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Shaft strength calculation with the MESYS Shaft Calculation

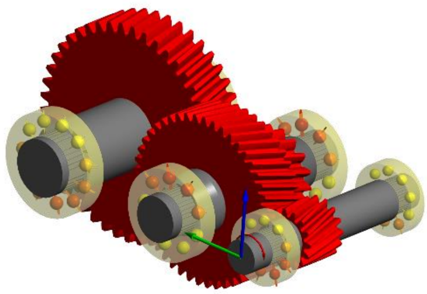
The MESYS Shaft and Bearing Calculation is mostly used with a focus on bearing calculations, and many of the customers are bearing manufacturers. In spite of this fact, the software also offers several options for shaft strength calculation that are not usually available in other products. In this way, the Shaft Systems Calculation is adopted by a number of transmission producers.

In many applications the operational conditions are not precisely known. Suppliers of standard gearing mechanisms indicate permissible torques or radial loads although the rotation direction depends upon the application. This means that the strength verification has to be done once for each rotation direction.

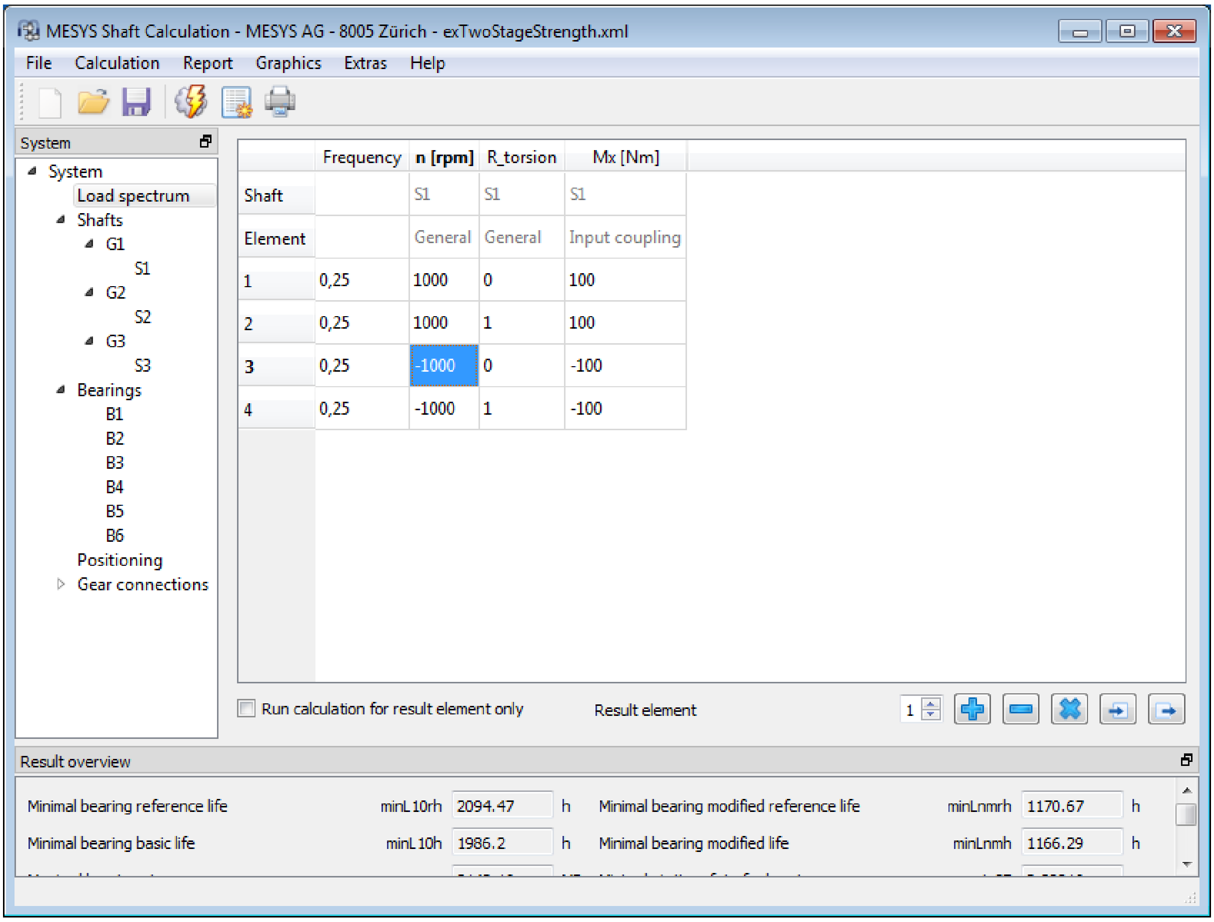
In the case of turning shafts alternating bending takes place, but what happens with the torsional stress? The assumption of pulsating torsion is often made for the strength verification, and others determine the stress ratio for torsion from the application factor and carry out the calculation with a virtually constant torsional moment. In practice, many applications have a few start-up processes and work at a unique or several virtually constant load levels. Consequently, there exist load cases with pulsating (or alternating) loading and further load levels with small amplitudes in torsion (in proximity to constant torsion).

For the shaft strength calculation according to DIN 743 or FKM, the permissible stress amplitude is dependent of the equivalent mean stress. Therefore the assumption of the alternating torsion is not a conservative one. As the equivalent mean stress increases, the permissible stress amplitude decreases, so the safety factors of those sections under bending loads that assume a constant torsion can be smaller than the ones under the assumption of pulsating or alternating torsion.

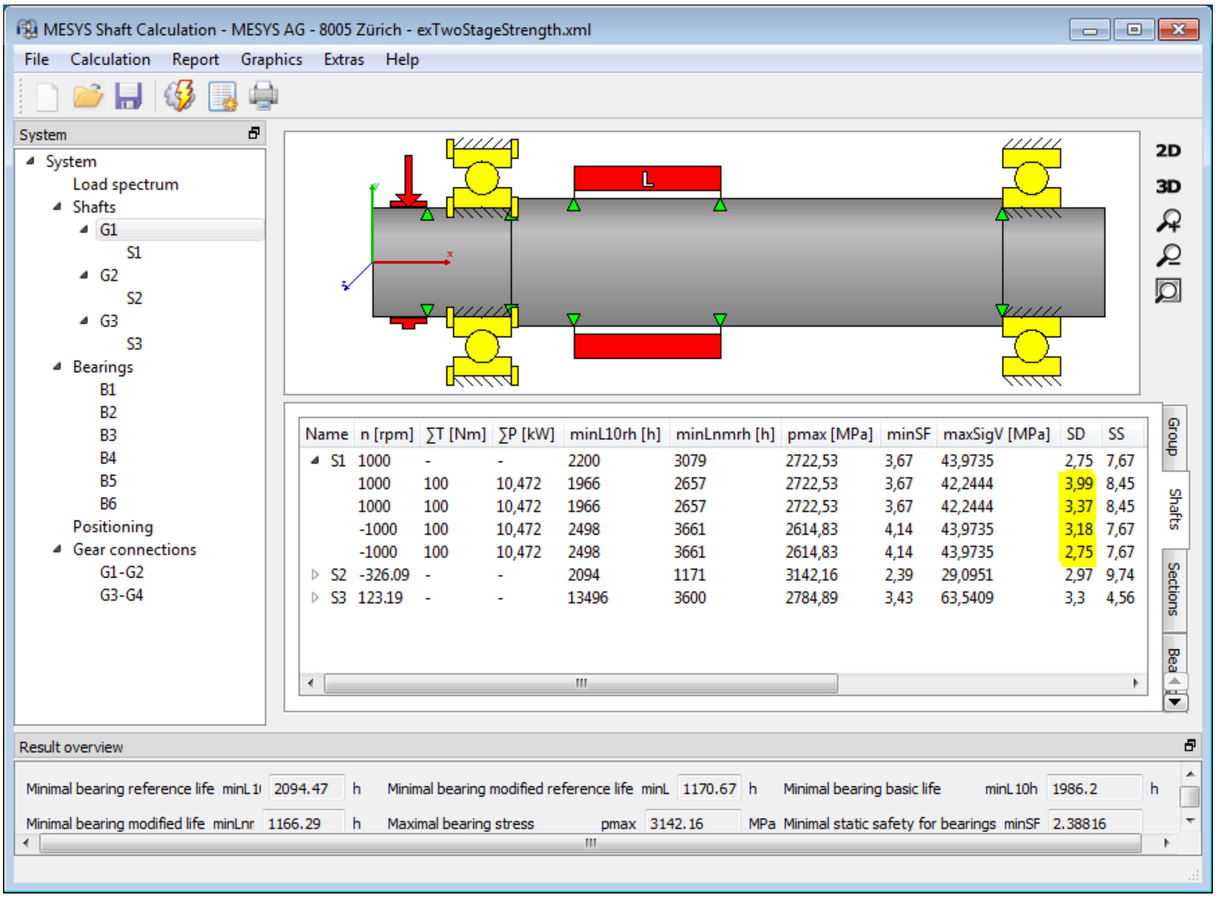
As example, a two-stage spur gearbox is considered. Both directions and the stress ratio R=0 (pulsating) as well as R=1 (constant) for torsion will be verified. Only the results for the input shaft will be shown.



A load spectrum with four load cases (two rotating directions and two stress ratios) is defined. Of course, the torque or other load types could be considered too. For the shaft strength, a fatigue strength verification will be conducted in each case; the software also allows a calculation with load spectra according to DIN 743-4.



For the input shaft will be selected five cross sections for the strength verification. As notch effects, a keyway for the propulsion, two shaft shoulders and an interference fit used to mount the gear on the shaft will be considered.



The strength verification according to DIN 743 will result in safety factors ranging from 2.75 to 3.99 with the four alternatives. The load case “Rotating direction Leftwards” with constant torsional torque is found to be critical. The results for the first three cross sections are as follows:

Load case	Torque	Stress ratio	Fatigue strength according to DIN 743			Static safety factors according to DIN 743			Bearing life
			A	B	C	A	B	C	
1	100 Nm	0 Pulsating	6.94	5.23	3.99	8.54	8.45	10.44	1966 h
2	100 Nm	1 Constant	8.54	4.02	3.37	8.54	8.45	10.44	1966 h
3	-100 Nm	0 Pulsating	6.94	3.46	3.18	8.54	7.67	9.06	2498 h
4	-100 Nm	1 Constant	8.54	2.91	2.75	8.54	7.67	9.06	2498 h

The cross section A (keyway for the propulsion) shows the smallest safety factor for pulsating torsion, the cross section B (shoulder) and C (interference fit) show in contrast the smallest safety factors for constant torsion. On one hand, the rotating direction to the left with constant torque is critical regarding the shaft strength. On the other hand, the bearing life will be critical if the shaft rotates to the right. This shows that the verification should be carried out for all cases. The MESYS Shaft Calculation allows it in one single step.

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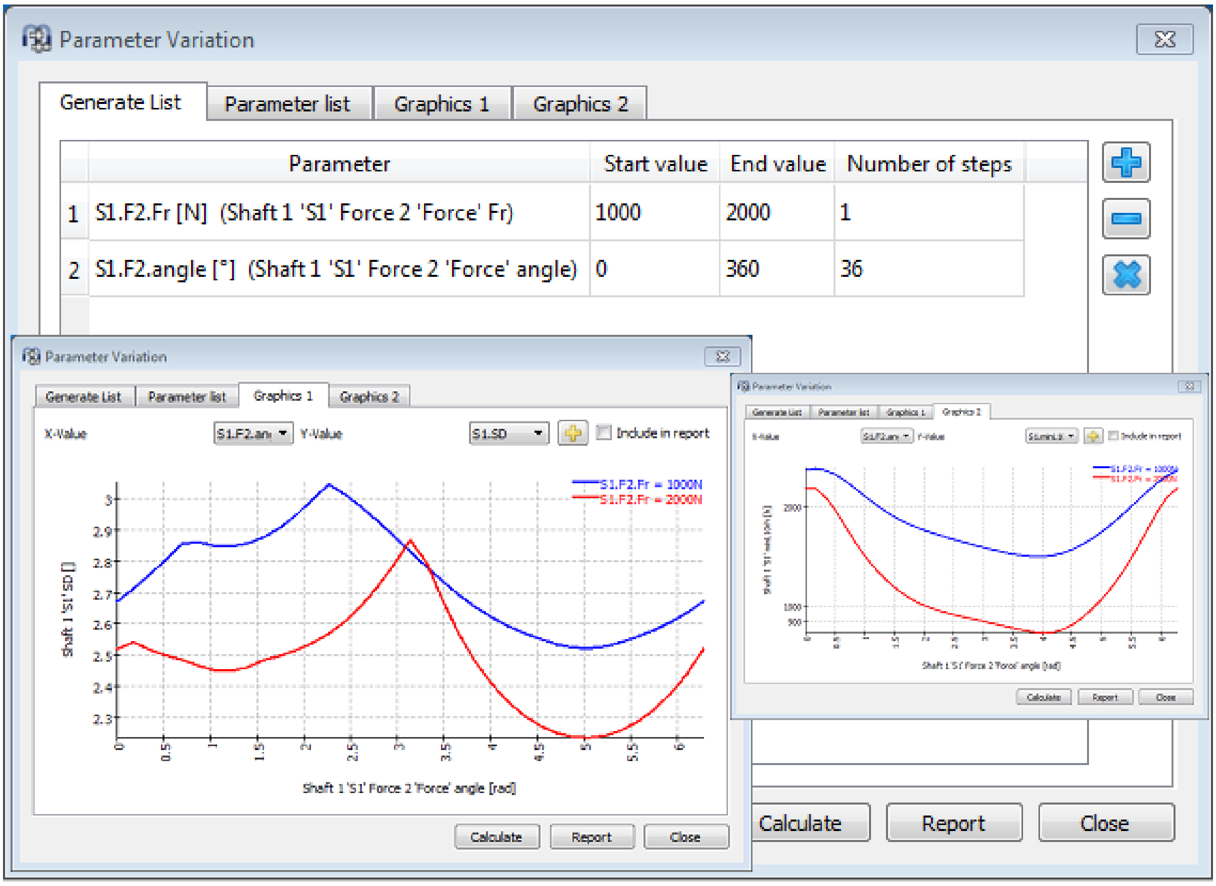
In the version 04/2015 of the Shaft calculation, an automatic parameter variation has been included, which is a tool that only was available for the bearing calculation so far. In order to show an example of application, we set an additional force whose direction can be considered to be unknown since it depends on particular assembly conditions. With the parameter variation the magnitude and direction of the force is varied:



Each load case is analysed by means of the load spectrum. In this way, 2x37x4=296 calculations steps of the shaft system will be run to generate the diagram. The whole process lasts 70 seconds, including three shafts under the consideration of non-linear bearing stiffness, load distribution of six bearings and gear calculations for the two stages according to ISO 6336. The same results could have been reached by just running the calculation for a single shaft and the process only would have needed few seconds.

The indicated safety factor is the minimum of the four load cases. For the external load, the fatigue strength according to DIN 743 decreases from 2.75 to around 2.2, and the bearing life gets reduced to around 800h.

The MESYS Shaft Calculation enables the user in a simple way to verify the strenght of shafts with several load cases. Moreover, the extension for shaft systems calculation assures the verification of a whole transmission mechanism and includes results for shaft strength, deformations, bearing life according to ISO 281 and DIN 26281, contact stress in bearings as well as safety factors for gearings. All in all, the software supports gear couplings such as spurgears, planetary gears, bevel gears or worm gears.