KISSSOFT
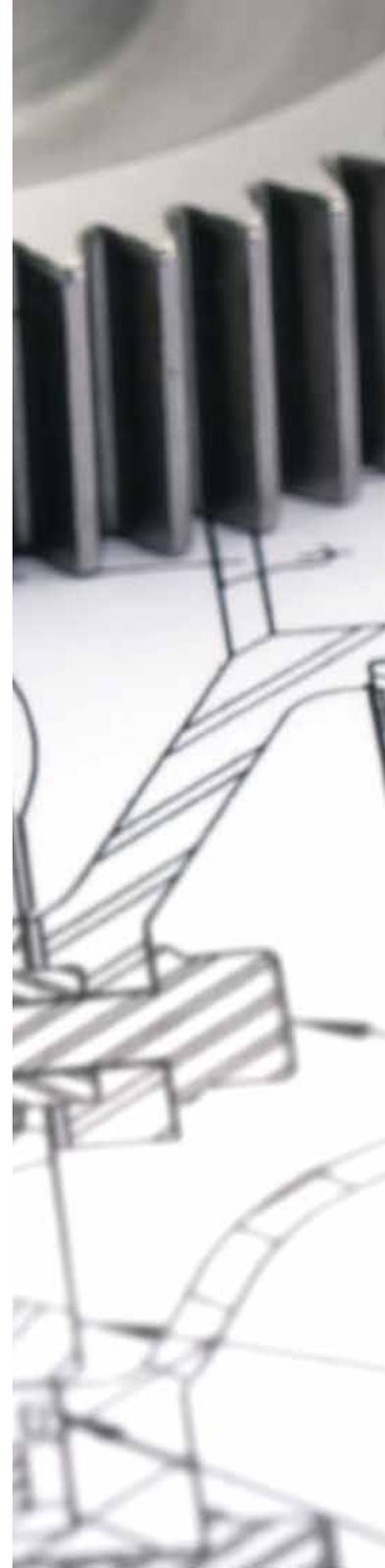# DESIGN, OPTIMIZATION
AND ANALYSIS OF
MACHINE ELEMENTS

SHARING KNOWLEDGE
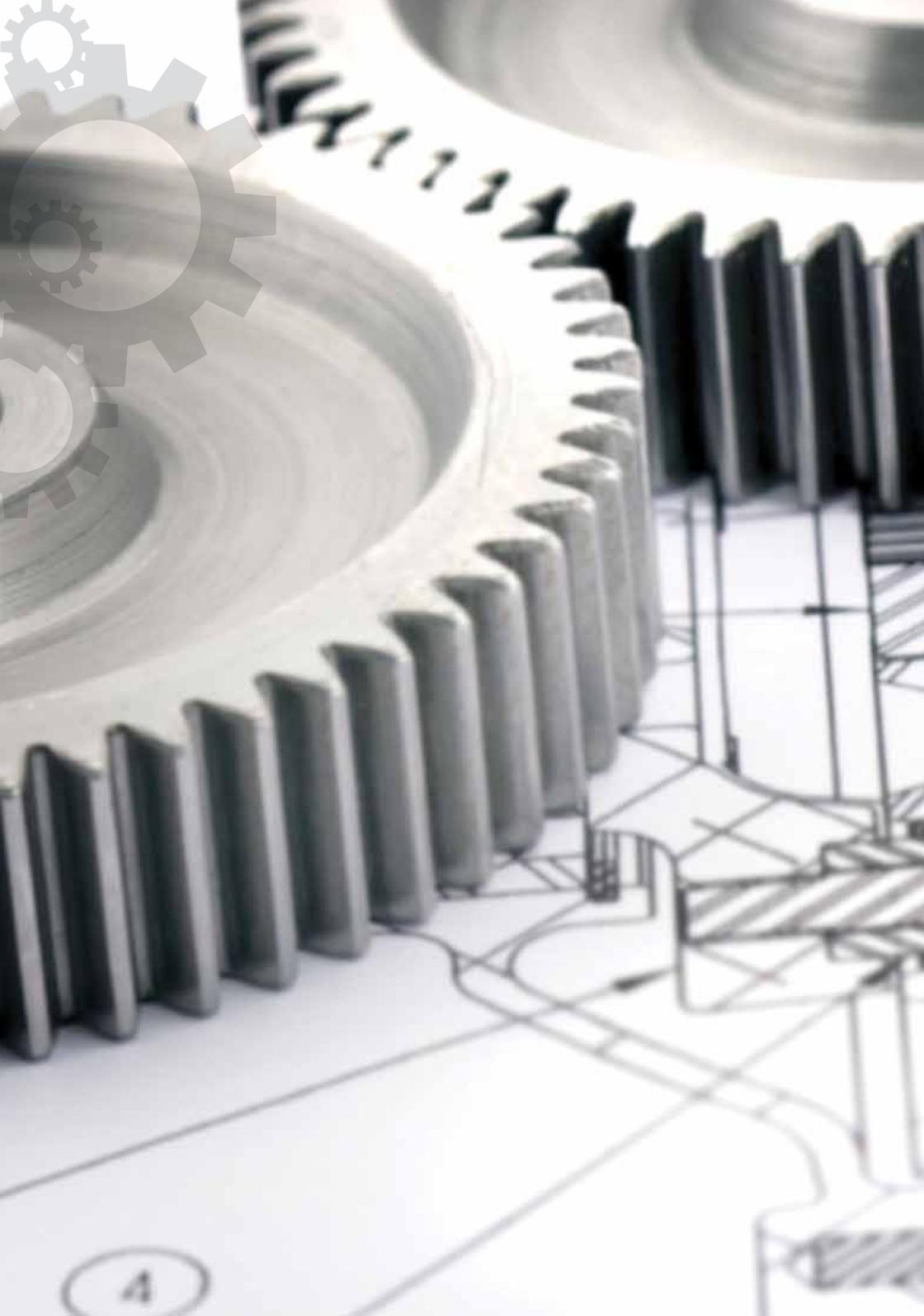
INTRODUCTION

KISSsoft AG develops design software for engineers and designers in a wide variety of fields: whether they manufacture cable car systems, gears for construction equipment, Formula 1 race car transmissions or the tiny gears used in Mars rovers, more and more companies all over the world have come to rely on KISSsoft calculation software.

Based on the applicable standards (ISO, AGMA, DIN), our software serves as a quick, high-quality tool for sizing machine elements, reviewing calculations, determining component strength and documenting safety factors and expected product life time.

PRODUCTS OVERVIEW

KISSsoft

KISSsoft is a program for sizing, optimizing and calculating designs for machine components such as gears, shafts and bearings, bolts, springs, connecting elements, belts and others. The application of KISSsoft ranges from fast and reliable strength analysis to highly sophisticated optimization and covers the whole design process of machine elements. The product can also be integrated in all popular CAD programs.

KISSsys

KISSsys is a software add-on for KISSsoft that allows users to model transmissions and drive trains. Instead of working with several, independent calculations, the whole gearbox is modeled and the analysis is performed for all gears, shafts and bearing simultaneously. KISSsys is very flexible due to the arbitrary kinematics of the modeled gearbox and the integrated programming language.

GPK

GPK is a program based on KISSsys and offers the same functionality with the only exception, that the models provided with this tool can not be changed. The models that come along with this package cover the most important standard kinematics, multiple stage helical gearboxes, bevel-helical-, worm-helical- and planetary gearboxes. Integrated into gearbox package GPK is a cost analysis which allows the design engineer to compare the estimated costs of manufacturing for several variants of a gearbox even during initial gearbox design. Comprehensive reporting functions ensure that he can document his work quickly and according to the current quality standards.

Engineering and consulting

We provide these services to help you in your efforts to design marketable products that can be produced economically. Our services include developing suggestions and providing expert opinions that are perfectly tailored to your unique situation.

KISSSOFT

KISSsoft is a software package for calculating machine elements. While gears are a natural focal point, owed to their central role in transmission, the software also covers shafts, bearings, connecting elements, springs, chains/belts and others.

Gears

Sizing calculations cover all common gear types: cylindrical gears, bevel gears, worm gears, helical gears, hypoid gears and face gears, for cylindrical gears also as planetary sets and gear racks. In addition to the strength analysis according to the respective standards (ISO, AGMA, DIN, VDI, Klingenberg), the program also offers a number of different design and optimization functions and methods exceeding the standards.

Shafts, bearings

Shaft and bearing modules are integrated, i.e., based on the definition of the shaft geometry, bearings and loads within the graphic shaft editor, the software allows the calculations for sizing roller and journal bearings, for shaft strength analysis according to DIN or FKM standards, calculating deflection lines, buckling loads, critical speeds and tooth profile deformation of shaft-mounted gears.

Connecting elements

In addition to bolts and pins, this category also includes shaft-hub connections, keys, interference fit, splines, and so on.

Springs

Relevant DIN methods, including databases on standard springs and materials and, of course, helpful design functions, are available for performing sizing calculations on the five most important types of springs.

Chains/belts

A number of specific calculation methods based on manufacturer data are available for belts; sizing calculations for chains are based on DIN standards.

Miscellaneous

This part of the software provides engineers with modules for performing general calculations (tolerance, hardness, Hertzian pressure).

CAD interfaces

Interfaces to common CAD programs make it easy to create 2D and 3D drawings of gears, which would otherwise be a very time-consuming process. Manufacturing data is transferred automatically to the CAD drawing.

Starting as an in-house tool of the gearbox manufacturer L. Kissling & Co. AG in Zürich in the early 1980s, KISSsoft has developed into all branches of machine design. It is the tool of choice for each engineer that has to size and analyse gears, shafts, bearings and the other machine elements.

GEARS

Besides spur and helical gears in different configurations such as gear pair, epicyclical, three or four gears, pinion and rack or as a single gear, the KISSsoft calculation program also covers bevel and hypoid gears, crossed axis helical gears, worm gears and face gears. In addition to the strength analysis according to the respective standards numerous optimization functions are offered. And of course all important geometry calculations are carried out, control measures for the manufacturing are provided and the tooth shape is represented in two and three dimensions.

Using current standards as its basis, KISSsoft serves as an easy and safe tool for verifying the strength of cylindrical gears and offers a number of different methods.

The software calculates resistance to pitting, scoring and breakage at the root of a gear tooth, and, if given a minimum safety factor, can also determine transmittable power and achievable service life.

Geometry calculations provide all relevant dimensions and test measures based on applicable standards and under full consideration of relevant tolerances.

The pre-sizing feature provides a series of suggestions for gear pairs aimed at solving a transmission problem – all at the click of a button. On the one hand, this step provides reasonable ranges for the module, centre distance, face width and number of teeth; on the other hand, the concrete solution also serves as a starting point for further optimization work. For cylindrical gears the fine sizing feature, which combs through entire ranges of parameters and validates solutions based on a variety of criteria, offers a powerful tool to find the optimal solution.

Other design functions are available that target specific parameters such as profile shift, tooth thickness tolerances, helix angle or reference profile; these functions then determine the value of the parameter based on pertinent criteria.

CAD interfaces allow the user to represent a gear in two-dimensional format as a DXF or IGES file or as a three-dimensional STEP or IGES model. Various levels of integration are also available for the CAD programs typically used in mechanical engineering; this integration option makes it possible to construct a 3D model automatically in the CAD program.

Detailed reports are created listing all gear data including geometry, tolerances and strength data. Report templates can be modified, project specific templates possible, length of report can be varied.
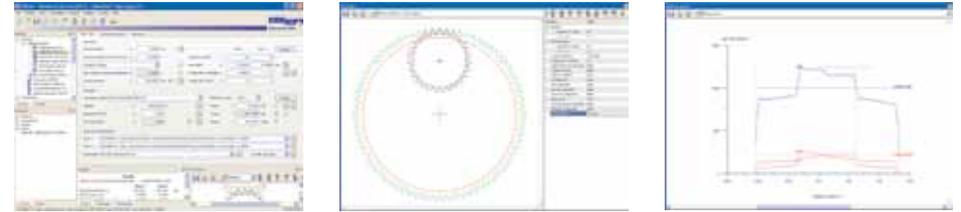

Special applications

The calculation programs are comprehensive and allow – by way of their modular design – for specific use in a large variety of fields:

○ **Industrial gearboxes:** Gear-sizing, optimization of gears in respect to strength, noise, precision and efficiency

○ **Automotive:** Fine lay-out of gears for restricted conditions in terms of available space, optimization noise and tooth stress

○ **Precision mechanics:** Calculation of geometry, deviation of base tangent length, reference profiles according to DIN 58400, interfering cutter/tool, optimization of tooth form for strength and noise

○ **Plastic gears:** Strength calculation for plastics (service life and influence of temperature) according to VDI 2545; calculation of backlash taking into account the swelling; optimization of profile modification for uniform, noise-optimization run; optimization of root rounding with display of root stress; radial und tangential strain of tooth form for discerning the casting form; spark-compensation for discerning of electrode

○ **High speed gearboxes or gear boxes with minimal backlash:** Sizing of addendum modification factor, proposition for profile correction and calculation, operating backlash taking into account temperature and assembly deviations, deep tooth form

○ **Special tools and special tooth forms:** Interface for reading tool data or tooth-form data which were drawn in CAD, calculation of tooth form reference profile, strength analysis

○ **Deep tooth form:** Proposal for deep-tooth form for user defined nominal contact ratio

○ **Equivalent design loads and service life:** Equivalent design loads using user defined spectra, to be managed in a database, life calculation according to Miner, Haibach and Corten-Dolan, calculation of service life or of transmissable torque

SHAFT AND BEARING ANALYSIS

The central element of the shaft and bearing calculation is the graphic shaft entry (shaft editor). This is where the inner and outer geometry of the shaft, bearings, and loads are defined. Based on this data, the included finite elements core executes all relevant calculations from the deflection line and course of torque, to critical speed, to strength verification in accordance with DIN or FKM guidelines. Stress concentration and notch effects are calculated automatically based on the norm. Duty cycles can be introduced for each load individually. A summarizing report provides an overview, specific reports offer very detailed information.
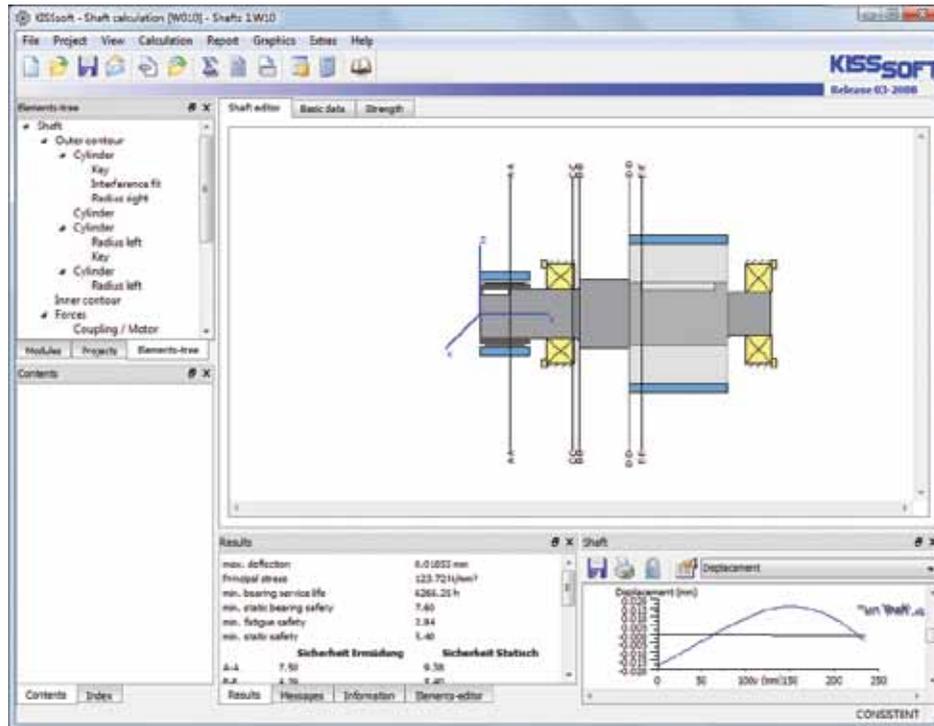
The graphic shaft editor allows the definition of shaft geometry with cylindrical and conical elements including notches, bearing arrangement, and loads. The editor also offers the import of the shaft geometry from a DXF file. Loads can either be defined classically through forces and moments, or through more complex load elements such as cylindrical gears, bevel gears, worm gears, couplings, pulleys, magnetic loads, etc. Where applicable, these elements can be linked to data in other KISSsoft modules. Individual load spectra can be assigned to all load elements.

The bearing calculation is integrated in the shaft calculation so that dimensions, forces, etc. are already available.

For roller bearings ISO281, including appendix 1,2 and 4 are implemented. Via one mouse click, the software filters all geometrically suitable bearings of the selected type out of the bearing database (approximately 15,000 bearings), evaluates them (service life and static characteristic number) and shows them to the user in a table for selection. For the calculation of the bearing life time the inner geometry and the load on the rolling parts can be taken into account, as well as the lubricant and the temperature. Thermal expansion of shaft or housing and displacement of bearings lead to changes in the forces. Statically over-determined systems with more than two bearings and O- or X-arrangement can be directly treated.

Journal bearing calculation can be quickly executed thanks to integration in the shaft calculation. The system handles hydro-dynamic and grease-lubricated radial journal bearings and hydrodynamic axial journal bearings.

Calculation of the natural frequencies of the shaft, with or without additional masses, is done automatically. The bearing and housing stiffness are taken into account, as well as the gyroscope effect of centrifugal masses.

A further feature of the shaft module determines the deformation of flanks of gears on the shaft. Given the deformation data the optimal profile can be derived for crowning. A load distribution calculation with graphic presentation determines the contact load factor $K_{H\beta}$ for the gear calculation; crowning and helical angle corrections can be specified.
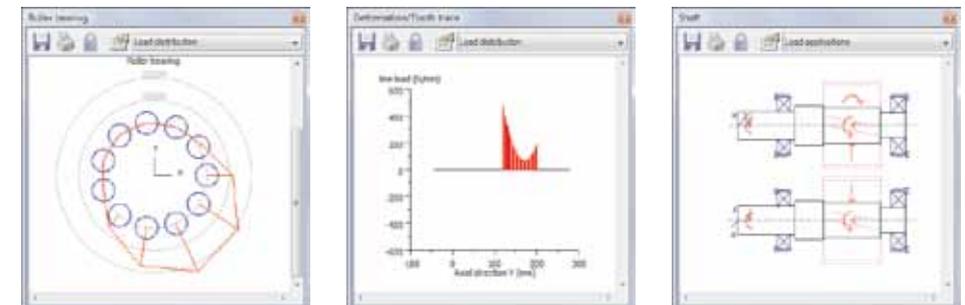
CONNECTIONS BETWEEN SHAFT AND HUB

For calculation of the shaft-hub connection the system checks whether the connection function as such (for the two force-fit connections cylindrical and conical interference fit) and whether the occurring fits remain below the permissible material characteristic values. All calculation modules offer design functions for strength-relevant geometric dimensions and the maximum transmissible torque.

For the cylindrical interference fit DIN 7190 is available, the conical interference fit is calculated according to Kollmann. For keys DIN 6885 is used. The spline connections according to DIN 5480 (2006), ISO 4156 (1991), ANSI B92.1 and ANSI B92.2 (1992) can either be calculated according to DIN 5466 or Niemann. For Woodruff keys, spline shafts and the polygons the specialized literature is referenced.

ELASTIC SPRINGS

This module treats cylindrical helical compression springs in accordance with EN 13906-01, helical compression springs in accordance with EN 13906-02, cylindrical leg springs in accordance with EN 13906-03, disk springs and spring packs in accordance with DIN 2092 and torsion bar springs with round cross section in accordance with DIN 2091. For this an extendable database is available in KISSsoft with the most frequent spring materials as well as several wire diameters. The spring characteristic curve is shown for illustration, as well as the Goodman diagram where applicable.

HIGH YIELD BOLTS

The calculation is according to VDI 2230, (1990 and 2003). Tables are integrated for all applicable elements, such as bolts in accordance with EN ISO 4762, 4014, 4017, 1207, 8765, 8676, EN 1662, 1665, standards for bores, washers, nuts, etc. Own definitions of bolts of almost any complexity, even banjo bolts are possible.

Plates, sleeve, segments, or prismatic bodies can be defined as clamped parts. The program can make recommendations for nominal diameter and thread length. Single bolts under longitudinal force, transverse force, flange connections with torque and bending moment and console connection with any bolt position can be defined and handled.

Consideration of eccentric stress and resilience and checks for divergence of the separating joint. Calculation with operating temperatures between –200 and +1000 degrees Celsius. Different temperatures can be specified for bolts and resilient parts.

BOLTS AND DOWELS

Bolt connections/dowel connections are classified in four calculation types depending on application case: the stresses of bolt, shaft, and hub (or component) with determination of resistance is calculated in accordance with the classic literature (Niemann, Maschinenlemente I. 3rd edition, 2001) for four different load configurations transverse dowel under torque, longitudinal dowel under torque, dowel pin under tensile force and transverse stressed bolt connection.
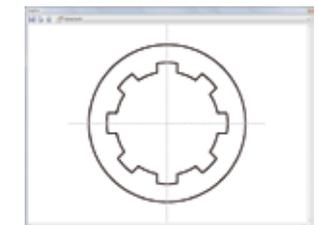
ADHESIVE, SOLDERED, WELDED CONNECTION

The calculation of adhesive or soldered connection has two specified stress cases: Shear force and torque load. Extendable database for adhesives and materials. The welded connection can be calculated for different, specified weld seam types on the basis of DIN 18800.

BELT DRIVES/CHAIN DRIVES

The belt calculation in KISSsoft offers manufacturer-independent calculation of V-belts and toothed belts; calculating guidelines of the manufacturers are used. Both calculation modules offer helpful configuration functions for belt length, center distance, the necessary width or number of belts, and so on. The chain geometry in the chain calculation is based on ISO 606, the basis of calculation is DIN ISO 10823. KISSsoft can make recommendations for chain type, number of links, and center distance.

MISCELLANEOUS

⚙ Tolerance calculation for summing up multiple tolerances of chain dimensions with statistics
⚙ Hardness conversion for conversion of hardness values from one system to another
⚙ Hertzian load implements the formulas for Hertzian load for general cases
⚙ FKM guideline for strength verification with local stresses

KISSSYS: ANALYSIS OF GEAR TRAINS

Introduction

The KISSsys software combines kinematic analysis, lifetime calculation, 3D graphics and user defined tables and dialogs with a programming language. It is the tool of choice for strength and lifetime analysis of various kinds of drive trains and gearboxes. KISSsys lets the user do quick yet detailed parametric studies of a complete power train in very little time to compare different variants of a concept. The machine elements calculated range from gears, shafts, bearings, shaft-hub connections to bolts. This will result in a more balanced starting design and fewer modifications will be necessary further down in the design process. Furthermore, documentation of the calculation is simplified and all calculation data for a whole drive train is stored in a single file.

KISSsys uses KISSsoft for the strength and lifetime calculations of the various machine elements.

Advantages

When designing a gearbox, an engineer must carry out an iterative process: Every change of an element of the gearbox (e.g. the helix angle of a gear) influences most other parts (e.g. the bearing loads). Checking these influences by manual calculation is extremely slow and prone to errors. The objective hence is to have not only a pair of gears parametrised but the whole drive train. This is achieved with KISSsys. Here, all parts (gears, shafts, bearings, connections) of the gearbox are linked and the strength/lifetime analysis is performed simultaneously for all elements. A three dimensional graphical presentation of the current state of the system immediately shows the geometrical influence of every change in parameters. This approach greatly accelerates the design process and results in a much more balanced design even during the concept phase. KISSsys features:

Kinematics calculation:
- Bevel, helical, worm and face gears, epicyclic gears (planetary, Ravigneaux, Wolfrom, …), chain and belt drives
- Model differential gears, activate/de-activate couplings, add slippage
- Add external loads and coefficients of efficiency
- Automatic 3D representation of the KISSsys model, parameterized graphics
- Collision checks between parts and parts to casing, import gear box casings as STEP or IGES

Special features:
- Calculation of load spectra for all machine elements included in the model
- Use variants of a gearbox in the same KISSsys model
- Perform sensitivity analysis automatically
- Automatically generate documentation for a complete gearbox analysis
- Use scripting language for automatisation of routine tasks
- Interface to KISSsoft, export to CAD programs

KISSsys boosts the efficiency of KISSsoft to a new level. Due to the system approach some core aspects of the calculation process like load definition, balanced design and documentation of the results get much easier and offer a higher degree of reliability by eliminating error prone steps.

EXAMPLE APPLICATIONS

Since the first version of KISSsys was released in 2001, it has been successfully applied to a wide variety of applications. In addition to those in the machine industry including geared motors, wind turbines, power tools, actuators, and so on, it has been used for wide-ranging projects in the automotive, agricultural and construction industry.

Analytical model of a wind turbine gearbox

Using KISSsys the complete gearbox, consisting of two planetary stages and one helical stage is modeled. Hence, the kinematics of the epicyclic gear is known and the loads on the gears, bearings and shafts can be calculated automatically. Using these loads, the lifetime of the mechanical elements is automatically calculated using KISSsoft in the background. It is hence sufficient to define the speed and torque acting on the input shaft in order to analyze all mechanical elements present. The lifetime analysis of the elements is performed in KISSsys using a damage accumulation algorithm instead of calculating a damage equivalent load, since the slope of the S-N curve of the bearings and gears is not equal. The load spectrum can either be defined manually or read from a text file. Since all analysis parameters and results are stored in variables, comprehensive reports can be generated.

Development of new drive concepts for tractors.

Power-split drives are used to achieve a continuously variable driving speed. To this end, a planetary gear set is used to divide the engine power into a hydrostatic and a mechanical component. In the hydraulic part, an axial piston pump drives a hydraulic motor with a large swash angle. The hydrostatic section thus acts as a CVT gearbox. The two power components are brought together on a summing shaft, fed to the centre differential, and then to the axle gear trains. The main tasks to be performed with KISSsys are the determination of the overall efficiency, the hydrostatic power ratio, and the service life calculation with customer-specific load conditions. Also of interest is the task of determining load spectra to be used in the tests that lead to the same degree of damage as the load spectra to be encountered in real world operation.

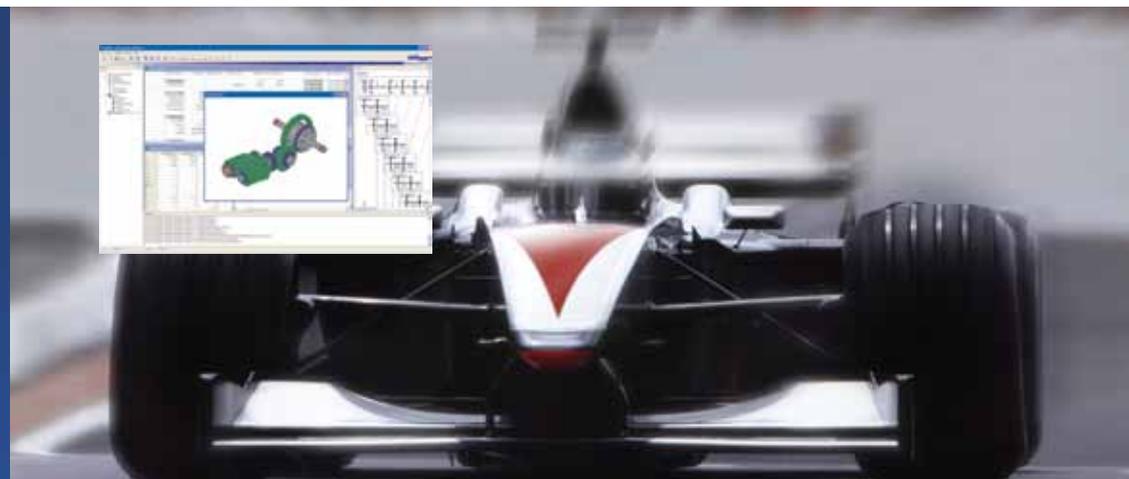## Modeling of a leading Formula 1 team's gearbox

This involved modeling the gearbox itself (7 forward and 1 reverse speed), the intermediate, bevel-gear reduction and the spur-wheel differential. The service life calculation is carried out for the gears, bearings and the shafts under load conditions measured during racing. One element of the duty cycle is composed of the frequency of use, the engine speed and torque and the selected gear. This makes use of one of the very powerful properties of KISSsys: when determining the overall service life with duty cycles, the power flow is first set for each group of load conditions corresponding to the speed selected and then the system calculation is carried out. The result is an easily comprehensible table of the service lifes of all parts calculated for the duty cycle. The critical elements (i.e. service life too short) and over-dimensioned elements (i.e. possible weight-saving) can then be picked out at once.

Large mobile cranes

Large mobile cranes have eight or more axles, of which the greater part is driven. The axle distribution gear trains, with their connected differentials and wheel-hub gearboxes, are correspondingly complex. A calculation for various load conditions (e.g. to compare driving on road and off road) therefore results in a large number of calculations for individual machine elements. The structuring of these calculations with KISSsys saves a great deal of time and improves the clarity of results.

Development of plastic gears/actuators

When designing actuators using plastic gears, e.g. for building automatisation, domestic appliances, disc drives or in automotive applications, the design space usually is given by a specified casing. Gears have to be designed such that they fit into the given space. 3D geometry of casings can be imported into KISSsys using neutral geometry formats. Collision checks are automatically executed accelerating the design process.