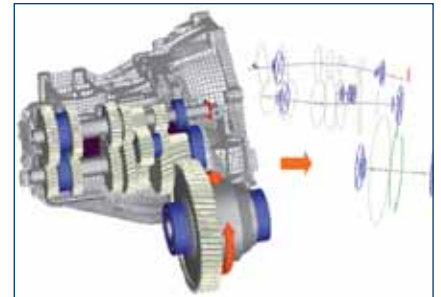
Romax offers four methods for predicting bearing life:

- ISO 281 – the basic bearing life calculation method based on approximate formulae
- Romax Adjusted – extends the ISO 281 calculation to include affects of misalignment
- Romax Advanced – uses an even more accurate model for contact stress than the previous two methods
- New ISO 281 Specification – follows on from the original ISO method, but also makes use of the advanced contact stress analysis and adds the affects of lubrication, temperature and contamination. This is the only method that makes allowance for extended life when operating below the material fatigue limit

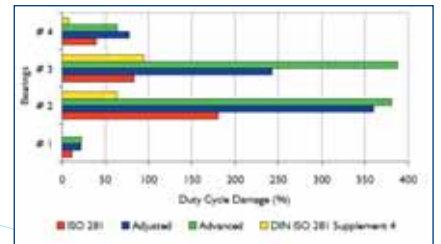
Romax is undertaking continual research to develop the software for even more accurate life prediction, such as consideration of raceway surface roughness or cage dynamics.



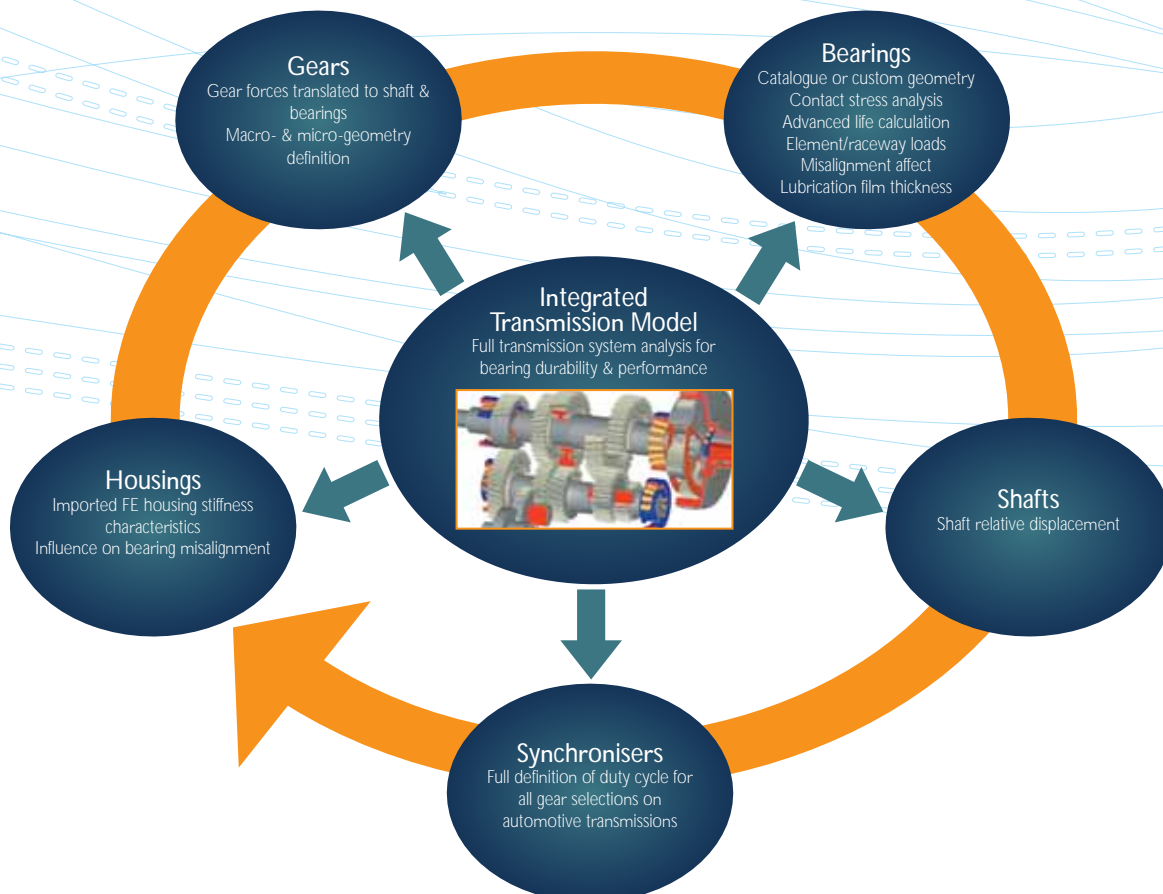
Catalogue and custom bearing geometry definition



Romax model incorporating housing and shaft deflections



Bearing duty damage calculated by four life methods



Advanced Ball Bearing

The Advanced Ball Bearing module allows complex analysis of the internal geometry within the bearing. You can assess the effect of internal clearance through calculating the load distribution within the shaft/bearing model. Contact patch analysis allows you to calculate contact ellipses which you can compare against the raceway geometry. In the case of bearings under high axial loading it is possible to assess if the element contact extends over the edge of the raceway which would result in a truncated contact patch and induce extremely high stresses. If ellipse truncation occurs then the bearing damage will instantly increase and the bearing is highly likely to fail before its intended life has been reached.

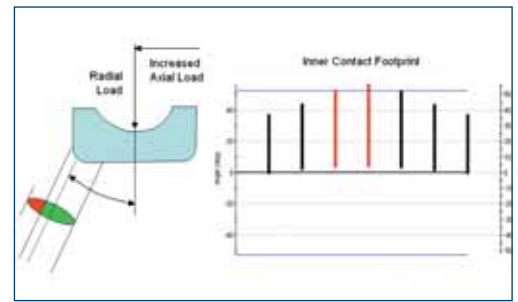
Centrifugal effects at high rotational speeds can have a large influence on element loading and contact angles and this factor can also be analysed within the software.

Capabilities

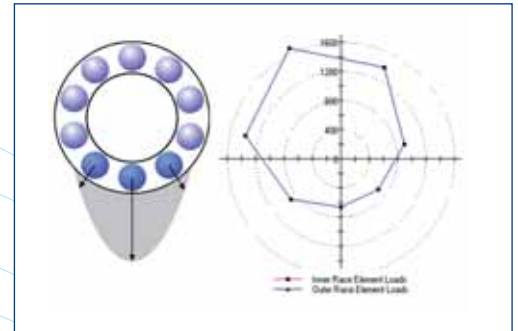
- Full definition of bearing internal geometry
- Element load distribution and contact stress analysis
- Contact patch analysis
- High speed centrifugal effects
- Advanced life calculation including misalignment and lubricant film thickness influences

Benefits

- Accurately predict bearing durability with full integration of system components
- Understand bearing performance under complex loading and deflections
- Carry out analysis of factors affecting life not typically considered in standard calculations
- Enables flexibility and quick calculation results



Contact footprint of balls on raceway considering overhang of shoulder



Load distribution for elements within a ball bearing design

Advanced Roller Analysis

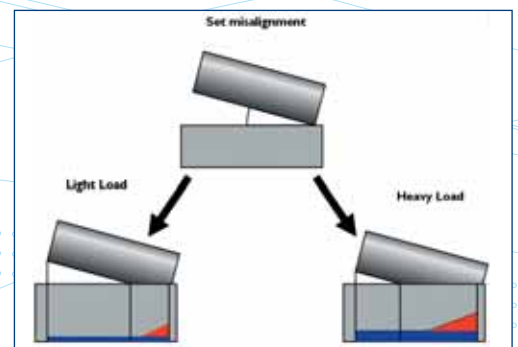
Advanced modules for roller bearing design allow you to optimise the roller and raceway profile for a specific driveline application. This process can be carried out for a given loading condition or duty cycle involving both radial load and misalignment. A number of options are available for profile modification such as semi-crowned, fully-crowned or a logarithmic profile; in addition, empirical measured data can also be entered. The software allows contact stress to be calculated for each individual roller bearing and by refining the profile, maximum stress can be considerably reduced to give an increase in bearing life. In addition to the raceway loading, rib loading on tapered or some cylindrical bearings can also be analysed within the software. You can study the relationship between axial load, radial load and rib loads to ensure no detrimental effect exists from the roller to rib contact for a particular bearing design.

Capabilities

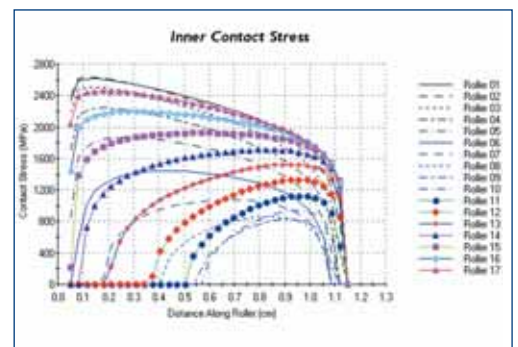
- Full definition of roller and raceway internal profile
- Contact stress analysis along roller length considering misalignment influence
- Calculation of rib and roller interface under radial and axial loading
- Advanced life calculation including lubrication film thickness analysis

Benefits

- Improve bearing life through optimisation of raceway and roller internal geometry under given load conditions
- Accurately assess load and stress conditions on the raceway, rib and rollers for any applied loading
- Diagnose and solve problems in existing designs on test or in the application



Influence of misalignment and load on contact stress



Typical results for inner contact stress for each roller in a bearing

Romax Engineering Services

Romax has a large number of experienced engineers in the field of bearing design, analysis and manufacture so is able to offer a wide range of engineering services to bearing manufacturers and end users. Romax engineering services are unique in offering a range of consulting and technology transfer programmes, working with both bearing suppliers and gearbox manufacturers across a variety of industry sectors.

Capabilities

Consultancy services that can be provided are listed in the following areas:

Bearing design

- Slewing bearing design, including wind turbine yaw and pitch bearings
- Large size bearing design for cylindrical and taper types
- Specialist bearing design for specific applications, including wheel hubs

Bearing analysis

- Bearing damage and endurance prediction for gearbox applications
- Analysis and improvement of raceway roller profile
- Finite element static analysis of raceway to rolling element contact
- Roller skew and misalignment assessment
- Lubrication and film thickness calculations
- Bespoke software development for analysis and design

Bearing manufacturing support

- Audit on manufacturing facilities to assess suitability of existing production
- Selection and specification of production machines and equipment
- Material and heat treatment specification definition
- Support set up of new or improved bearing manufacturing plants

Failure investigation

- Investigation of failure causes in various applications
- Failure countermeasures and DFMEA considerations

Technical due diligence

- Review of existing bearing designs for performance and manufacture
- Risk assessment and approval of new bearing suppliers for lower cost
- Test specification definition and specification setting

Feasibility study

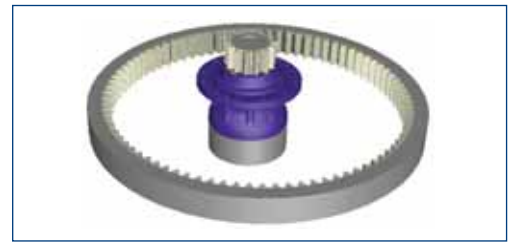
- Market research on bearing supply for various business sectors
- Benchmarking of competitor products
- Sales and marketing support for bearing suppliers
- Technology road map for product development

Training

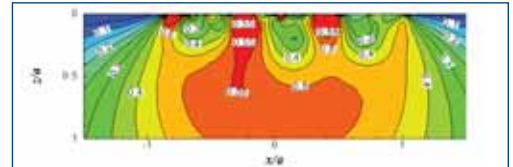
- Theoretical aspects of bearing design and analysis
- Types of failure modes and bearing inspection methods
- Overview of bearing manufacturing processes and quality procedures
- Information on materials and heat treatment used for bearings
- RomaxDesigner use in relation to bearings and application based case studies

Benefits

- Reduce risk on introducing new bearing designs or suppliers and minimise failures
- Improve capability to develop new products and achieve cost down targets
- Shorter development time with lower requirement for testing and reduced design iterative steps
- Optimise bearing design, manufacturing and quality processes
- Partner with a transmission and bearing technology expert with over 20 years experience



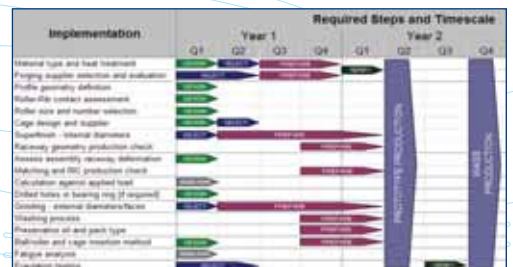
Yaw bearing design and system model



Surface roughness affect on film thickness and subsurface stress distribution



Raceway defect identified from grinding damage



Example of technology roadmap for bearing development

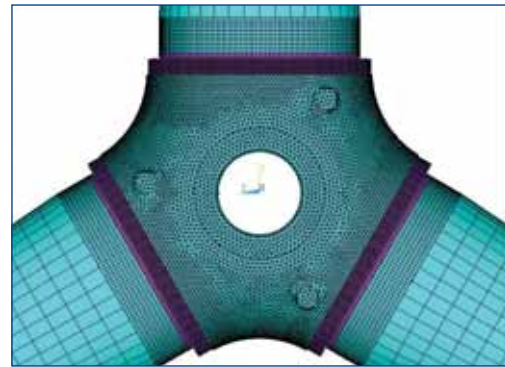


Bearing training session held at Romax

Bearing Finite Element Analysis

Use of Finite Element (FE) analysis allows for the flexible structural analysis of bearing components. However, there are many disadvantages of conventional large FE models where small contact zones require large mesh sizes and extensive operator input to create them.

Romax contact elements and plug-ins for ANSYS allow roller or ball contacts to be modelled in unrefined structural meshes providing accurate stiffness calculations.



3D FE model of wind turbine

Capabilities

- Perform full 3D FE static analysis for bearing assembly
- Consider axial, radial and bending loads
- Vary contact angles with load around bearing circumference
- Take into account flexible structures
- Include the effects of pre-load and internal clearance
- The results from bearing FE analysis include:
 - rolling element load sharing
 - bearing contact angle, contact stress and contact dimensions
 - bearing life prediction

Benefits

- Quickly and easily build complex 3D models
- Efficiently solve huge non-linear models using standard hardware
- Avoid convergence problems in complex contact models
- Accurately and efficiently calculate contact stiffness

Case Study: Wind Turbine Bearing Analysis for Certification

The issue

Wind turbine gearbox applications have to be designed and tested according to strict standards to ensure the long reliability requirements are maintained. Germanischer Lloyd Wind Energy (GL Wind) is an internationally operating certification body for wind turbines which assesses the suitability of gearbox designs before they can be used in-service. Design and selection of the bearings is of prime importance in wind turbine gearboxes, Romax was asked to provide durability calculations for a bearing manufacturer against a specified duty cycle and extreme load cases in order to pass the required certification.

The solution

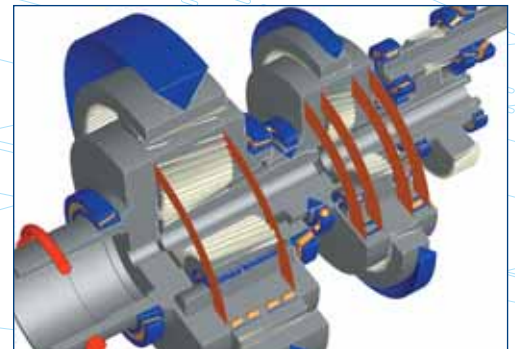
Romax provided the facility to produce reports with durability results needed to satisfy guidelines produced by GL, with analysis for wind turbine gearboxes easily carried out in RomaxDesigner. This allowed modelling of the detailed shaft geometry, complex planetary gear systems, spline connections, FE housing models and internal bearing details.

The result

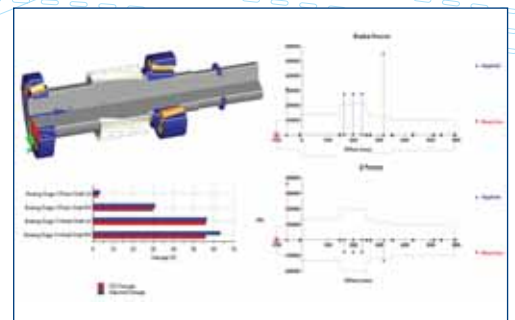
Reports for bearing performance provided by Romax for GL Wind certification have allowed the supplier to successfully use their products in wind turbine applications. With extensive experience in this area, Romax now offers this type of service to gearbox and bearing manufacturers along with providing consultancy for the detailed design issues involved with these large size bearings.

Analysis process

- Evaluate and select bearings using Load Duration Distributions (LDD) and extreme loads
- Calculate rating life according to ISO 281 and DIN ISO 281 Supplement 4
- Investigate and optimise pre-load, clearances, misalignment, bearing internal geometry and lubrication conditions
- Use detailed results such as static safety factors, bearing raceway stress contours and rolling element load sharing to validate bearing selection



Model of a three stage planetary and helical wind turbine gearbox design



Bearing load and life results for high speed shaft in wind turbine gearbox

Case Study: Low Cost Bearing Supplier Selection

The issue

Romax was asked to undertake a review for a medium duty truck transmission, to assess the use of bearings from low cost suppliers to ensure sufficient load capacity and good manufacturing quality were present to maintain reliability. The gearbox manufacturer requested, using RomaxDesigner's total system approach, detailed analysis of the bearing types along with Romax expertise during the manufacturing audit of the potential bearing manufacturer.

The solution

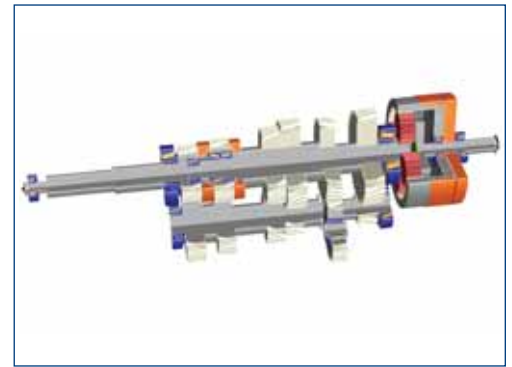
Analysis results were reviewed in terms of durability, raceway surface profiles, stiffness and contact stress. Advanced life calculations were carried out for each of the bearing positions considering the vehicle duty cycle and the affects of lubrication, contamination and temperature. Romax manufacturing specialists spent time at the bearing production facility to investigate quality against the required design intent.

The result

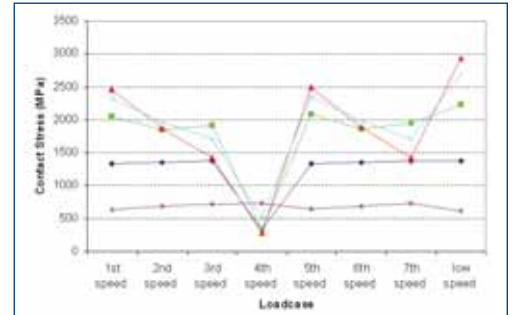
The use of the analysis results allowed a number of different bearing designs to be assessed, with the internal geometry being entered directly into the model. Risk assessment could then be performed on the supplier's bearing designs and optimisation of the raceway profiles carried out to ensure sufficient performance was obtained for the required reliability. The capability of the supplier to manufacture and achieve the required design drawings tolerances was verified.

Bearing evaluation

- Bearing selection and optimisation based on analysis of the complete system gearbox within the model
- Assessment of all factors affecting bearing performance such as pre-load, misalignment, lubrication and production variability to identify key influences on bearing performance
- Significant time and costs were saved by modelling and manufacturing auditing to verify the suitability of all components without the need for extensive and expensive testing



Cross section of the model for a heavy duty truck transmission showing bearing positions



Maximum contact stress results for bearings within the gearbox under duty cycle loading

Multi-shaft Analysis

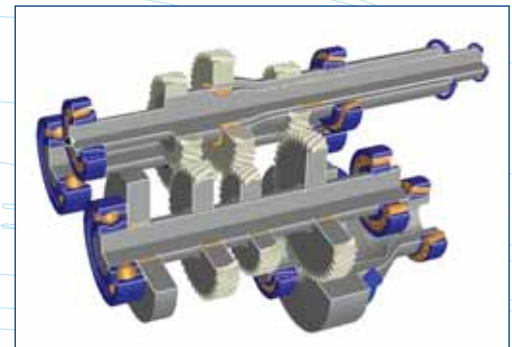
Recently, transmission engineers have been considering some unusual shaft/bearing arrangements for a new generation of gearboxes. The new arrangements present such a challenge to the traditional analysis methods and tools that Romax Technology has been asked by major bearing manufacturers to help. Using our software's unique analysis capabilities, such an arrangement can be modelled and analysed in a short amount of time. A study we carried out considered two concentric shafts connected via one thrust and two radial needle roller bearings. The analysis had to take into account the elastic deflections of all the components, the radial internal clearance of the two radial needle roller bearings and the pre-load of the tapered roller bearings that support the shafts. Changing the pre-load/end-play of the tapered roller bearings had a dramatic effect on the life of the thrust needle roller bearing.

Capabilities

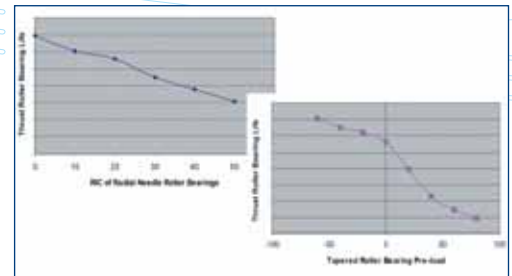
- Analysis of multi-shaft arrangements not usually possible by conventional tools
- Consideration of bending of the complex shaft arrangement and the interaction between different bearing deflections
- Consideration for the affects of bearing pre-load and internal clearance
- Consultancy on any unusual or complex shaft bearing arrangement requiring analysis

Benefits

- Fast and cost effective development process for complex arrangements
- Understand the influence on performance from factors such as bearing position and shaft design
- Improve concept designs at an early stage with accurate prediction of bearing life and stiffness for various load conditions
- Enhance ability to assess mounting condition of all bearings within the assembly in terms of pre-load and clearance



Example of multi-shaft arrangement and model in a new gearbox design



Influence on thrust bearing life from needle radial internal clearance and taper bearing pre-load



Romax Bearing Design & Analysis

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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

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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.

"At NTN, there is no doubt that RomaxDesigner has greatly improved and accelerated preliminary development. However, much shorter development times are just one of many advantages of the program. The simulation contributes greatly to a much better understanding of the effects that occur in the system as a whole and also within the bearing itself. This means that any necessary action can then be taken, whilst making the whole process transparent to the customer."

NTN Bearings