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Distributed indeterminacy evaluation of cable-strut structures: formulations and applications

Key words:

Flexible structures;
Cable-strut structures;
Distributed indeterminacy;
Initial force design;
Force finding;
Singular value decomposition;
Form transforming

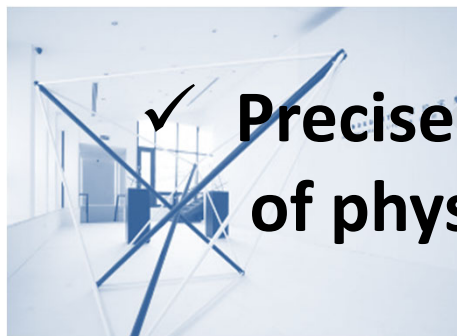


Introduction



◆ Objective of this study:

Investigation of *distributed indeterminacy* for
cable-strut structures



✓ **Precise interpretation
of physical meanings**



✓ **Substantial applications
in engineering**



Definition of DSI



$$\begin{aligned} \mathbf{t} &= -\mathbf{S}(\mathbf{S}^T \mathbf{F} \mathbf{S})^{-1} \mathbf{S}^T \mathbf{e}_0 \\ &= -\mathbf{K} \left[\mathbf{F} \mathbf{S} (\mathbf{S}^T \mathbf{F} \mathbf{S})^{-1} \mathbf{S}^T \right] \mathbf{e}_0 \end{aligned} \quad (1)$$

\mathbf{t} - a vector of element forces

\mathbf{K} - diagonal stiffness matrix

\mathbf{e}_0 - a vector of element elongations

\mathbf{F} - diagonal flexibility matrix

\mathbf{S} - self-stress states

$$\mathbf{\Omega} = \mathbf{F} \mathbf{S} (\mathbf{S}^T \mathbf{F} \mathbf{S})^{-1} \mathbf{S}^T \quad (2)$$

The diagonal entry of matrix $\mathbf{\Omega}$ is defined as the distributed static indeterminacy (DSI).

Physical meanings and applications of DSI



In good agreement with the Maxwell's rule

+

As an essential indicator of assemblies incorporating the geometry, topology and element stiffness

=

Physical meanings

➤ **Grouping**

+

➤ **Robustness analysis**

+

➤ **Structural sensitivity theory**

=

Applications

Definition of DKI



$$\mathbf{d} = \mathbf{N}[\mathbf{Z}\mathbf{M}(\mathbf{M}^T \mathbf{Z}\mathbf{M})^{-1} \mathbf{M}^T] \mathbf{f} \quad (3)$$

\mathbf{d} - a vector of nodal displacements

\mathbf{Z} - stress matrix

\mathbf{f} - a vector of element forces

\mathbf{M} - modes of mechanisms

$\mathbf{N} = \mathbf{Z}^{-1}$

$$\Phi = \mathbf{Z}\mathbf{M}(\mathbf{M}^T \mathbf{Z}\mathbf{M})^{-1} \mathbf{M}^T \quad (4)$$

The diagonal entry of matrix Φ is defined as the distributed kinematic indeterminacy (DKI).

Applications of DKI



Application 1

- ✓ DKI indicates the mobility of every node along x -, y - and z - direction in every equilibrium configuration

Application 2

- ✓ A feasible solution to the form transforming for deployable space structure