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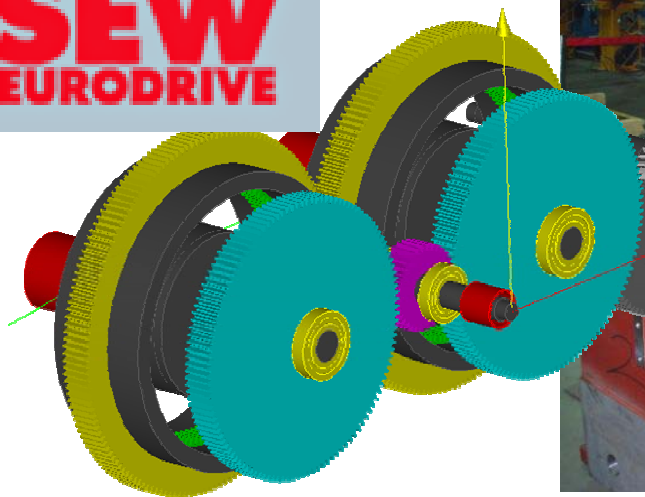
Using KISSsys in design and verification of a large crane gearbox

SEW China and KISSsoft AG used KISSsoft and KISSsys software in the development of a large crane gearbox. Exchanging data between Switzerland and China became very simple due to the fact that all relevant gearbox data is contained in one single KISSsys file. Every design change could be implemented rapidly, sent across the globe and re-analyzed. Instead of sending pages and pages of calculation reports, the calculation file itself, containing all updated strength and lifetime data was sent back and forth between SEW China and KISSsoft AG.

Furthermore, the design process was accelerated due to the time difference. In afternoon, the Chinese colleagues would send the KISSsys model containing all necessary design data to Switzerland for verification and modification and by the time they got back to the office the next morning, the results were all available to them in their Email!

Any design changes that became necessary during the manufacturing phase (due to e.g. limited availability of certain tools) were relayed to Switzerland where the modification was implemented in the KISSsys model. All necessary load cases were then re-analyzed immediately and the results sent back to China, informing about the feasibility of the required change within minutes to hours.

The gearbox has proven itself in its first year of operation and a happy customer decided to purchase additional gearboxes from SEW.



Project 06-042, Differential Gearbox, KISSsys

KISSsoft AG thanks SEW Eurodrive China for allowing us to publish this application report. See www.sew-eurodrive.com for more information on SEW.

Customer	Supplier	Project	Document
SEW Industrial Gears (Tianjin) Co. Ltd. Tianjin 300457 China www.sew-eurodrive.com	KISSsoft AG Uetzikon 4 8634 Hombrechtikon Switzerland www.KISSsoft.ch	Title: Differential Crane Gearbox No.: 06-042 Date: 1.8.06 Manager: HD @: hanspeter.dinner@KISSsoft.ch	Version: 0 Autor: HD Date: 18.7.07 Approved: HD Date: 18.7.2007

Table of contents

1	The calculation model.....	2
1.1	How did SEW benefit.....	2
1.2	The application.....	2
1.3	The KISSsys model.....	3
1.4	Data exchange using the KISSsys model.....	4
2	Calculations.....	4
2.1	Kinematics.....	4
2.2	Shafts and bearings.....	5
2.3	Keys.....	6
2.4	Gearing.....	7
2.5	Reports.....	8

1 The calculation model

1.1 How did SEW benefit

- 1) Allowing two parties simultaneously to work on the design, the development time was reduced. This was achieved by using a shared software platform and by maintaining all relevant design data in one single KISSsys file that could be shared easily by email.
- 2) Data management, storage and exchange was simplified. When dealing with multiple components, a tight schedule and several load cases, managing all design and calculations in one single KISSsys file helps the engineer to reduce his workload. Error prone exchange of data from one calculation to another is eliminated as all calculations are connected with each other in KISSsys. Data exchange is automatic, the engineer is relieved of this boring task.
- 3) Documentation generation, both for analysis reports and CAD data, was automatised. All analysis reports can be generated automatically from KISSsys for the whole gearbox, relieving the engineers from the tedious task of compiling engineering analysis reports. Furthermore, CAD interfaces allowed the fast generation of production data from KISSsoft.
- 4) Manufacturing aspects were considered in gearbox sizing phase. KISSsoft integrated gear geometry calculation continuously checks whether gears sized or rated can be machined using a given tool and whether any meshing errors occur for the final, manufactured gear geometry.

1.2 The application



During the design phase, the kinematic condition had to be checked continuously. The resulting gear ratio had to be maintained within a few percent deviation of the desired gear ratio. Therefore, whenever some gear data was changed, the kinematics of the gearbox was reanalyzed to verify that the resulting ratio was within the requirements. Using the fine sizing options in KISSsoft, the target ratio per gear pair could be specified. In the final design, therefore a deviation in the total ratio less than 0.1% was achieved!

Based on the kinematic definition in KISSsys (see below), all powers, torques and speeds are calculated. This kinematic conditions serve as input into the strength calculations.

In addition to the two input torques and speeds, forces acting on the output side of the gear box were considered.

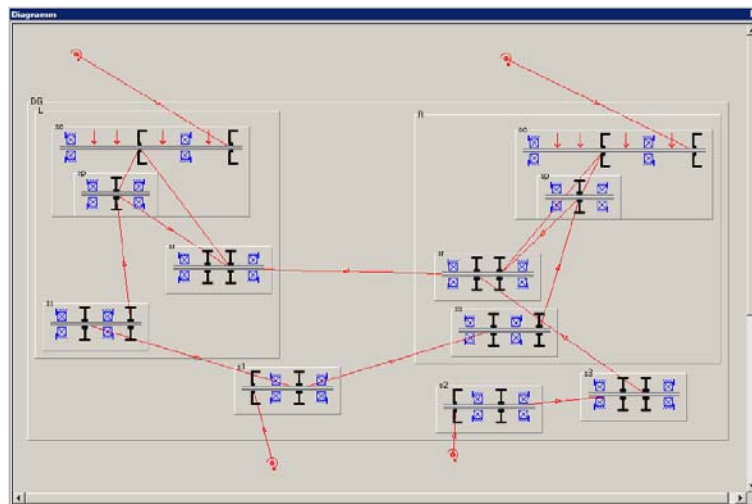


Figure 2.1-1 Representation of the gearbox kinematics. Power flowing is indicated by red arrows. The two planetary units are of identical design.

2.2 Shafts and bearings

Shafts are crucial in any hoisting application; any shaft failure may result in the load lifted to fall. Shaft strength is therefore checked for a worst case load assumptions and rating the shafts both for fatigue and static strength. The rating was done along DIN743 standard and using the most critical cross sections as defined by the local load and stress concentrations.

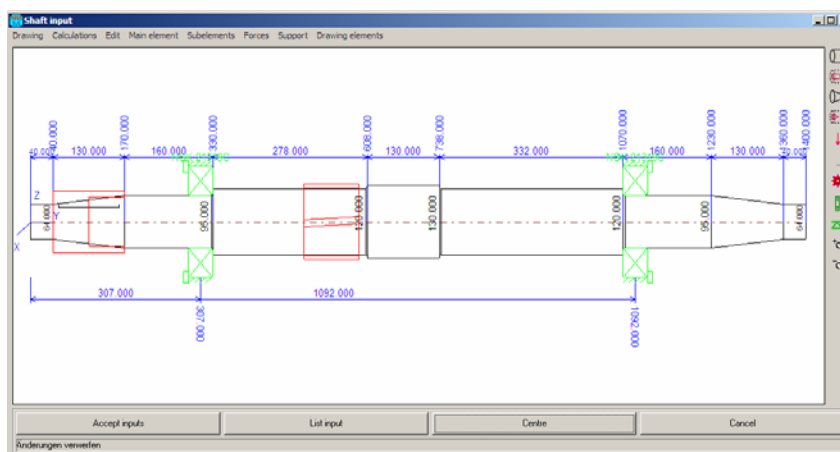


Figure 2.2-1 Shaft model of one of the input shafts as modelled in KISSsoft and then integrated in KISSsys

The bearing calculation was done along ISO281 using static and dynamic load capacity numbers. Resulting radial and axial bearing forces as well as rotational speeds were automatically calculated in the shaft calculation and forwarded as input to the bearing life calculation. The required lifetime was met, as well as the required static strength of the bearing.

The bearing selector was used to find the smallest possible bearing, by scanning the KISSsoft bearing database for suitable bearings in terms of required diameter and lifetime.

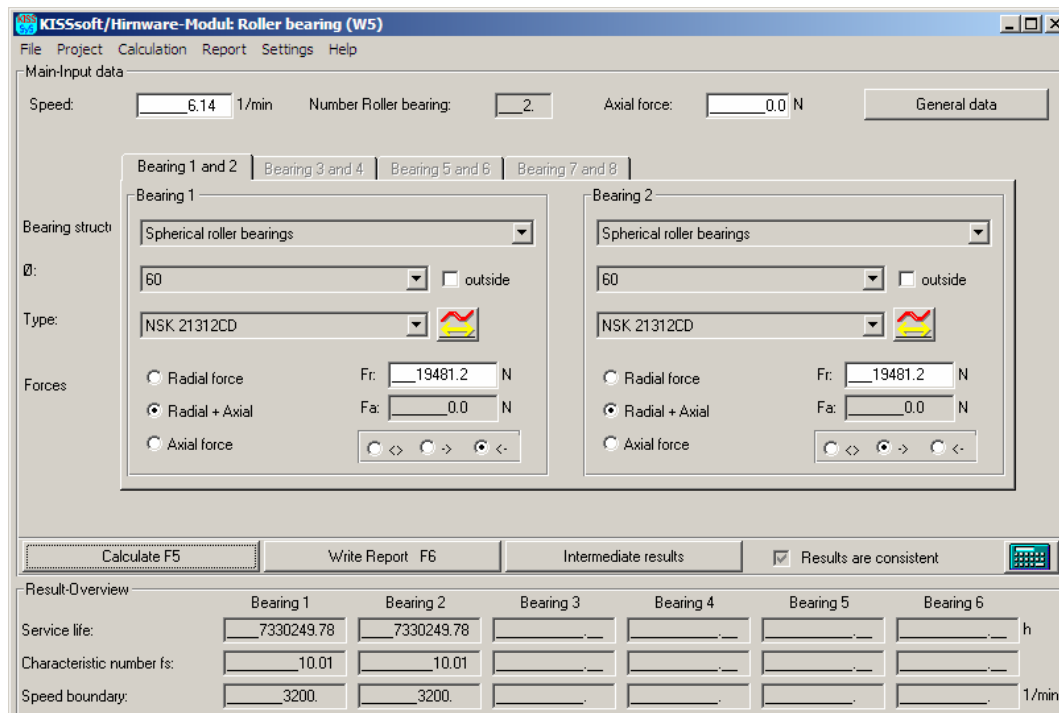


Figure 2.2-2 Bearing rating is integrated in shaft analysis, bearing forces acting are automatically calculated from gearing loads acting on the shafts.

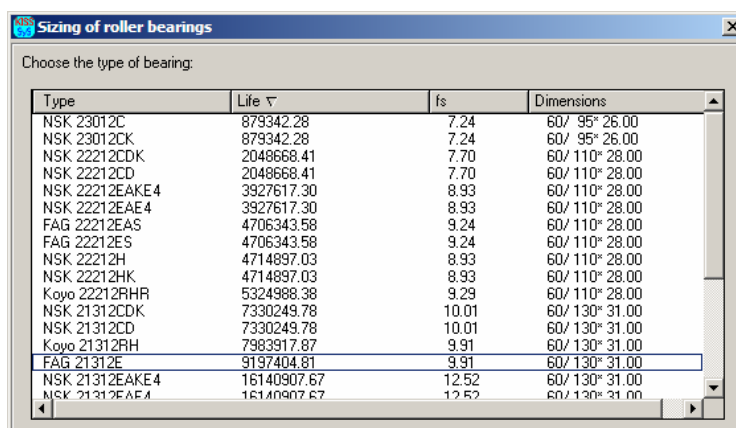


Figure 2.2-3 The bearing selector was used to find a suitable bearing of minimal size but sufficient lifetime.

2.3 Keys

A total of four keys were analysed simultaneously. The key calculation takes into account the surface pressure between key, shaft and hub. This again is a function of the effective contact area, torque applied and shaft diameter. The permissible surface pressure is a function of the material strength and the type of loading (shock loads, alternating loads).

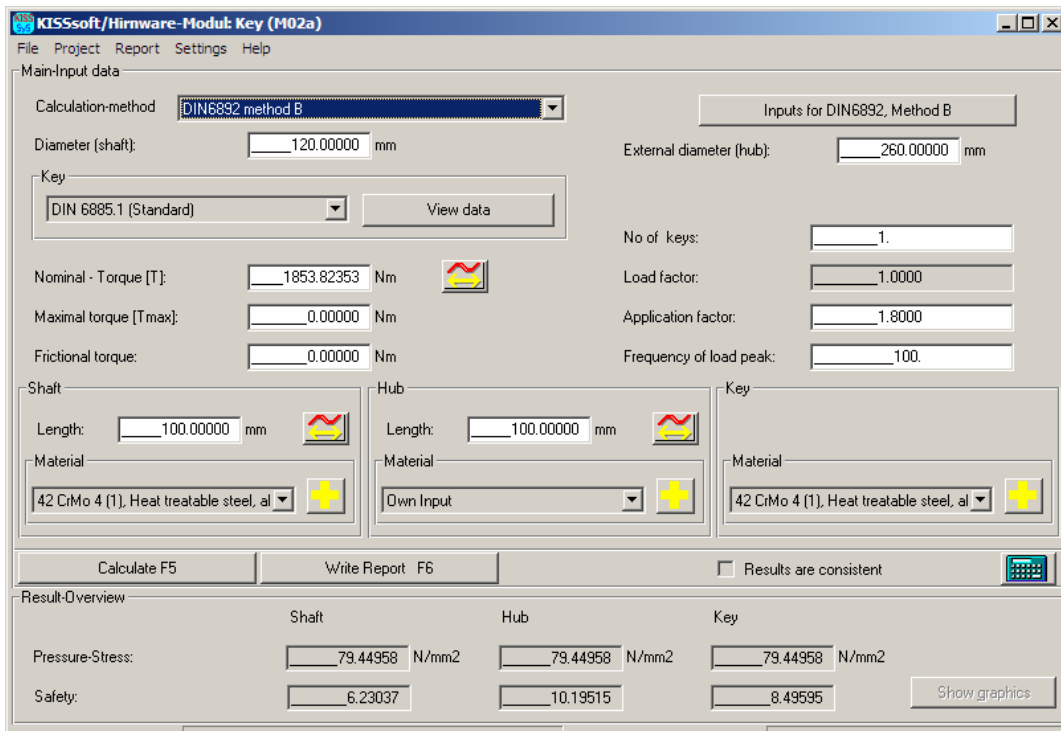


Figure 2.3-1 Key rating along DIN6892 in KISSsoft

2.4 Gearing

Gear sizing was based on given target ratio, power transmitted and size constraint. Gearing quality was defined by SEW as well as material choice. Based on this data, using the KISSsoft gear sizing function, gearing data optimized in terms of mass, strength and manufacturing (use of available tools) was performed. The subsequent gearing rating can be done along DIN3990, ISO6336 or AGMA2001 standards. The KISSsoft gear geometry calculation was used to check the final gear geometry based on simulation of the manufacturing process in order to avoid and meshing error on the final gears.

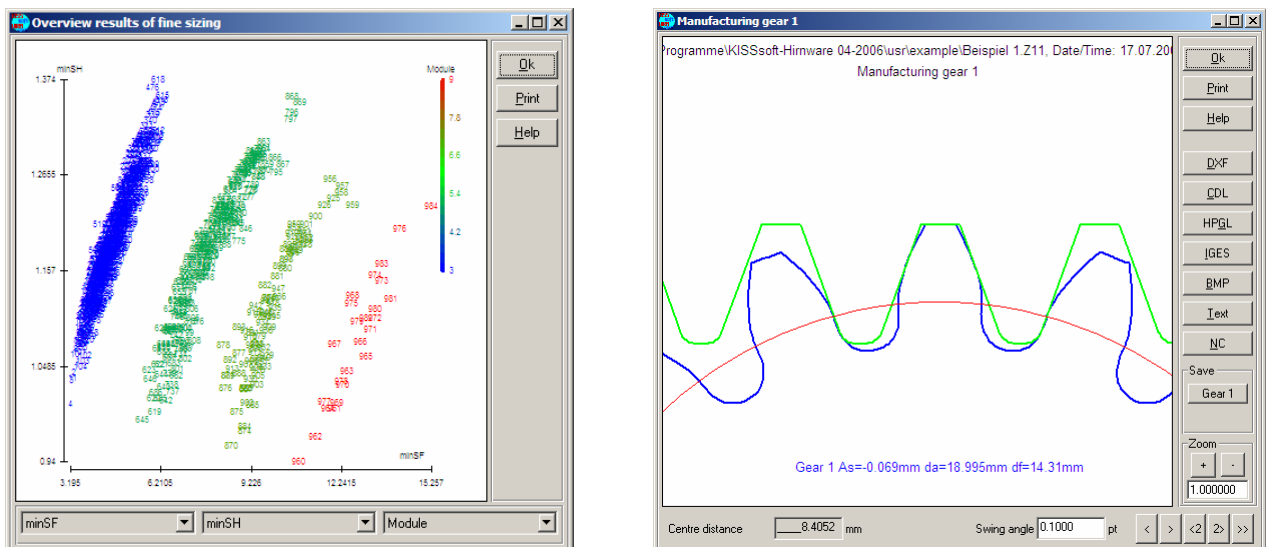


Figure 2.4-1 Left: Possible gearing solutions within a given parameter space. Right: simulation of gear geometry based on hob geometry.

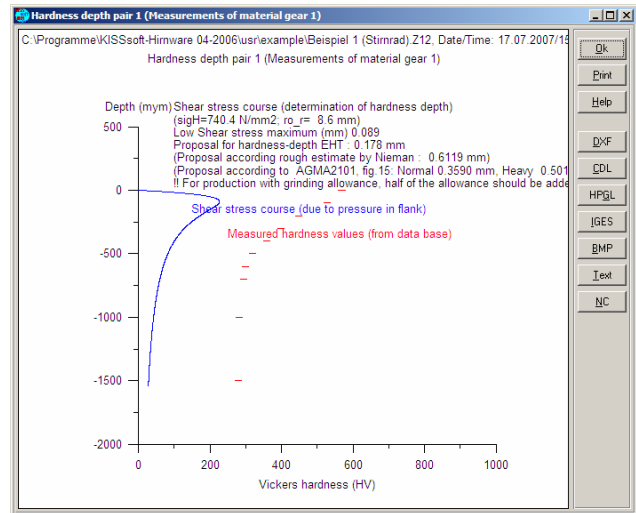
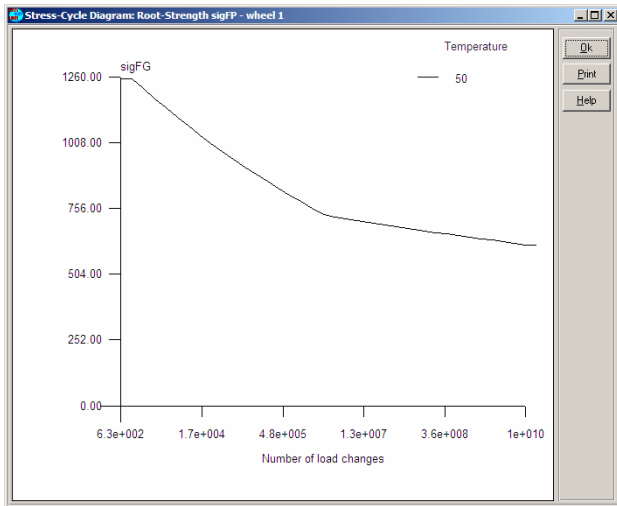
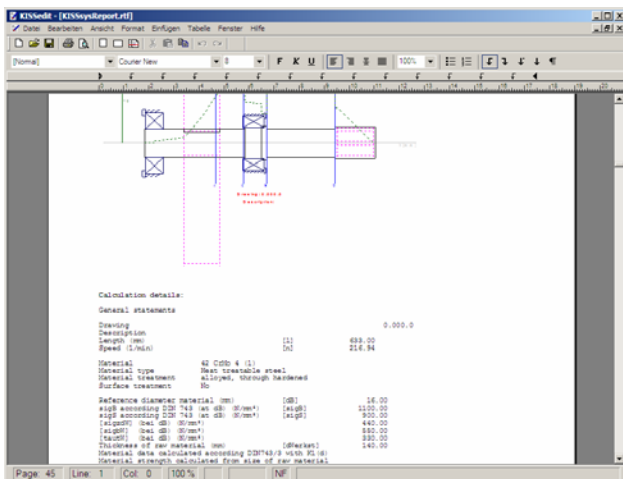
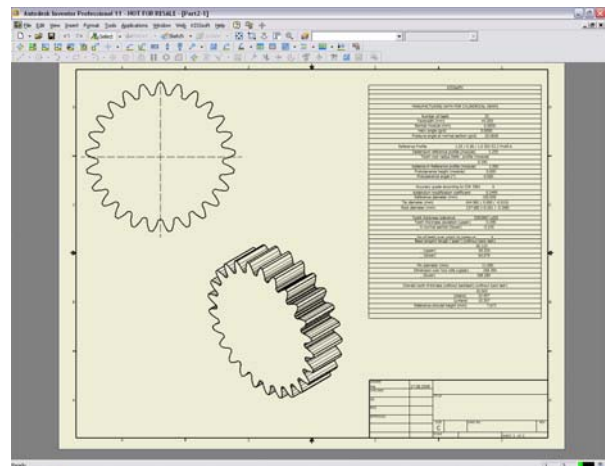


Figure 2.4-2 Left: S-N curve used for rating (bending) along ISO6336, using ML material data. Right: shear stress inside of tooth for determination of required hardness depth.

2.5 Reports

Besides the comprehensive strength calculation report (total of 151 pages per load case), the most critical results (like safety factors and life times for bearings) were summarised in tables as shown below. Furthermore, gear manufacturing data as required on the drawings as well as summary reports were generated.

fileName	z1z6L	z1z6R	z2z3	z4z6R	z6z6
P	41.842	79.619	45.003	45.003	49.846
T1	532.75	1013.7	573	1853.8	13261
T2	1841.8	3504.7	1853.8	11973	13261
n1	750	750	750	231.82	35.894
n2	216.94	216.94	231.82	35.894	35.894
mn1	8	8	8	8	8
beta1	0	0	5	0	0
alpha1	20	20	20	20	20
z1	35	35	17	24	155
z2	121	121	55	155	155
a	625	625	288	726.6	1250
b1	100	100	100	100	100
b2	100	100	100	100	100
x1	0.32532	0.32532	0.36134	0.75197	0.6435
x2	-0.19956	-0.19956	-0.49687	0.64352	0.64352
SF1	12.911	8.115	7.8801	5.1013	2.3122
SF2	11.794	7.4144	6.9712	2.6133	2.3122
SH1	4.061	3.2435	2.143	1.852	1.5633
SH2	4.061	3.2435	2.143	0.89793	1.5633
SSint	4.5919	4.2594	3.3977	3.8512	5.9015
SB	32.568	14.746	2.5885	9.4727	54.463
RefProfile1	GE Ref Profile	GE Ref Profile	GE Ref Profile	GE Ref Profile	GE Ref Profile



Manufacture-Tolerances

Tolerances for helical gear sets ISO 1328-1:1994			
Accuracy grade		6	6
Pitch single deviation	(µm)	+- 8.5	+- 10.0 (fpt)
Normal base pitch deviation	(µm)	+- 8.0	+- 10.0 (fpb)
Pitch total deviation	(µm)	27.0	46.0 (Fp)
Pitch tension deviation	(µm)	+- 12.0	+- 21.0
(Fpz/θ)			
Profile total deviation	(µm)	11.0	15.0 (Fa)
Tooth trace total deviation	(µm)	14.0	15.0 (Fb)
Single flank tooth-to-tooth transmission error	(µm)	11.0	13.0 (fi')
Single flank comp. T.E.	(µm)	38.0	59.0 (Fi')
Profile deviation	(µm)	8.5	11.0 (ffa)
Profile angular deviation	(µm)	+- 7.0	+- 9.0 (fhfa)
Tooth trace form deviat.	(µm)	10.0	11.0 (ffb)
Tooth trace angular deviation	(µm)	+- 10.0	+- 11.0 (fHb)
Tolerances for helical gear sets ISO 1328-2:1996			
Concentricity dev.		0.0	37.0 (Fr)
Double flank composite transmission error		0.0	52.0 (Fi'')
Double flank tooth-to-tooth transmission error		0.0	15.0 (fi'')

Figure 2.5-1 Different output and report formats accessible from both KISSsoft and KISSsys