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INVESTIGATION OF THE NONLINEAR OSCILLATION OF THE PASSENGER CAR SUSPENSION

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ABSTRACT

The model of oscillations in vertical plane of passenger automobile suspension with the nonlinear characteristic is developed by finite elements method. The oscillation process of suspension is investigated. As the result the gain-frequency characteristic of the passenger automobile suspension is obtained.

Here the oscillation of the passenger car body is examined, when the ratio of the stiffness of the springing medium and damper ratio of the shock absorber can be changing in time. It means that the calculations are nonlinear.

The oscillation process is described by the following equation [1].

$$[M]\{u''\}+[C]\{u'\}+[K]\{u\}=\{F(t)\} \tag{1}$$

where $[M]$, $[C]$ and $[K]$ are the matrices of finite elements mass, damper and stiffness, correspondingly. Here $\{u''\}$ is a vector of the nodal accelerations, $\{u'\}$ is a vector of the nodal velocities, $\{u\}$ is a vector of the nodal displacements, $\{F\}$ is a vector of the external loads and (t) is time.

The process of the suspension oscillation is nonlinear. Here $[C]$ and $[K]$ are not constant in time. During the calculation the iteration procedure based on the Newton–Raphson method is taking place. At each iteration step the convergence of the system should be checked. As a result of finite element reducing of the oscillation system and using the nodal equilibrium equations the following algebraic equation system is obtained [2]:

$$[K]\{u\}=\{F^a\} \tag{2}$$

where $[K]$ is a coefficient matrix, $\{u\}$ is a vector of the unknown degrees of freedom, $\{F^a\}$ is a vector of applied loads.

The iteration procedure is done in the following succession.

1. Assume $\{u_0\}$. $\{u_0\}$ is usually the converged solution from the previous time step. On the first time step, $\{u_0\}=\{0\}$.
2. Compute the updated tangent matrix $[K_i^T]$ and the restoring load $[F_i^{nr}]$ from configuration $\{u_i\}$.
3. Calculate $\{\Delta u_i\}$.
4. To obtain next approximation $\{u_{i+1}\}$ the vectors $\{\Delta u_i\}$ and $\{u_i\}$ are augmented.
5. Steps from the second to the fourth points are repeated until the system reached convergence.

If the analysis includes path-dependent nonlinearities, then the solving process requires that some intermediate steps be in equilibrium in order to correctly follow the load path. This is reached

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effectively by specifying a step-by-step incremental analysis. It means that the final loading vector is obtained by increasing current vector at each step and implementing Newton-Raphson iterations. Graphically the mentioned procedure has the view shown in Fig. 1.

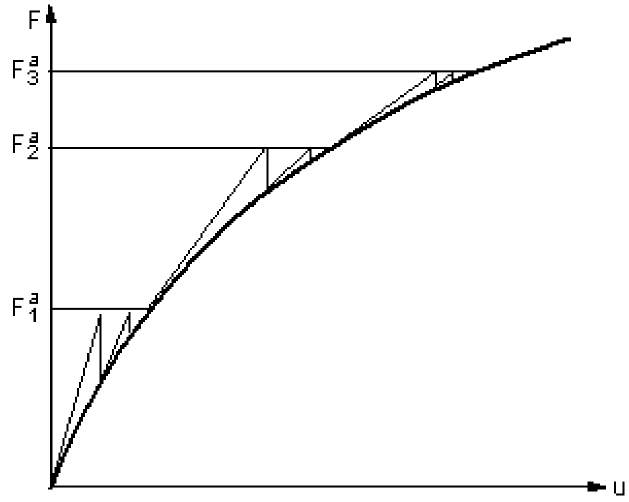

Fig. 1 Approximation of Newton – Raphson procedure

Except the Finite Element MASS21, which is used for automobile's cushioned and unsprung masses modeling the Finite Element with library name COMBIN39 is used, which is appropriate for nonlinear calculations. In the current article mentioned Finite Element is used for modeling of the automobile's suspension.

COMBIN39 is unidirectional Finite Element with generalized force-deflection capability. The element has longitudinal and torsional one, two and three-dimensional applications [2-5].

The element has large displacement capability for which there can be two or three degrees of freedom at each node. The geometry of the Finite Element is shown in the Fig. 2.

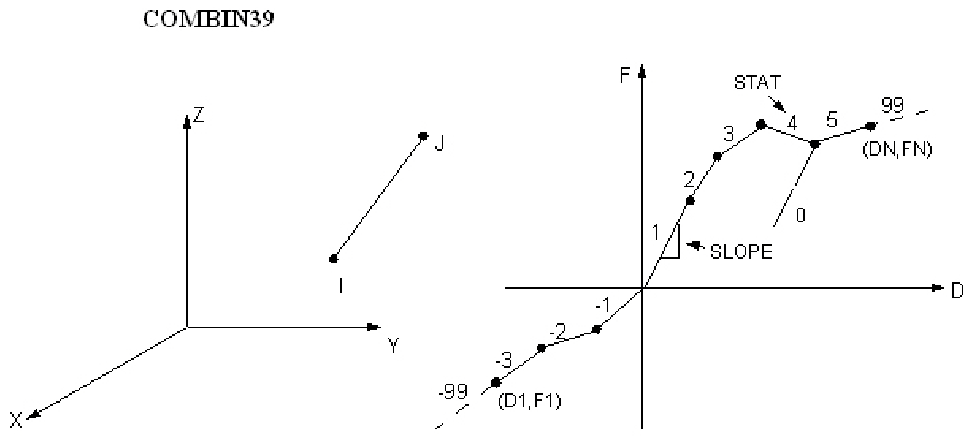

Fig 2 Mode of COMBIN39

The element is defined by two node points and by a generalized force-deflection curve. The special case of mentioned curve is shown on Fig. 2.

The force deflection curve, in connection with the input options of the element, can vary. The possible cases are shown in the Fig. 3.

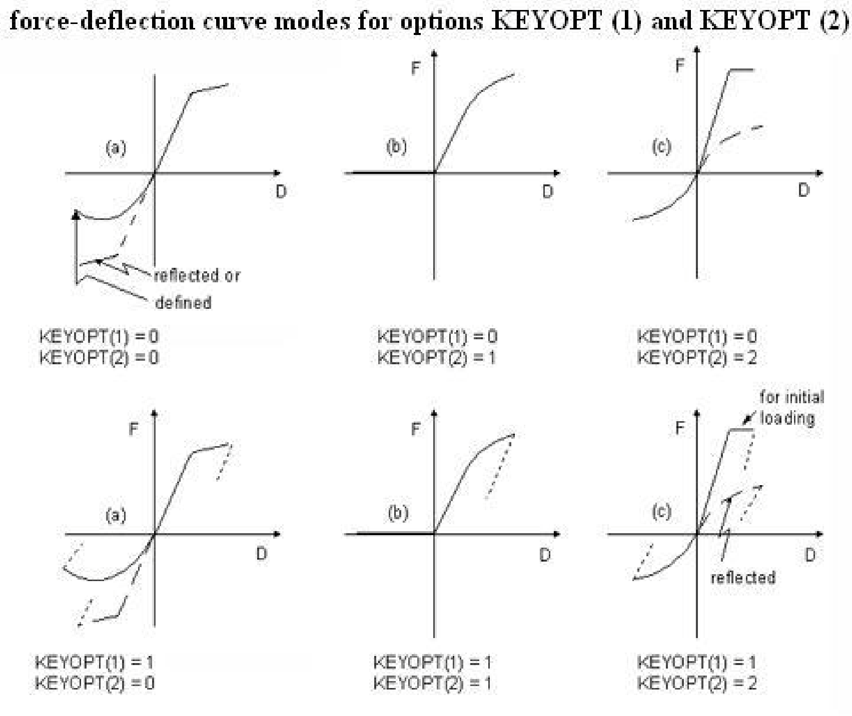

Fig. 3 Possible modes of force-deflection curve

The bicycle model of the passenger car is examined. As an example the Volkswagen Passat passenger car was taken to develop the computational model. In modelling almost all parameters were inputted by variables, which gives an opportunity to investigate any passenger car body of this class by changing them (m1, m2, m3, m4, k1, k2, k3, k4, c1, c2, c3, c4 etc.).

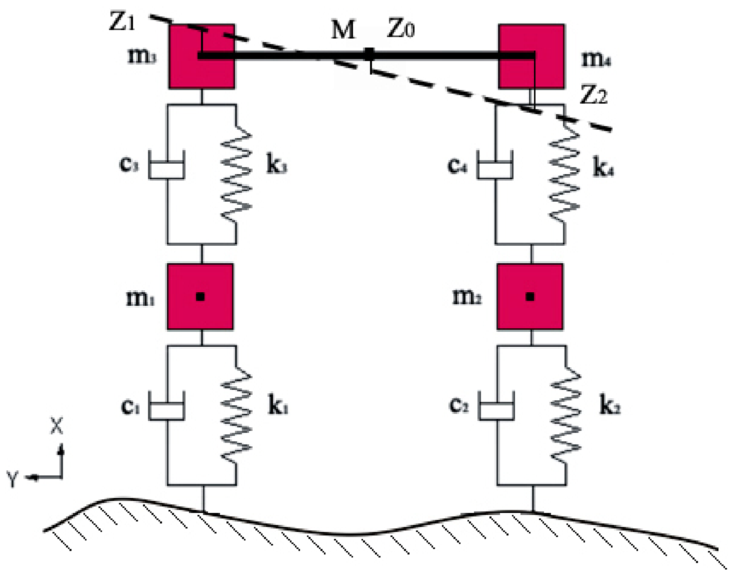

Fig. 4 The oscillation model

During the nonlinear calculations, as it was mentioned above, the convergence of the system at each step of iteration is checked. Here as a criterion of convergence of finite elements their deformation is used. The value of deformation would not exceed the input number during all process.

Used program packet gives an opportunity to obtain the displacement at the current moment of the time during the loading. On figure below the input criterion and displacement at each step of iteration are shown.

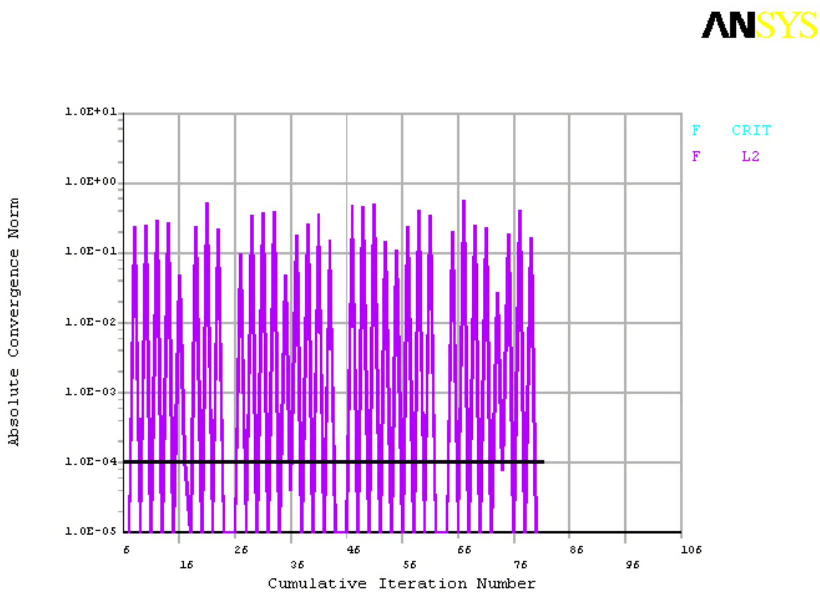

Fig. 5 Convergence check during the calculation

Investigation of the passenger car suspension by the Finite Element Method is done. The oscillation process of passenger car in vertical plane is examined, when the road irregularities are sinusoidal.

In order to obtain the gain-frequency characteristics of an automobile, it is assumed that

$$\varepsilon_y = 1 \qquad (3)$$

It means that the oscillation of the front axle of an automobile does not influence on the oscillation of the rear axle. This means that the association of the wheelbase of the car and length of the irregularity wave (that is phase of sinusoid) are not taken into account. Using mentioned assumption, the oscillation of the one axle of the bicycle model is examined.

In this case the gain-frequency characteristic has the form shown on the Fig. 6.

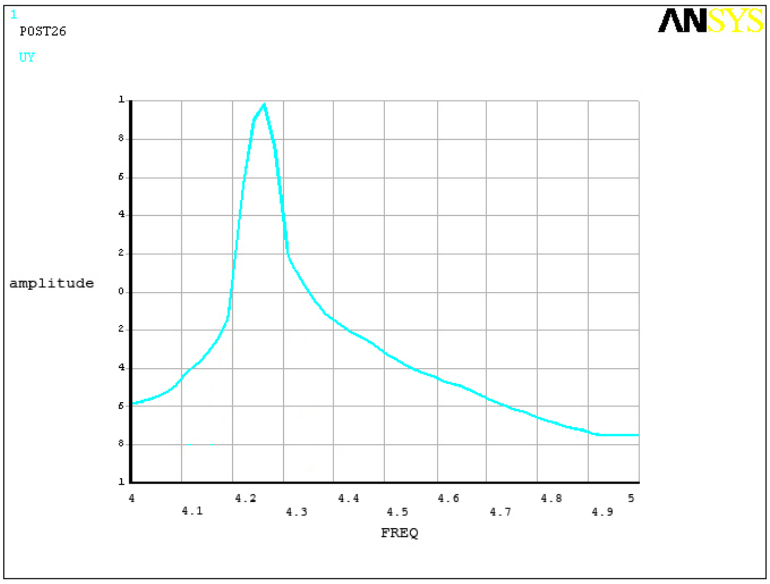

Fig. 6 Gain-frequency characteristic of nonlinear oscillation

So the development of the calculation model of an automobile's suspension by method of Finite Elements and investigation of its oscillation when stiffness is not constant are implemented. Above described method gives an opportunity to implement the investigation with higher accuracy, to apply loads with maximum approximation and to obtain more accurate results.

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