THE ELASTODYNAMICS MODEL OF THE MCGILL SCH¨O NFLIES MOTION GENERATOR

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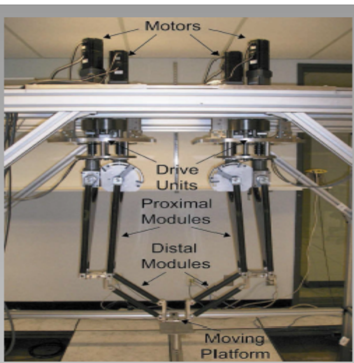
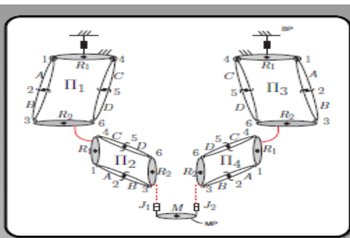
The elastodynamics model of the McGill Sch¨onflies Motion Generator is the subject of this paper. A modular approach, based on Matrix Structural Analysis, is used to derive the expression of the generalized stiffness matrix of the robot. A four-bar linkage, the -joint, forms the elementary cell composing the robot; two such couples of these joints are laid out in series to obtain each of the two robot limbs. Then, the two limbs are coupled to the moving platform by means of two revolute joints of vertical-axes. The aluminum-parts, except for the two long beams of the distal -joint, are considered rigid bodies, while the carbon-fiber parts and those two long aluminum beams are flexible bodies. The stiffness matrices of the flexible bodies are obtained by means of FEM models, while the mass and inertia properties are considered by means of generalized masses. The linearized elastodynamics equations are derived considering small displacements and neglecting power losses. Finally, the natural frequencies of the robot are found for a given configuration.



General description

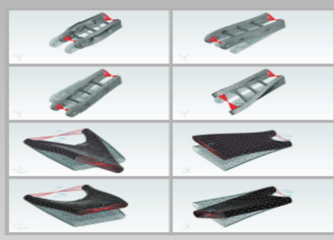
- Linear elastodynamics analysis based on Matrix Structural Analysis and FEA
- Modular approach by means of four Π-elementary modules
- Five rigid bodies: two shoulder brackets, two distal brackets and the moving platform
- Two flexible aluminum bodies (isotropic)
- four flexible carbon-fibre links (orthotropic)
- Ideal joints without friction and backlash



Properties of materials

Carbon-fibre		
Young Modulus	E_1	$1.75 \cdot 10^{11}$ (Pa)
	E_2	$1.75 \cdot 10^{11}$ (Pa)
Shear Modulus	G_{1z}	$6.73 \cdot 10^{10}$ (Pa)
	G_{2z}	$6.73 \cdot 10^{10}$ (Pa)
	G_{12}	$5.00 \cdot 10^{10}$ (Pa)
Stress limits: Tension	σ_{t1}	$1.50 \cdot 10^{9}$ (Pa)
	σ_{t2}	$1.50 \cdot 10^{9}$ (Pa)
Stress limits: Compression	σ_{c1}	$1.20 \cdot 10^{9}$ (Pa)
	σ_{c2}	$1.20 \cdot 10^{9}$ (Pa)
Shear	τ	$7.00 \cdot 10^{6}$ (Pa)
Poisson's ratio	ν	0.3
Density	ρ	1810 (kg/m³)
Thickness	t	0.0008 (m)

Aluminum		
Young Modulus	E	$70 \cdot 10^{9}$ (Pa)
Shear Modulus	G	$25 \cdot 10^{9}$ (Pa)
Stress limits: Tension	σ_t	$400 \cdot 10^{6}$ (Pa)
Stress limits: Compression	σ_c	$400 \cdot 10^{6}$ (Pa)
Shear	τ	$250 \cdot 10^{6}$ (Pa)
Poisson's ratio	ν	0.33
Density	ρ	2700 (kg/m³)



FIRST FOUR EIGENFREQUENCIES OF THE MCGILL SMG

Eigenfrequencies ω_i, [Hz]			
Elastodynamics model			
38.27	88.26	120.02	120.02
FEA model			
37.01	81.78	120.06	120.06

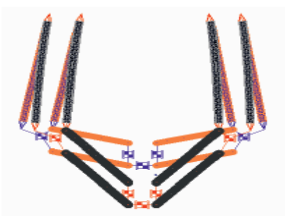


FIGURE 1: FIRST MODE

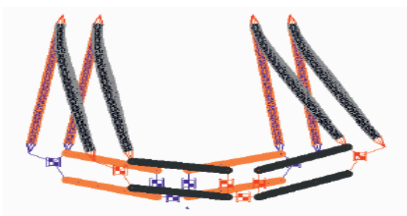


FIGURE 2: SECOND MODE

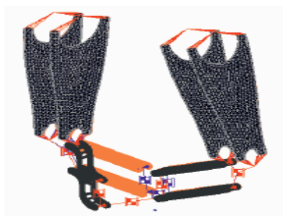


FIGURE 3: THIRD MODE

Advantages and applications

- determining the lowest eigenfrequencies inside the robot workspace;
- performing sensitivity studies to vibrations upon changes of geometric, inertial or structural parameters;
- improving control system strategies taking into account small deformations of the structure;
- drastically reducing the effort in FEM models re-meshing and reassembling.

Limitations and drawbacks

- use of single lumped mass/inertia matrices for the flexible parts to avoid multiple virtual cuts;
- constraints definition inside the lower and upper-flexible parts to obtain two-nodes stiffness matrices;
- local buckling phenomena for the carbon fiber parts strongly depend on the kind of constraints chosen to link the end points to the boundary nodes of the end surfaces;
- rigid connections imply undesired increments in stiffness.