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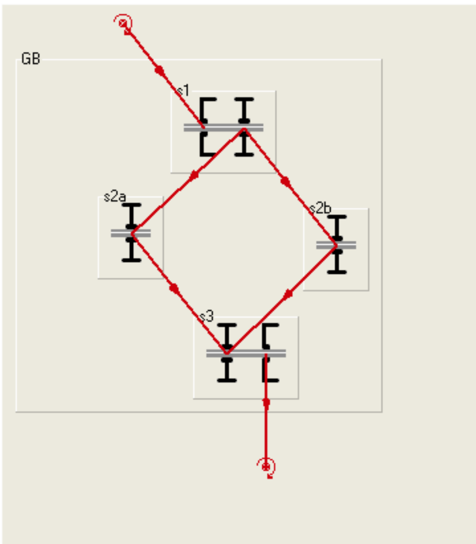
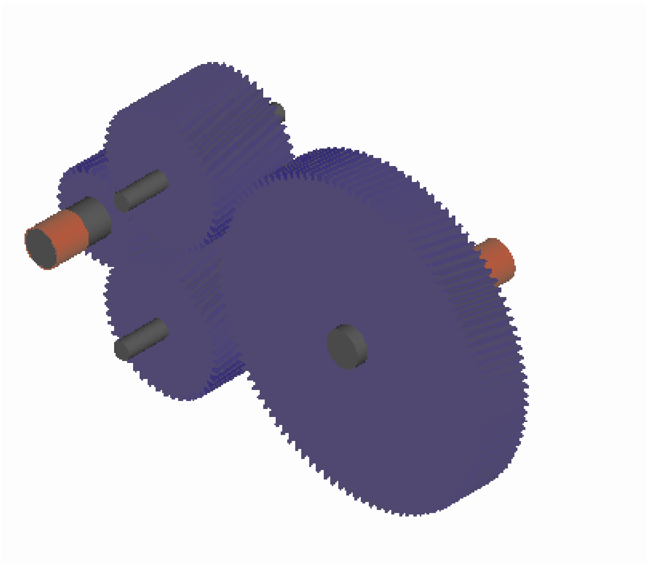
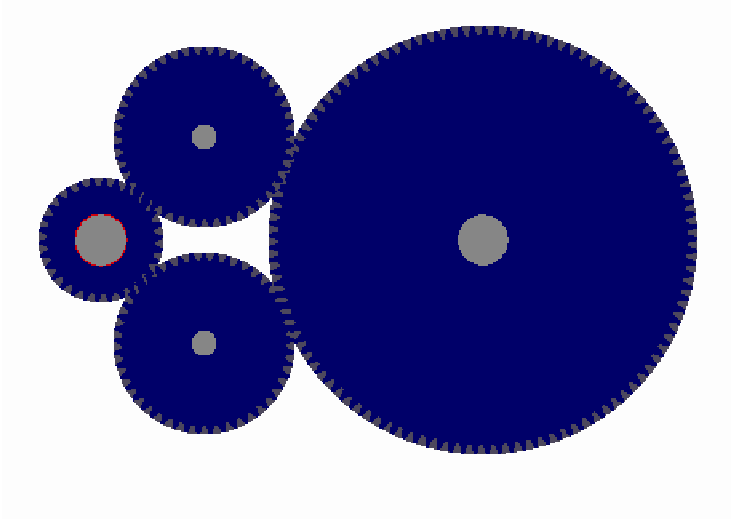
KISSsys Instruction for Power Split Though Several Paths and The Problem of Over defined Kinematics







1 Introduction

1.1 Definition

If gearbox has two or more power paths from input to output, with same ratio and they are active in same time, kinematic condition is over defined. Power is transferred with all these paths simultaneously and in theory all of them are carrying the same amount of the load. In reality power is not equally distributed between the paths because of manufacturing errors, deflections and several other reasons. This method can be used in the case where loads are getting too high for single components to be transferred. The application of the principles in this paper makes only sense when the power flow is not symmetric.

1.2 KISSsys kinematics

When this type of gearbox is modeled to the KISSsys normal approach is not possible because speed of the components can be defined through several paths giving over defined conditions. If calculation of the described system is tried with default settings in KISSsys an error message appears.

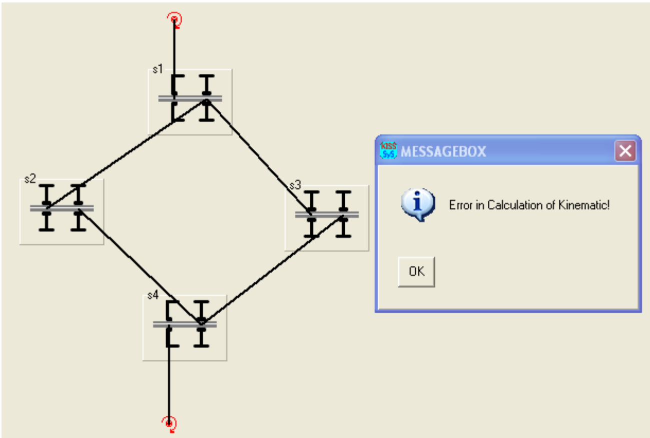


Figure 1.2-1 Error message in kinematics calculation with over defined kinematics

In this case there will be a closed loop between gears via given number of paths. This kind of model is not possible to calculate by KISSsys automatically using normal kinematics calculation, because it is not known how much power must be delivered through different paths. As there is no possibility to enter springs and dampers between the gears (this is the common solution in reality), there must be another way to model such a system.

Also this kind of loop doesn't allow iteration for torque to be calculated correctly. Anyway there is a way to do that, but it requires small changes for normal kinematics calculation procedure and this is why we need to create special conditions for the KISSsys to be able to calculate kinematics correctly.

1.3 Example models

This example will guide you through how to create model in KISSsys in case if power is for several paths and then collected again back to the same gear. This approach may be necessary to use in cases where power or torque is high and space for using single gears strong enough is not possible. There it is possible to separate power to go through several paths to keep components relatively smaller. This may also give overall cheaper solution. Also because of smaller loads on single components smaller gears as well as bearings can be used.
Following solution possibilities are explained:

- Gear inactivation
- Split input side
- Split output side
- Planetary type solution

Models used describing these examples and solutions are also available for more detailed investigation.

2 Models

2.1 Gear activation

Inactivate some of the gear connections and the tell program “manually” what will be the power values for every path.

2.1.1 The model

Create a model with two power lines connected to same input and same output gears.

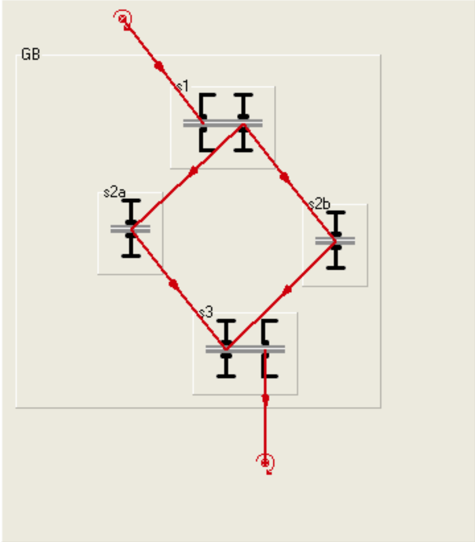


Figure 2.1-1 Gearbox model with two power paths

2.1.2 Model setup

To be able to perform calculation we need to deactivate another of the paths by adding new variable called “activated” to one of the gear connections. To do this select one of the gear connections and go to the properties window. Create a new “real” type variable named “activated” and set value to 0 (zero) for this variable. Now this gear connection is “open”.

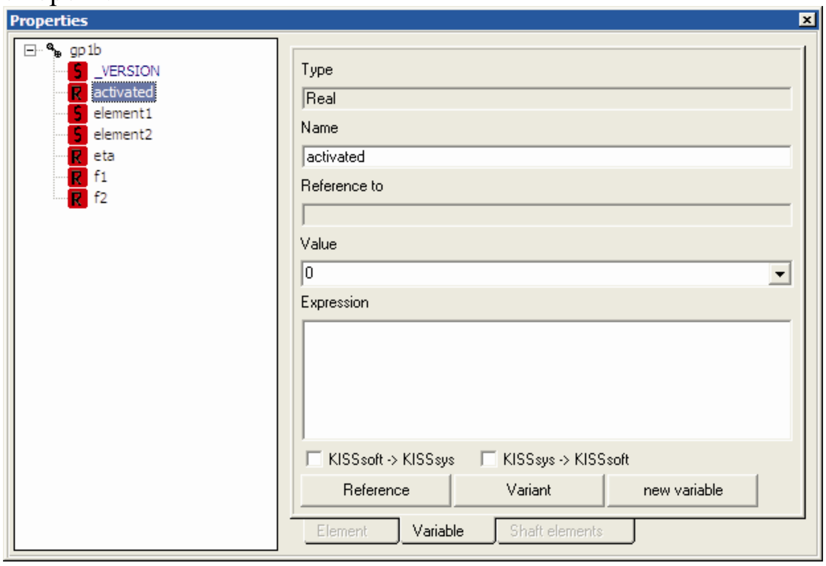


Figure 2.1-2 Creating a new variable "activated" to one of the gear connections

This means that now there will be still connection between gears, but it is set to be inactive (similarly as clutch connections can be activated or inactivated). See more instructions of adding this variable from the instructions “ins-205-01-Gear-activations.pdf”.

Create also another new variable to be able to change the power share between paths.

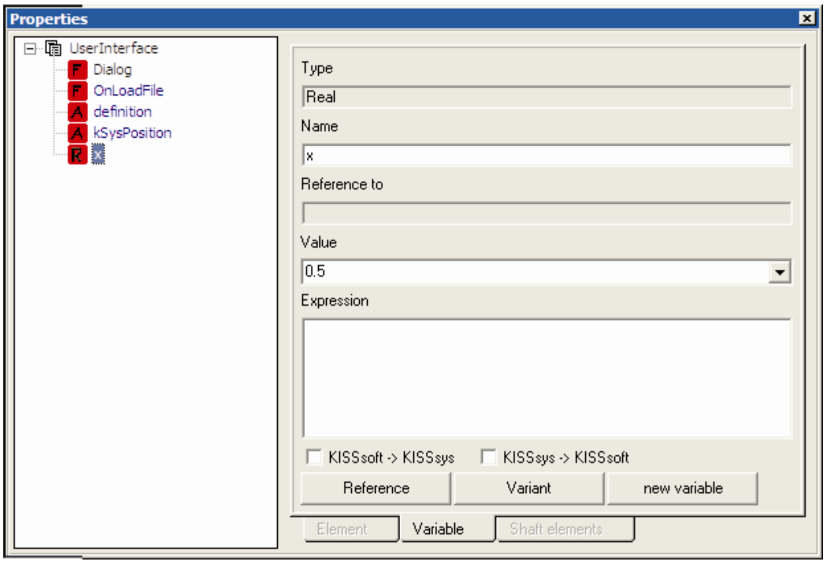


Figure 2.1-3 Definition of the variable for the power share

2.1.3 Kinematic modification

Kinematics calculation procedure must be modified to be able to calculate correctly with new model. It means that calculation is first performed with one of the paths only (another inactivated) and after kinematics calculation power is divided between both paths according to desired shares. In the example file following method is used.

Created calculation procedure:

//calculate first kinematic normally
System.calcKinematic();
	First kinematics will be calculated normally and with this all power will the go through only one activated path.

//divide forces by the amount of power share
GB.gp1b.f1=GB.gp1a.f1*(1/(1+UserInterface.x));
GB.gp1b.f2=GB.gp1a.f2*(1/(1+UserInterface.x));
GB.gp1a.f1=GB.gp1a.f1-GB.gp1b.f1;
GB.gp1a.f2=GB.gp1a.f2-GB.gp1b.f2;
	Then divide power values for connections according to power divisions. Power share value is defined under variable "x".
	
	Gear connections "gp1a" and "gp2a" belong to active path.

GB.gp2b.f1=GB.gp2a.f1*(1/(1+UserInterface.x)); GB.gp2b.f2=GB.gp2a.f2*(1/(1+UserInterface.x)); GB.gp2a.f1=GB.gp2a.f1-GB.gp2b.f1; GB.gp2a.f2=GB.gp2a.f2-GB.gp2b.f2;	
kSys_Refresh(); System.kSoftCalculate(); kSys_Refresh();	Refresh everything Do the strength calculation

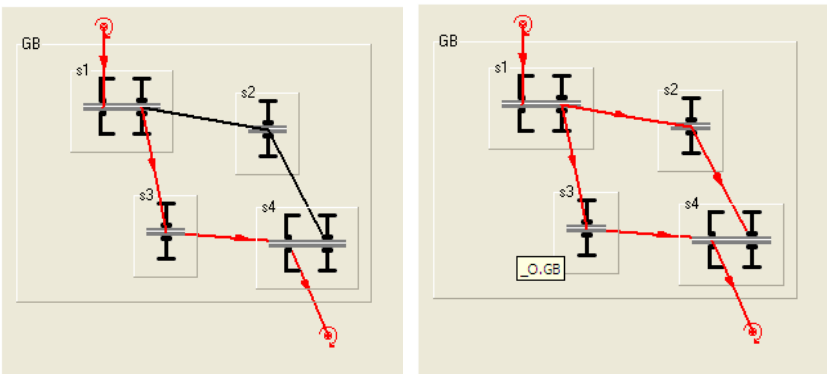


Figure 2.1-4 Power flow diagrams with normal kinematics and after power sharing

With this method efficiency for both paths needs to be the same, because kinematics is calculated only with another path activated. It is recommended to use 100% efficiency in this case.

Note! Special care must be taken for the multiple meshing of the input or the output gear. Remember to adjust "number of load cycles" and "alternating bending coefficient" for gear calculations.

2.2 Split input

Insert two inputs to the model instead of only one. System is not over defined anymore and normal calculation is possible.

2.2.1 The model

Create a model with two power lines connected to the same output gears. Define two input points and set torque values for the power lines.

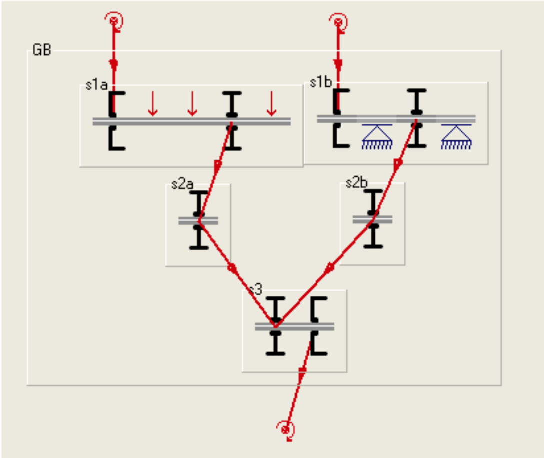


Figure 2.2-1 Gearbox model with two power paths

2.2.2 Model setup

In this case we are having two separate input points, but in reality they are the same and there is only one pinion. This requires therefore link between input shafts “s1a” and “s1b” to consider both gear connection loads on the input shaft. The resulting gear-forces of split gear “z1b” can be then applied on the other shaft “s1a”. The gear forces can be calculated by calculating the bearing forces of the shaft. In order to apply the forces on another shaft, transfer the bearing forces of “s1b” to two forces on the shaft “s1a”.
This can be done manually by adding bearings and forces and creating links between bearing forces and loads, with load and deflection values. The strength of the elements in the model can now be calculated.

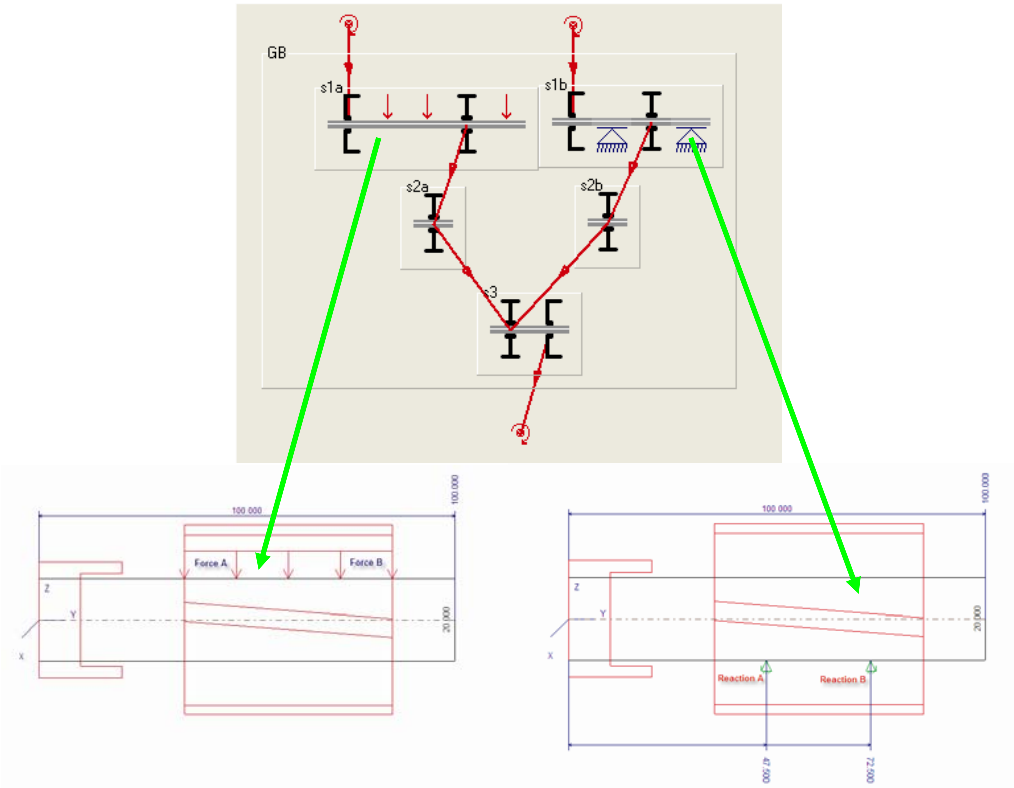


Figure 2.2-2 Force transfer between shafts

Force A = Reaction A and Force B = Reaction B.

This described connection is simply done by entering the variable name of the bearing forces into the expressions of the centrical force variables. Additionally the user has to activate under “System/Properties” “kSysKinematicFunc” the option “Call ‘OnCalcTorque’ during calculation of kinematics”. This function iterates through the shaft calculations until deflection and bearing forces stay constant. See more instructions of bearing-force connections form the instructions “ins-020-01-Bearing-force-connection.pdf”

Create a new variable to be able to change the power share between paths.

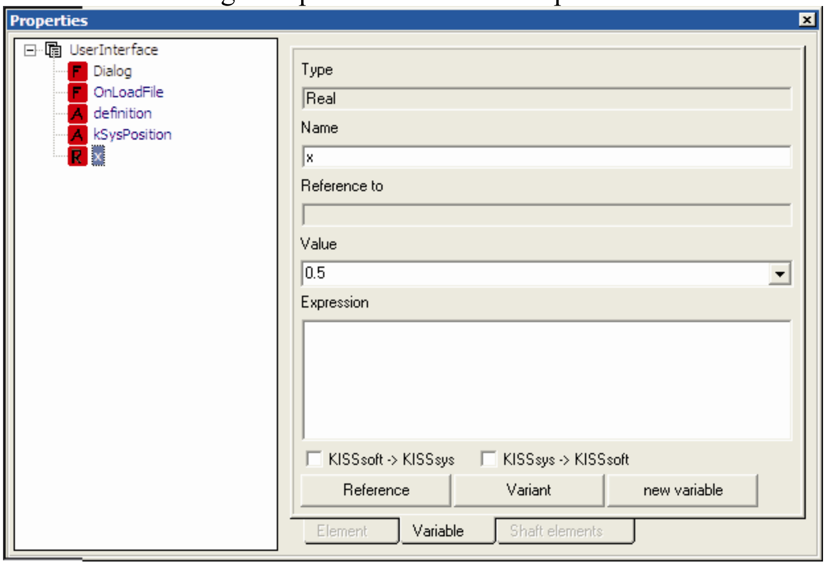


Figure 2.2-3 Definition of the variable for the power share

2.2.3 Kinematic conditions

Boundary condition for the kinematic calculation needs to be now defined correctly. Define Input speed and torque for the “InputA” and also torque for the “InputB”. Output is left to be calculated according to the kinematics.

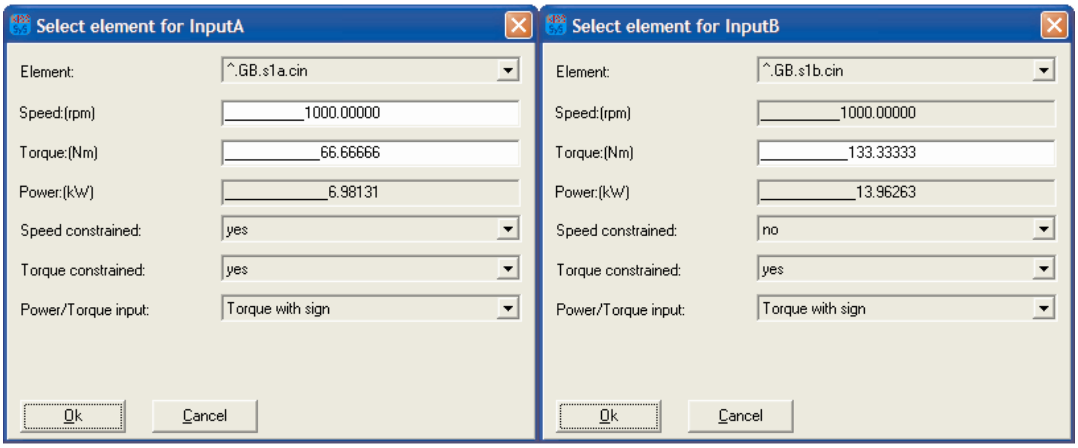


Figure 2.2-4 Boundary conditions for the kinematic calculation

Create also condition to the power line B (InputB torque) to be defined according to the “InputA” torque and torque split value. Speed of the B line is calculated from the ratios.

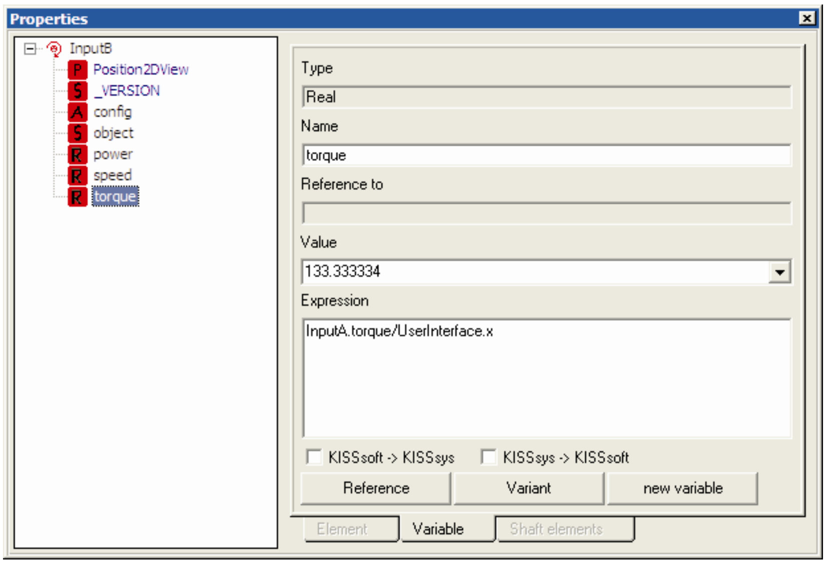


Figure 2.2-5 Power line B torque defined from torque in line A and power share

With this method efficiency for both paths can be defined freely.

Note! Special care must be taken for the multiple meshing of the input or the output gear. Remember to adjust "number of load cycles" and "alternating bending coefficient" for gear calculations.

2.3 Split Output

Insert two outputs to the model instead of only one. System is not over defined anymore and normal calculation is possible.

2.3.1 The model

Create a model with two power lines connected to the same input and two separate outputs. Define two output points and set torque values for the power lines.

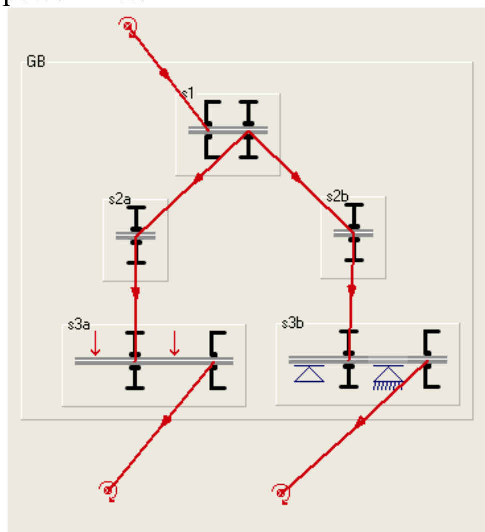


Figure 2.3-1 Gearbox model with two power paths

2.3.2 Model setup

In this case we are having two separate output points, but in reality they are the same and there is only one gear. This requires therefore link between output shafts "s3a" and "s3b" to consider both gear connection loads on the output shaft correctly. The resulting gear-forces of split gear "z3b" can be then applied on the other shaft "s3a". The gear forces can be calculated by calculating the bearing forces of the shaft. In order to apply the forces on another shaft, transfer the bearing forces of "s3b" to two forces on the shaft "s3a".
This can be done manually by adding bearings and forces and creating links between bearing forces and loads, with load and deflection values. The strength of the elements in the model can now be calculated.

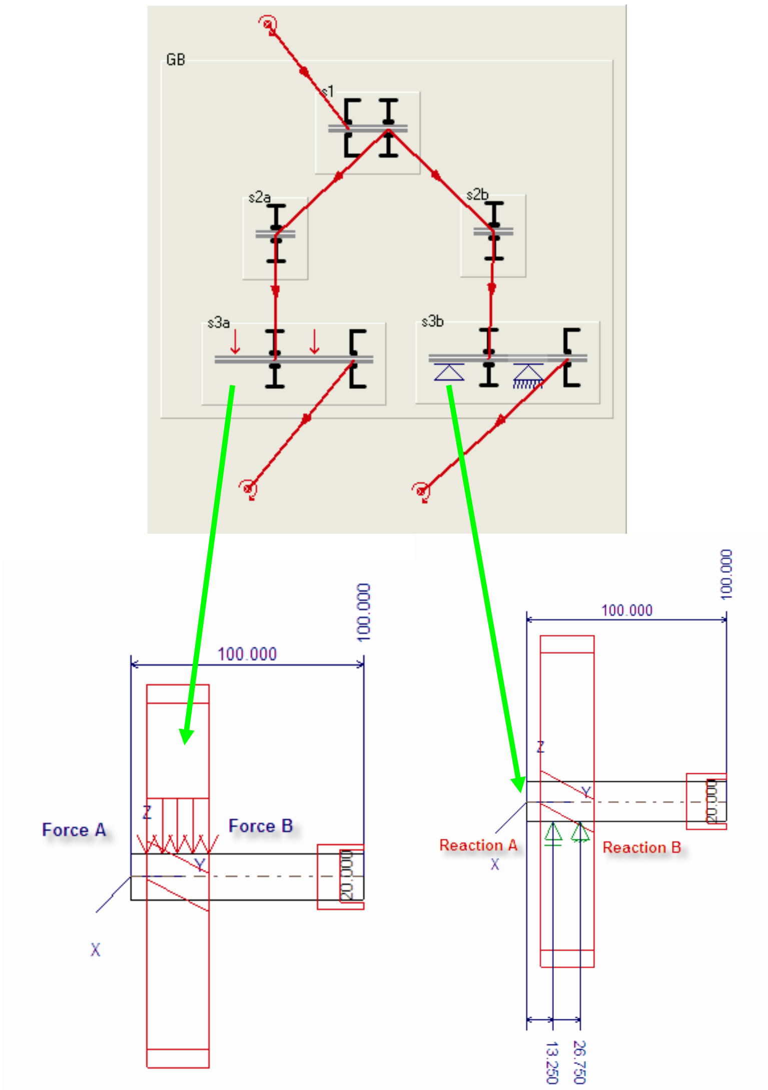


Figure 2.3-2 Force transfer between shafts

Force A = Reaction A and Force B = Reaction B.

This described connection is simply done by entering the variable name of the bearing forces into the expressions of the centrical force variables. Additionally the user has to activate under “System/Properties” “kSysKinematicFunc” the option “Call ‘OnCalcTorque’ during calculation of kinematics”. This function iterates through the shaft calculations until deflection and bearing forces stay constant. See more instructions of bearing-force connections form the instructions “ins-020-01-Bearing-force-connection.pdf”

Create a new variable to be able to change the power share between paths.

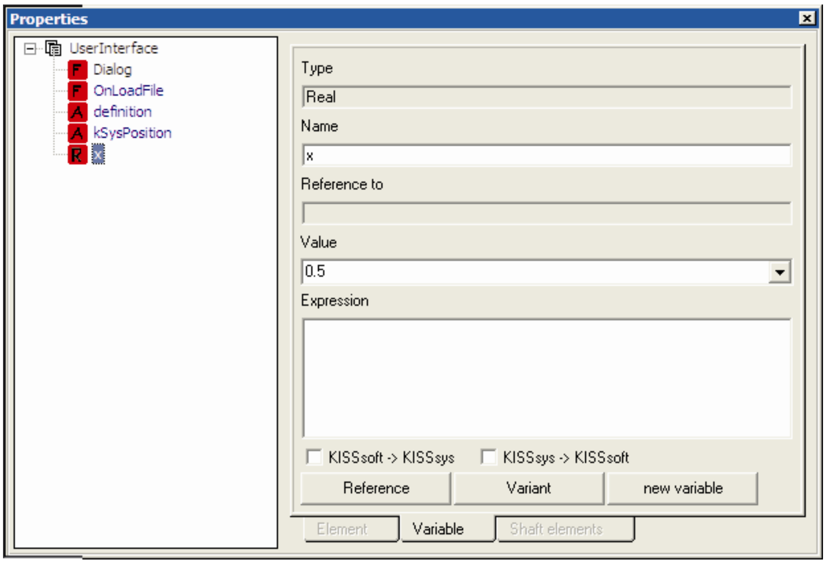


Figure 2.3-3 Definition of the variable for the power share

2.3.3 Kinematic conditions

Boundary condition for the kinematic calculation needs to be now defined correctly. Define Input speed and torque. Also constrain power for the “OutputB” and let ”OutputA” to be calculated.

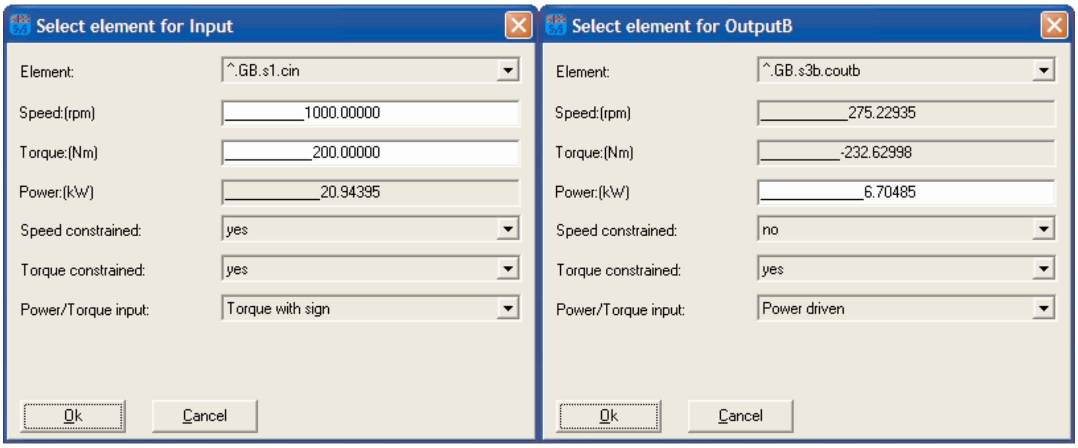


Figure 2.3-4 Boundary conditions for the kinematic calculation

Create also condition to the power line B (OutputB power) to be defined according to the “OutputA” power and power split value. Speeds of the both outputs are calculated from the ratios.

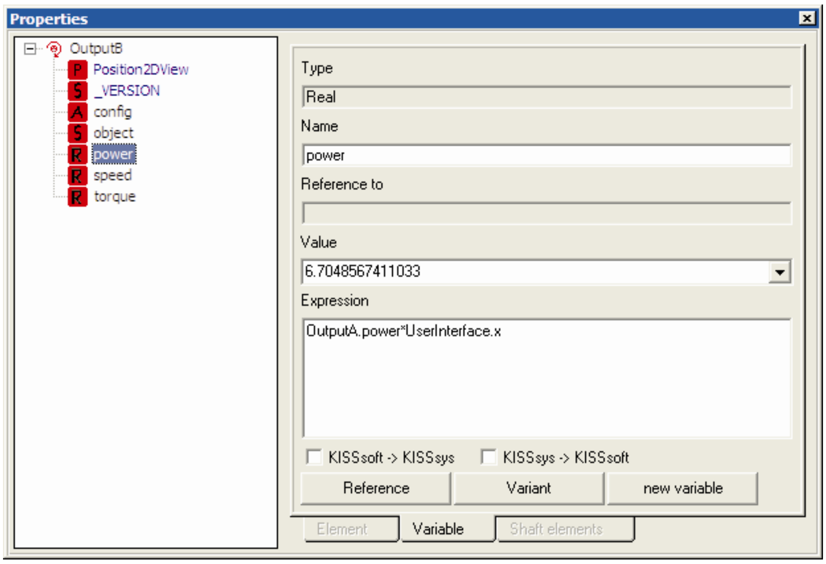


Figure 2.3-5 Output power B is defined from power in output A and power share

With this method efficiency for both paths can be defined freely.

Note! Special care must be taken for the multiple meshing of the input or the output gear. Remember to adjust “number of load cycles” and “alternating bending coefficient” for gear calculations.

2.4 Planet type

Model with “planet” type solution is created having only one “planet” and connection between “carriers”.

2.4.1 The model

Create a model with two power lines connected to same input and same output gears. Use planet type modeling, adding fixed shafts (“s2a” and “s2b”) for the power sharing gears (“s2”) and create a connection with “kSysCouplingConstraint” between the power lines (“ab”). Define also “kSysPlanetCarrierCoupling” (“cc”) and define “NofPlanets” to be one for both lines.

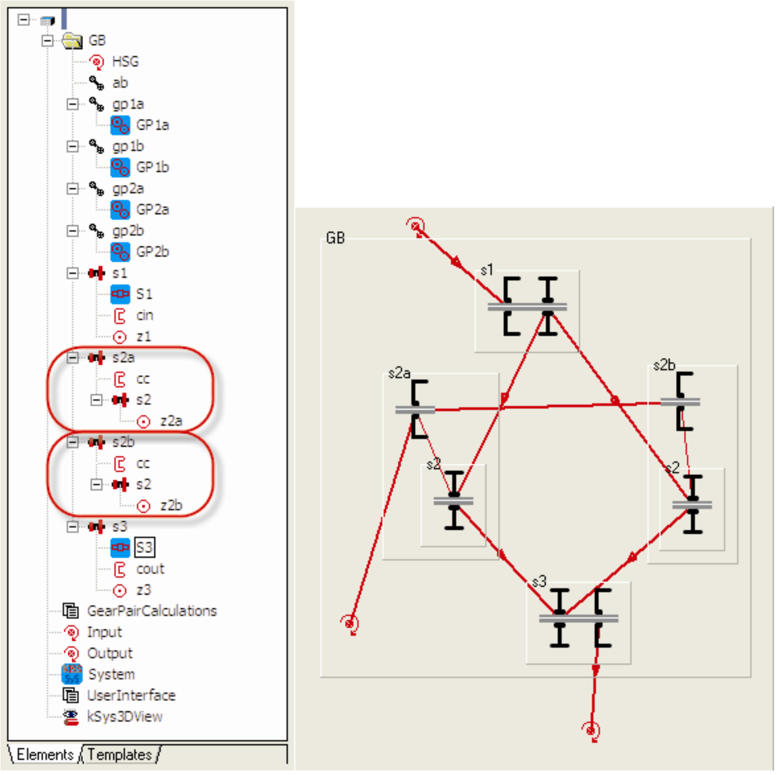


Figure 2.4-1 Gearbox model (tree and schematic) with two power lines with “planet type” solution.

Note that gear connections need to be now defined as planetary connections between “sun-planet” in all cases.

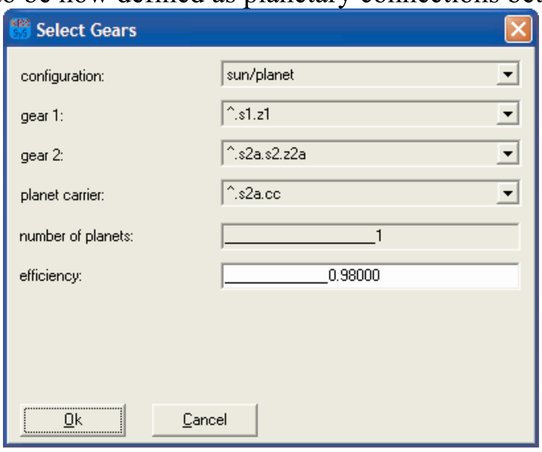


Figure 2.4-2 Gear connection definitions

2.4.2 Model setup

In this method virtual "planet" carrier is created to be able to do calculation for a over defined kinematic conditions. "Number of planets" in both lines are defined to be one.

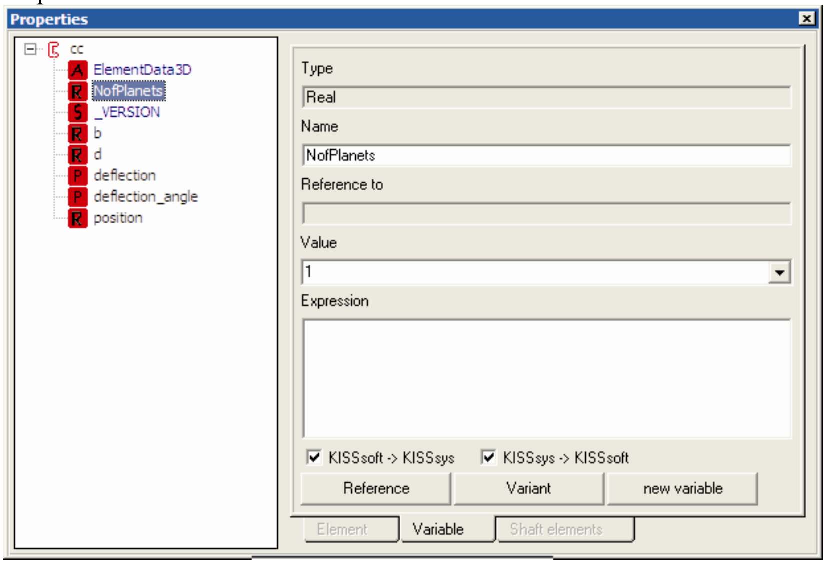


Figure 2.4-3 Gears per power line transferring the load

Also a link between power lines is needed to be created with coupling connection. Speed for the "virtual planet carriers" need to be also defined to be zero. This can be done similarly as for planet gear modeling by adding a "kSysSpeedOrForce" component and defining speed to be zero.

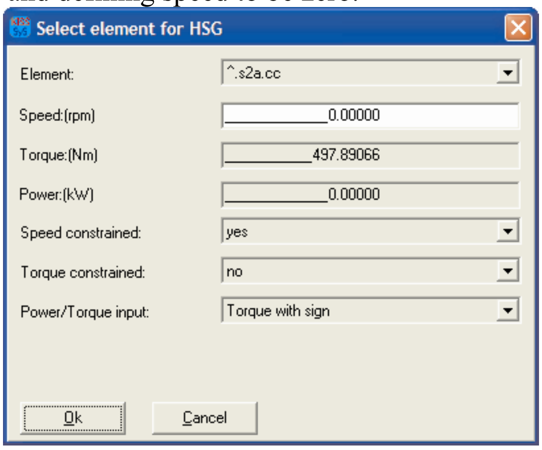


Figure 2.4-4 Boundary condition for the "virtual" parts

Create also a new variable to be able to change the power share between paths.

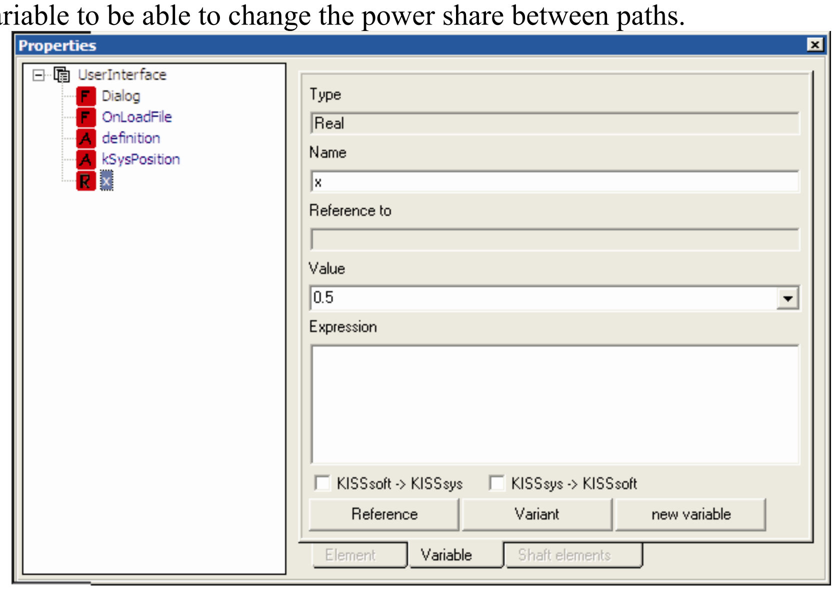


Figure 2.4-5 Definition of the variable for the power share

2.4.3 Kinematic modification

Before to be able to do the kinematic calculation correctly we need to create a formula between "planet" carriers to tell program what is the power share between the power lines. To do this add expression for the "carrier" connections "ab" properties under variable "f1"

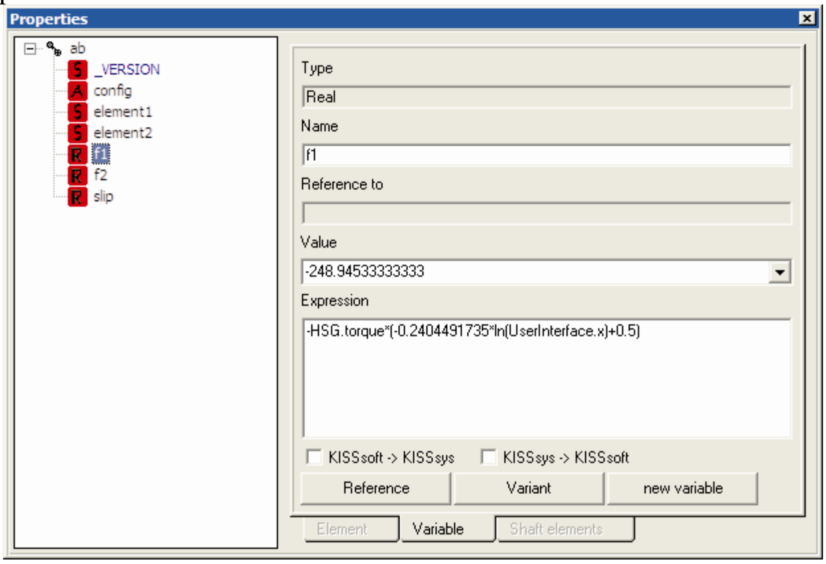


Figure 2.4-6 Power share calculation formula

Given formula gives correct power share between lines when power share is defined as fractions in the defined variable "x". With this method efficiency for both paths can be defined freely.

Note! Special care must be taken for the multiple meshing of the input or the output gear. Remember to adjust "number of load cycles" and "alternating bending coefficient" for gear calculations.