KISSSOFT

Calculation programs for machine design

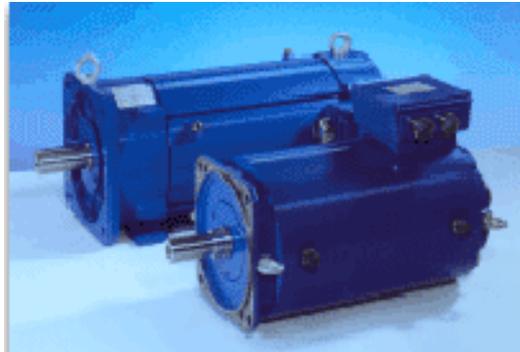KISSsoft AG   -   ☎ +41 55 254 20 50
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KISSsys application:

Automatic generation of characteristic curves

based on critical speeds for electro motors

1 Task

For different speeds of an electromotor, the maximum possible mass flanged on its shaft is to be calculated so that the critical speed (bending) does not fall below the operating speed. The position of this (lumped) mass on the shaft varies. The permissible masses calculated are being used as technical data in a catalogue. The objective is to reduce the time required to generate this data considerably.

2 Solution

For a given pair of starting values (position of the mass on the shaft and operating speed), the permissible mass is calculated using an iteration. Using starting values, the critical speed of the shaft is calculated and compared to the operating speed. Based on the difference between the two, the estimate for the mass is varied. The iteration is terminated successfully when the difference between calculated critical speed and operating speed is smaller than an allowable error. This iteration is performed for all combinations of operating speed and position of mass and the results are compiled in a table. From there, the results can be exported to e.g. Excel for graphical representation.

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3 Description of the model

3.1 Structure of the shaft

The shaft geometry is defined in KISSsoft and includes the bearings, a distributed mass to represent the winding of the electromotor and the lumped mass to represent the mass to be flanged on the shaft:

Figure 3.1-1 Shaft geometry with supports and the lumped mass at the right end of the shaft (red arrow)

The position of the mass at the right end of the shaft can be varied from y=1515mm to 1715mm. The geometry of the shaft can be modified at any time. The bearings are assumed to be rigid (infinite radial stiffness), but can also be defined with a given bearing stiffness.

3.2 The user interface

The calculation of the permissible mass is controlled using the user interface shown below:

Analyze			No. of speeds	4	Accuracy (Upm)	5	Start mass (kg)	100		
			No. of positions	4	Max. iterations	10				
	Speed (Upm)									
Position (mm)	3900	4200	4500	4800	4000	4000	4000	4000	4000	
1500	446.8	372.7	310.9	259.9	0	0	0	0	0	
1550	290.6	243	203.7	170.5	0	0	0	0	0	
1600	191.4	160.4	135	113.5	0	0	0	0	0	
1650	126.4	106.1	89.8	75.9	0	0	0	0	0	
1650	0	0	0	0	0	0	0	0	0	
1650	0	0	0	0	0	0	0	0	0	
1650	0	0	0	0	0	0	0	0	0	
1650	0	0	0	0	0	0	0	0	0	
1650	0	0	0	0	0	0	0	0	0	
1650	0	0	0	0	0	0	0	0	0	
1650	0	0	0	0	0	0	0	0	0	

Figure 3.2-1 User Interface to control analysis and to show the results

The model allows for calculation of twenty operating speeds and twenty positions of the mass on the shaft. The number of operating speeds and number of positions to be considered is set using „No. of speeds" and „No. of positions". In the above figure, four speeds and four positions are to be analyzed hence, sixteen results are created. The positions are defined in the column „Position (mm)". The operating speeds for which the critical mass is to be sought are given in the row „Speed (Upm). Additionally, settings for running the iteration are necessary (permissible error, start mass), which is started by double click on "Analyze". The results can then be copied and pasted into e.g. Excel:
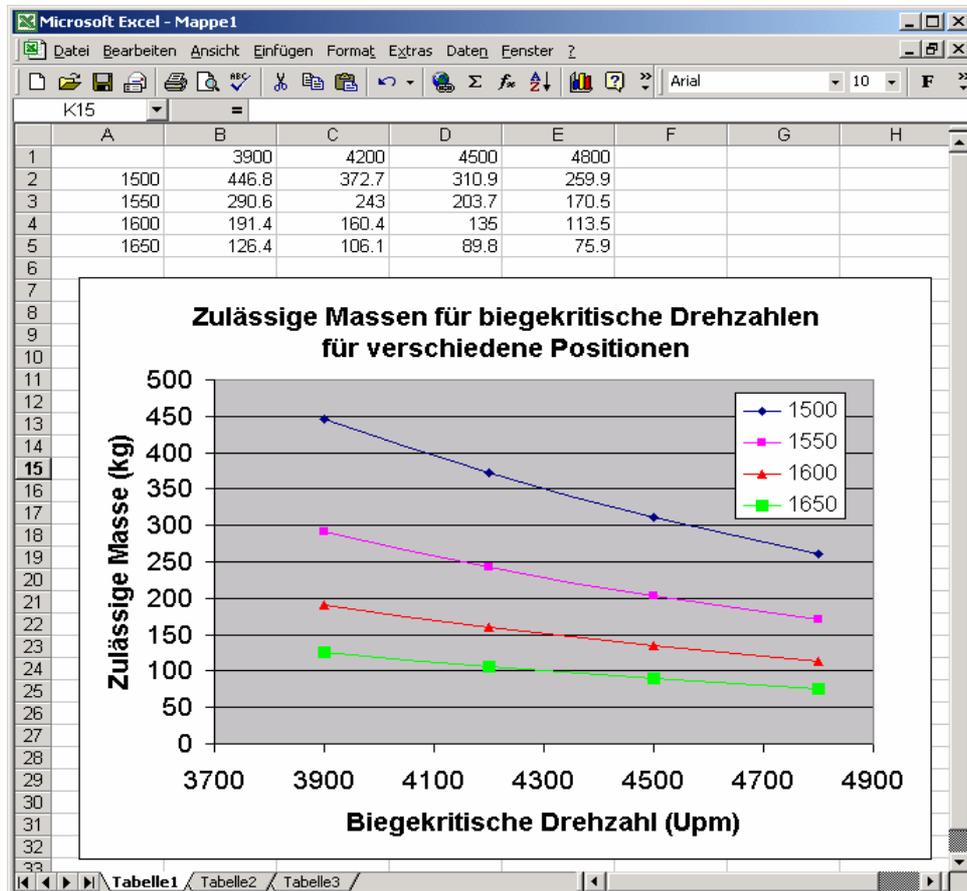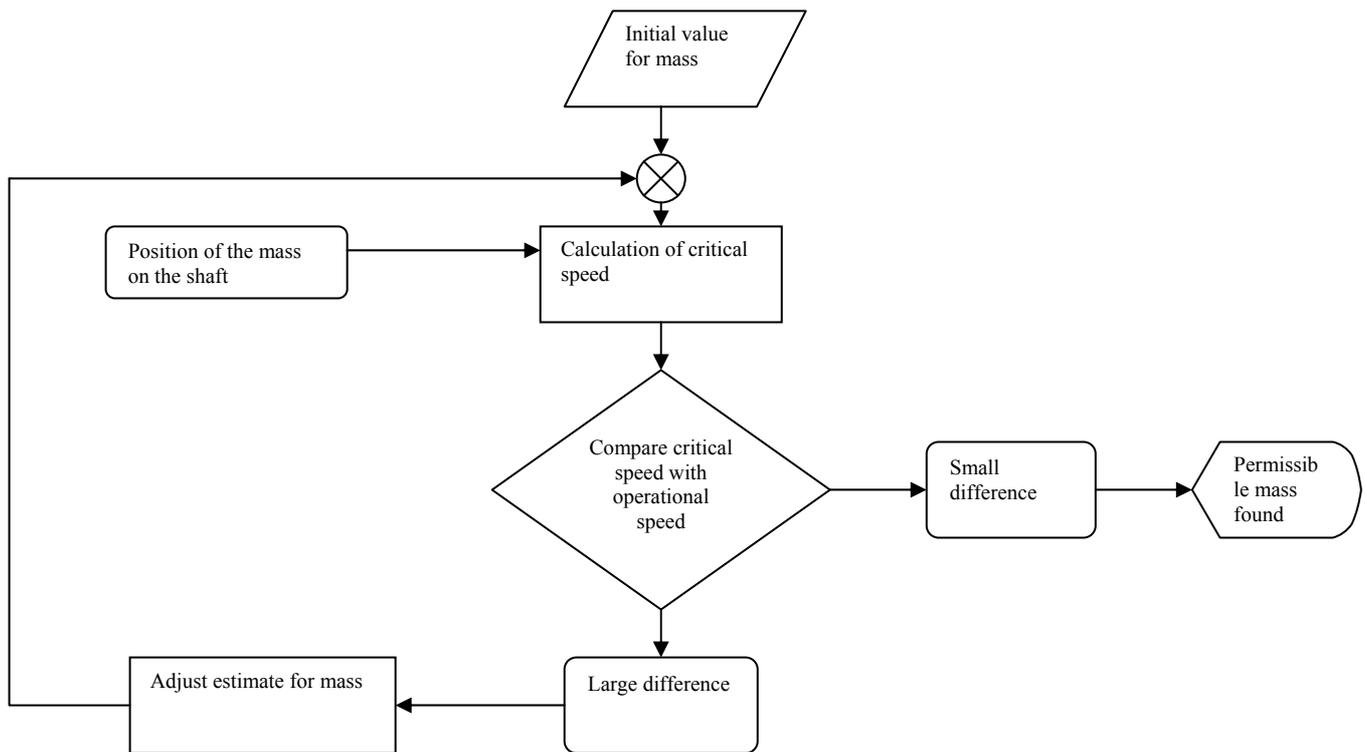

Figure 3.2-2 Graphical representation of the results in e.g. Excel

Following the above outlined process, characteristic curves can be generated in very short time.

3.3   Iteration

The KISSsys model described here is based on an algorithm to search for a target value. Here, the target for the critical speed is the operating speed. Hence, the iteration is repeated as long as the critical speed of the shaft – mass arrangement divers considerably from the operational speed:

```
                        ┌──────────────┐
                        │ Initial value │
                        │   for mass   │
                        └──────────────┘
                               │
                               ▼
                              ⊗
                               │
  ┌─────────────────┐   ┌──────────────────┐
  │ Position of the │──▶│ Calculation of    │
  │ mass            │   │ critical          │
  │ on the shaft    │   │ speed             │
  └─────────────────┘   └──────────────────┘
                               │
                               ▼
                         ◇ Compare critical  ◇──────▶ ┌──────────┐    ┌──────────┐
                         │ speed with         │       │ Small     │───▶│ Permissib │
                         │ operational        │       │ difference│    │ le mass   │
                         │ speed              │       └──────────┘    │ found     │
                         ◇                    ◇                        └──────────┘
                               │
                               ▼
  ┌──────────────────┐   ┌──────────────────┐
  │ Adjust estimate  │◀──│ Large difference  │
  │ for mass         │   │                   │
  └──────────────────┘   └──────────────────┘
```

The iterations starts with an initial estimate for the mass (field „Start mass (kg)") to be defined by the user. The closer this start value is to the permissible mass, the fewer steps are necessary to complete the iterations. With the start mass at the defined position, the first critical speed of the shaft is calculated in KISSsoft and returned to KISSsys. In KISSsys, this value is then compared to the operational speed of the shaft. The estimate for the mass is then adjusted and the iteration is repeated. If the difference between these two values is below a critical value (defined in „Accuracy (Upm)"), the iteration is terminated. As a safety feature, the maximum number of steps in the iteration not to be exceeded can be limited („Max. Iterations").

The iteration is repeated for every pair of given values for the operational speed and the position of the mass on the shaft.

The code for the iteration looks as follows:

```
System.iteratetomass                                            _ □ ×

   Compile          Save          Execute          Quit

VAR i,j,m0,m1,f0,f1,dm,df,k,ffehler;

//Schlaufe über die Speeds, Zähler=i
    FOR i=0 TO nspeed-1 DO
        //Schlaufe über die Positionen, Zähler=j
            FOR j=0 TO npos-1 DO
                //Iteration zur Lösung
                SysRotor.Rotor2.kSysMass.position=System.xpos[j];
                        //Startwert für die Masse übernehmen
                        m0=System.startvaluemass;
                        k=0;
                        // Frequenz zur ersten Msse rechnen
                        SysRotor.Rotor2.kSysMass.mass=m0;
                        System.calcKinematic();
                        SysRotor.Shaft.Calculate();
                        f0=SysRotor.Shaft.bcr1;
                        DO

                            // Frequenz zur zweiten Masse rechnen
                            m1=1.01*m0;
                            SysRotor.Rotor2.kSysMass.mass=m1;
                            System.calcKinematic();
                            SysRotor.Shaft.Calculate();
                            f1=SysRotor.Shaft.bcr1;

                            // Differenzen:
                            dm=m1-m0;
                            df=f1-f0;

                            // Newton_Schritt:
                            m0=m0 - (f0-System.fcrit[i])/df*dm;

                            SysRotor.Rotor2.kSysMass.mass=m0;
                            System.calcKinematic();
                            SysRotor.Shaft.Calculate();
                            f0=SysRotor.Shaft.bcr1;
                            ffehler=System.fcrit[i]-SysRotor.Shaft.bcr1;

                            kSys_Message("Element: "+CADH_ValToStr(i+1)+"/"+CADH_ValT

                            k=k+1;
                        UNTIL abs(ffehler)<System.accuracy OR k>=System.kmax;
                        IF k>=kmax THEN
                            System.massresults[j][i]=999;
                        ELSE
                            System.massresults[j][i]=CADH_Round(m0,1);
                        ENDIF
                NEXT
    NEXT
```

Figure 3.3-1 Code for the mass calculation

Using two loops, for each speed and for each position the iteration is performed. The first iteration starts with two starting values and follows the Newton procedure.

4 Conclusion

Using KISSsys, an analytical model has been established with which, permissible masses to be flanged on a shaft can be calculated. The masses are calculated such that the critical speed of the shaft is above the operational speed. The calculation can be performed for twenty different operational speeds and twenty different positions of the mass. The time required for calculation of these four hundred combinations is in the range of five to ten minutes, whereas the generation of the curves shown above without this model took several hours.