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Brake Squeal Analysis is supported by two step process - Optistruct

Product: Optistruct
Product Version: Optistruct 14.230 or above

Topic Objective

Brake Squeal Analysis with OptiStruct.

Topic Details

General formulation :
Brake squeal solution sequence is a Modal Complex Eigenvalue solution. As you may know the complex eigenvalue analysis is formulated in the following manner:

$$\left\{p^2 M + pB + \left(K + igK + i\sum G_E + \alpha_f K_f\right)\right\}\{\Phi\} = 0$$

*K_f is zero for Break Squeal Analysis

Where,
K is the stiffness matrix of the structure
M is the mass matrix
G_E is the element structural damping matrix
B is viscous damping matrix
g is global structural damping coefficient
K_f is the extra stiffness matrix by direct matrix input
α_f is the coefficient of extra stiffness matrix

The Modal Complex Eigen solution subcase uses the first case as a STATSUB(BRAKE). The first step in this subcase is to find the modes and eigenvalues of the system with its original mass matrix, and the stiffness matrix which contains information about the total state of the system is give a follows

$$K_{sys} = K + K_{geom}^{PL} + K_{gap}^{NL}$$

The modal projections of the system matrices is given by

$$\Phi^T M \Phi = I$$
$$\Phi^T B \Phi$$
$$\Phi^T K_{sys} \Phi = \Lambda + \Phi^T \left(K_{gap}^{NL} - K_{gapsym}^{NL}\right) \Phi$$

Three important results are taken from this subcase - the geometric stiffness matrix(KPL geom), KPL geom accounts for geometric stiffness from the brake pressure loads and two converged gap stiffness matrices - the complete gap matrices (KNLgap) and gap matrices with normal stiffness terms only (KNL gapsym).

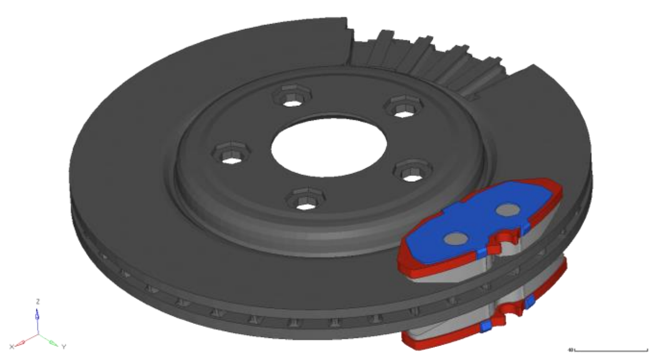
Implementation :

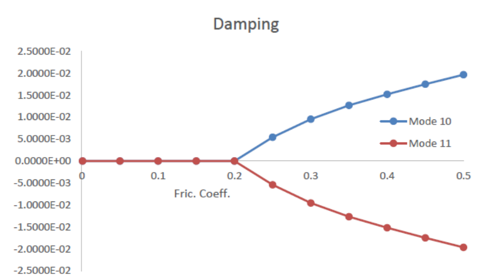
Eigenvalue analysis on this system will yield information on the system stability. The eigenvalues are of the form ω(i - g/2), from which the natural frequency and damping can be obtained. An eigenvalue with a positive real part or negative damping indicates instability.

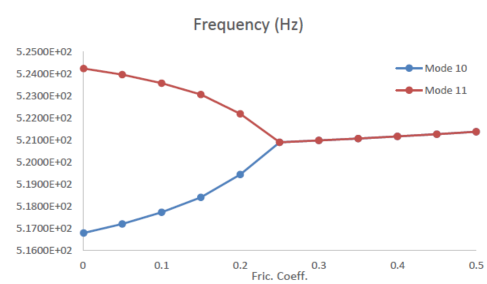
- Squeal is a friction induced dynamic instability caused by coupling of neighboring modes.
- Instability is caused by unsymmetric terms in the friction matrix.
- Modal space to extract complex eigenvalues is formed by considering only the normal terms between the disc-pad contact.

The Complex Eigen Frequency Extraction method will have the following

- Include initial stiffness and load stiffness effects from a preload condition.
- Include friction, and unsymmetric load stiffness contributions.
- This cannot be used with cyclic symmetry modeling
- Friction induced dynamic instability due to mode coupling
- Coupled simulation
    - Nonlinear static analysis
    - Complex eigenvalue analysis
- N2S and S2S contact definitions are supported







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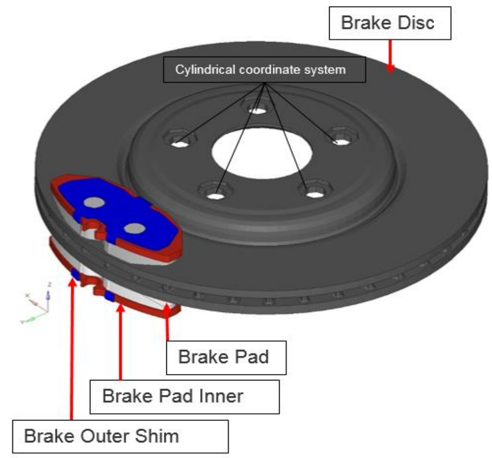
Modal coalescence is where modes converge at a point on Frequency/Damping vs Friction Coeff

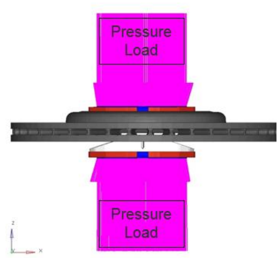
Example : Brake Assembly FE Model Details

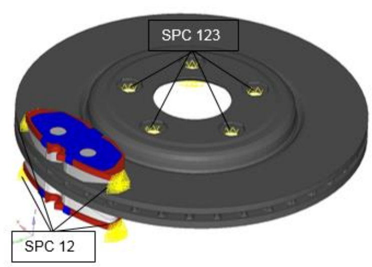
- Hexahedral Mesh is created for the Brake Assembly
- All parts are defined with Material MAT1
- All parts are defined with Solid Element Property
- Define Cylindrical coordinate system at bolt holes
- Surface to Surface Contacts are defined between
  - Brake Pad and Disc
- Three Sub cases are defined as below
  - Nonlinear static analysis
    - Pressure Load on Pad
  - Nonlinear static analysis with CNTNLSUB
    - Pressure Load on Pad
    - And Rotation of the Disc
  - Complex eigenvalue analysis with BRAKE



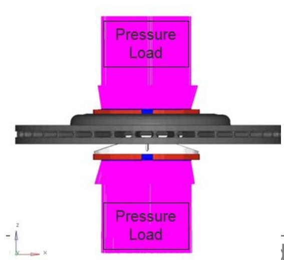
Brake Assembly Loading & Boundary Conditions

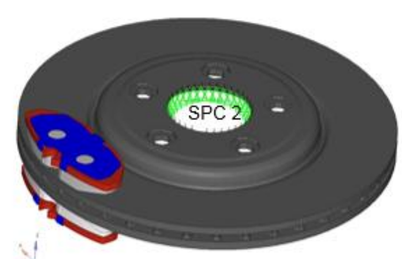
1. Nonlinear static analysis
   Pressure Load on Pad and Constraint the bolt holes as shown in the below figure.

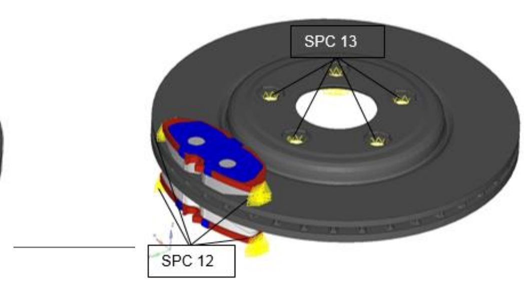




2. Nonlinear static analysis with CNTNLSUB
   Pressure Load on Pad, Rotation of the Disc and Constraint the bolt holes as shown below







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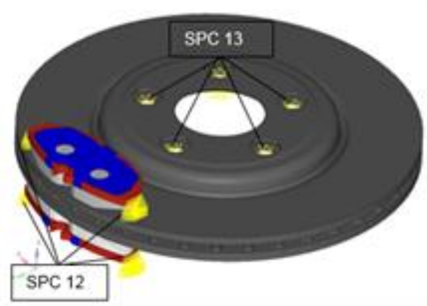
Please Note :Prescribed rotation in OptiStruct is always in degrees.

3. Complex eigenvalue analysis with BRAKE
   - Define the Eigenvalue Extraction with Lanczos Method
   - Define the method for Complex Eigenvalue Extraction
   - Define the BRAKE Sub Case using STATSUB
   - Boundary Constraints as shown in the figure.



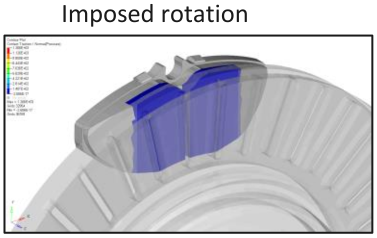
Important information about the Subcase.

- The prescribed rotation should be large enough to ensure the contact between the disc and the pad is in kinetic friction, but small enough to ensure small displacement NLSTAT.
- Kinetic friction is a constant value (independent of velocity), and prescribing rotation using SPCD is equivalent to prescribing rotational speed. The important outcome is that the contact nodes are in kinetic friction mode and it does not matter how fast or how far you move this using SPCD

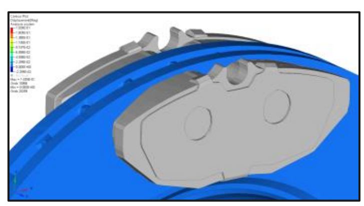
As rule of thumb:5 degrees of Prescribed rotation is good enough

Brake Squeal Analysis Results

Imposed rotation



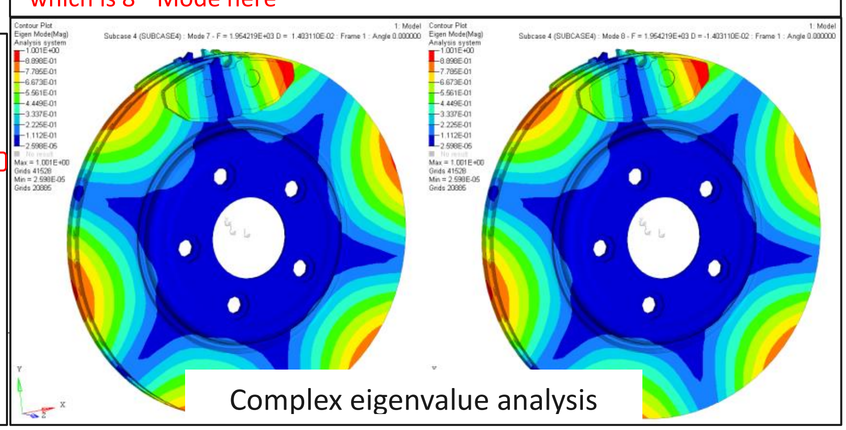
Contact pressure due to piston loading



Unstable mode

Subcase	Mode	Eigenvalue(R)	Eigenvalue(I)	Frequency	Damping
4	1	0.000E+00	3.519940E+03	5.602158E+02	0.000000E+00
4	2	0.000E+00	3.773789E+03	6.006172E+02	0.000000E+00
4	3	0.000E+00	5.173436E+03	8.233780E+02	0.000000E+00
4	4	0.000E+00	5.544524E+03	8.824384E+02	0.000000E+00
4	5	0.000E+00	6.010333E+03	9.565742E+02	0.000000E+00
4	6	0.000E+00	1.091314E+04	1.736881E+03	0.000000E+00
4	7	-8.614E+01	1.227872E+04	1.954219E+03	1.403110E-02
4	8	8.614E+01	1.227872E+04	1.954219E+03	-1.403110E-02
4	9	0.000E+00	1.787736E+04	2.845270E+03	0.000000E+00
4	10	0.000E+00	1.813206E+04	2.885808E+03	0.000000E+00
4	11	0.000E+00	1.864523E+04	2.967481E+03	0.000000E+00
4	12	0.000E+00	1.900343E+04	3.024490E+03	0.000000E+00
4	13	0.000E+00	1.962776E+04	3.123855E+03	0.000000E+00
4	14	0.000E+00	2.083954E+04	3.316716E+03	0.000000E+00
4	15	0.000E+00	2.224027E+04	3.539649E+03	0.000000E+00
4	16	0.000E+00	2.371496E+04	3.774352E+03	0.000000E+00
4	17	0.000E+00	2.388185E+04	3.800914E+03	0.000000E+00
4	18	0.000E+00	2.596568E+04	4.132567E+03	0.000000E+00
4	19	0.000E+00	2.671466E+04	4.251770E+03	0.000000E+00
4	20	0.000E+00	2.979553E+04	4.742106E+03	0.000000E+00
4	21	0.000E+00	3.009830E+04	4.790293E+03	0.000000E+00
4	22	0.000E+00	3.032931E+04	4.827059E+03	0.000000E+00
4	23	0.000E+00	3.051137E+04	4.856036E+03	0.000000E+00
4	24	0.000E+00	3.089758E+04	4.917503E+03	0.000000E+00

The Positive Eigen Value after 1st Negative value is the unstable mode, which is 8th Mode here



Complex eigenvalue analysis