Supplementary Material

Appendix 1 - The structure and values of the elements in vectors and matrices that form the system of motion equations.

The vector of generalized coordinates $\{\mathbf{q}\}$ of size 34 is formed from sub-vectors $[\mathbf{q}]_h$ of size 6, $[\mathbf{q}]_t$ of size 18, $[\mathbf{q}]_m$ of size 3, $[\mathbf{q}]_{hh}$ of size 4, and $[\mathbf{q}]_{as}$ of size 3 (eqn. 1):

$$\{q\}^T = \{\{q\}_h \quad \{q\}_t \quad \{q\}_m \quad \{q\}_{hh} \quad \{q\}_{as}\} \tag{1}$$

where T is the vector transposition operation.

The sub-vectors describe the individual components of the harvester and include generalized coordinates that correspond to these components. The sub-vector $[\mathbf{q}]_h$ describes the harvester as a whole. The sub-vector $[\mathbf{q}]_t$ describes the wheels of the harvester. The sub-vector $[\mathbf{q}]_m$ describes the manipulator. The sub-vector $[\mathbf{q}]_{hh}$ describes the harvester head with the log fixed in it. Finally, the sub-vector $[\mathbf{q}]_{as}$ describes the anchor system of the harvester. These sub-vectors have the following structure (eqn. 2, eqn. 3, eqn. 4):

$$\{q\}_h^T = \{q_1 \quad q_2 \quad q_3 \quad q_4 \quad q_5 \quad q_6\} \tag{2}$$

$$\{\mathbf{q}\}_t^T = \{ q_7 \quad q_8 \quad q_9 \quad q_{10} \quad q_{11} \quad q_{12} \quad q_{13} \quad q_{14} \quad q_{15} \quad q_{16} \quad q_{17} \quad q_{18} \quad q_{19} \quad q_{20} \quad q_{21} \quad q_{22} \quad q_{23} \quad q_{24} \} \tag{3}$$

$$\{q\}_m^T = \{q_{25} \quad q_{26} \quad q_{27}\}; \quad \{q\}_{hh}^T = \{q_{28} \quad q_{29} \quad q_{30} \quad q_{31}\}; \quad \{q\}_{as}^T = \{q_{32} \quad q_{33} \quad q_{34}\} \tag{4}$$

The vectors of generalized velocities $\{\dot{\mathbf{q}}\}$ and generalized accelerations $\{\ddot{\mathbf{q}}\}$ are structurally equivalent to the vector $\{\mathbf{q}\}$. The generalized coordinates q_k must be replaced by the corresponding generalized velocities $\dot{q}_k$ or generalized accelerations $\ddot{q}_k$.

The vector of generalized forces {**Q**} of size 34 is formed from sub-vectors $[\mathbf{Q}]_h$ of size 6, $[\mathbf{Q}]_t$ of size 18, $[\mathbf{Q}]_m$ of size 3, $[\mathbf{Q}]_{hh}$ of size 4, and $[\mathbf{Q}]_{as}$ of size 3 (eqn. 5):

$$\{Q\}^T=\{\{Q\}_h \quad \{Q\}_t \quad \{Q\}_m \quad \{Q\}_{hh} \quad \{Q\}_{as}\} \tag{5}$$

These sub-vectors have the following structure (eqn. 6, eqn. 7, eqn. 8):

$$\{Q\}_h^T=\{Q_1 \quad Q_2 \quad Q_3 \quad Q_4 \quad Q_5 \quad Q_6\} \tag{6}$$

$$\{\mathbf{Q}\}_t^T=\{Q_7 \quad Q_8 \quad Q_9 \quad Q_{10} \quad Q_{11} \quad Q_{12} \quad Q_{13} \quad Q_{14} \quad Q_{15} \quad Q_{16} \quad Q_{17} \quad Q_{18} \quad Q_{19} \quad Q_{20} \quad Q_{21} \quad Q_{22} \quad Q_{23} \quad Q_{24}\} \tag{7}$$

$$\{Q\}_m^T=\{Q_{25} \quad Q_{26} \quad Q_{27}\};\ \{Q\}_{hh}^T=\{Q_{28} \quad Q_{29} \quad Q_{30} \quad Q_{31}\};\ \{Q\}_{as}^T=\{Q_{32} \quad Q_{33} \quad Q_{34}\} \tag{8}$$

Vector of projections of operational forces F_x, F_y, F_z on the coordinate axes (eqn. 9):

$$\{F\}^T=\{F_x\ F_y\ F_z\} \tag{9}$$

The diagonal matrix [**A**] of coefficients for the generalized coordinates of size 34×34 is formed by combining diagonal sub-matrices $[\mathbf{A}]_h$, $[\mathbf{A}]_t$, $[\mathbf{A}]_m$, $[\mathbf{A}]_{hh}$, and $[\mathbf{A}]_{as}$ (eqn. 10):

$$[A]=\begin{bmatrix} [A]_h & [0]_{6-18} & [0]_{6-3} & [0]_{6-4} & [0]_{6-3} \\ [0]_{18-6} & [A]_t & [0]_{18-3} & [0]_{18-4} & [0]_{18-3} \\ [0]_{3-6} & [0]_{3-18} & [A]_m & [0]_{3-4} & [0]_{3-3} \\ [0]_{4-6} & [0]_{4-18} & [0]_{3-6} & [A]_{hh} & [0]_{3-3} \\ [0]_{3-6} & [0]_{3-18} & [0]_{3-3} & [0]_{3-4} & [A]_{as} \end{bmatrix}, \tag{10}$$

where $[\mathbf{0}]_{m\text{-}n}$ is the zero matrix of size m×n.

Elements of the main diagonal of the diagonal sub-matrix $[\mathbf{A}]_h$ of size 6×6 (eqn. 11):

$$[A]_h=diag\left[-\frac{3c_{rwt}c_{tx}}{3c_{tx}+2c_{rwt}};\ 3c_{st}-\frac{c_r c_w}{c_r+c_w};\ -3c_{st}-\frac{c_r c_w}{c_r+c_w};\ -1.5c_{st}z_h;\ -c_{rwt}\frac{(B_h-x_h)^2}{L_r};\ c_{tx}\sum_{k=1}^{k=1}(x_{tk}-x_h)\right], \tag{11}$$

where x_h, z_h are the coordinates of the mass center for the harvester itself, B_h is the distance to the mass center of the anchor winch, L_r is the distance to the anchor tree, c_{rwt} is the stiffness coefficient of the "anchor tree-anchor rope-anchor winch" system, c_{st} is the stiffness coefficient of the "suspension-wheelset-soil" system in the vertical direction (along the axis y).

Elements of the main diagonal of the diagonal sub-matrix $[\mathbf{A}]_t$ of size 18×18 (eqn. 12):

$$[A]_t = diag[-0.5c_{tx}; -0.5c_s; -0.5c_{tz}; -0.5c_{tx}; -0.5c_s; -0.5c_{tz}; -0.5c_{tx}; -0.5c_s; -0.5c_{tz}; \rightarrow$$

$$\rightarrow -0.5c_{tx}; -0.5c_s; -0.5c_{tz}; -0.5c_{tx}; -0.5c_s; -0.5c_{tz}; -0.5c_{tx}; -0.5c_s; -0.5c_{tz}]. \quad (12)$$

Elements of the main diagonal of the diagonal sub-matrix $[\mathbf{A}]_m$ of size 3×3 (eqn. 13):

$$[A]_m = diag\left[-(6c_{tx}+c_{rwt});\ c_{ty}\frac{2x_{t1}-x_{t2}-x_{t3}}{x_{t1}+x_m};\ c_{tz}\frac{2x_{t1}-x_{t2}-x_{t3}}{x_{t1}+x_m}\right], \quad (13)$$

where x_{tk}, x_m are coordinates of the manipulator base and the mass center of the wheel mounted on the k-th axis.

Elements of the main diagonal of the diagonal sub-matrix $[\mathbf{A}]_{hh}$ of size 4×4 (eqn. 14):

$$[A]_{hh} = diag\left[-(6c_{tx}+c_{rwt}+c_{mx}q_{m1});\ 2c_{tgy}\frac{2x_{t1}-x_{t2}-x_{t3}}{x_{t1}+x_{hh}}-c_{my};\ c_{tz}\frac{2x_{t1}-x_{t2}-x_{t3}}{x_{t1}+x_{hh}}-c_{mz};\ -l_G\right], \quad (14)$$

where c_{mx}, c_{my}, c_{mz} are stiffness coefficients of the manipulator along the axes x, y, z, x_{hh} is the coordinate x of the mass center of the harvester head, l_G is the log suspension length.

Elements of the main diagonal of the diagonal sub-matrix $[\mathbf{A}]_{as}$ of size 3×3 (eqn. 15):

$$[A]_{as} = diag\left[c_{rwt}+\frac{2}{3}c_{tx};\ \frac{c_r c_{at}}{c_r+c_{at}};\ 0.5\frac{3c_{rwt}c_{tx}}{2c_{rwt}+3c_{tx}}\left(\frac{H_L}{H_{at}}\right)^2\left(3-\frac{H_L}{H_{at}}\right)\right], \quad (15)$$

where H_L is the height of the anchor rope attachment to the anchor tree.

A square matrix $[\mathbf{B}]$ of coefficients for generalized velocities of size 34×34 is formed by combining diagonal sub-matrices $[\mathbf{B}]_h$, $[\mathbf{B}]_t$, $[\mathbf{B}]_{hh}$ and rectangular sub-matrices $[\mathbf{B}]_{mt}$, $[\mathbf{B}]_{ht}$, $[\mathbf{B}]_{hht}$, $[\mathbf{B}]_{ast}$, $[\mathbf{B}]_{has}$ (eqn. 16):

$$[\mathbf{B}] = \begin{bmatrix} [\mathbf{B}]_h & [\mathbf{B}]_{ht} & [\mathbf{0}]_{6-3} & [\mathbf{0}]_{6-4} & [\mathbf{B}]_{has} \\ [\mathbf{0}]_{18-6} & [\mathbf{B}]_t & [\mathbf{0}]_{18-3} & [\mathbf{0}]_{18-4} & [\mathbf{0}]_{18-3} \\ [\mathbf{0}]_{3-6} & [\mathbf{B}]_{mt} & [\mathbf{0}]_{3-3} & [\mathbf{0}]_{3-4} & [\mathbf{0}]_{3-3} \\ [\mathbf{0}]_{4-6} & [\mathbf{B}]_{hht} & [\mathbf{0}]_{3-6} & [\mathbf{B}]_{hh} & [\mathbf{0}]_{3-3} \\ [\mathbf{0}]_{3-6} & [\mathbf{B}]_{ast} & [\mathbf{0}]_{3-3} & [\mathbf{0}]_{3-4} & [\mathbf{B}]_{as} \end{bmatrix}. \tag{16}$$

Diagonal sub-matrix $[\mathbf{B}]_h$ of size 6×6 (eqn. 17):

$$[\mathbf{B}]_h = diag[0; -6\beta_s; 0; 0; 0; 0]. \tag{17}$$

Diagonal sub-matrix $[\mathbf{B}]_t$ of size 18×18 (eqn. 18):

$$[B]_t = diag[-2\beta_{tx}; -0.5\beta_s; -2\beta_{tz}; -2\beta_{tx}; -0.5\beta_s; -2\beta_{tz}; -2\beta_{tx}; -0.5\beta_s; -2\beta_{tz}; \rightarrow$$

$$\rightarrow -2\beta_{tx}; -0.5\beta_s; -2\beta_{tz}; -2\beta_{tx}; -0.5\beta_s; -2\beta_{tz}; -2\beta_{tx}; -0.5\beta_s; -2\beta_{tz}]. \tag{18}$$

Diagonal sub-matrix $[\mathbf{B}]_{hh}$ of size 4×4 (eqn. 19):

$$[B]_{hh} = diag[0; -(\beta_{h1}+\beta_{h2}+\beta_{h3}); 0; -\beta_d l_G], \tag{19}$$

where β_d is the coefficient of viscous resistance of the harvester head damper.

Rectangular sub-matrix $[\mathbf{B}]_{ht}$ of size 6×18 (eqn. 20):

$$[B]_{ht} = -[\begin{matrix} \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 \\ 0 & \beta_{ty} & 0 & 0 & \beta_{ty} & 0 & 0 & \beta_{ty} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \beta_{ty}(z_t+z_h) & 0 & 0 & \beta_{ty}(z_t+z_h) & 0 & 0 & \beta_{ty}(z_t+z_h) & 0 \\ 0 & 0 & \beta_{tz}(x_{t1}-x_h) & 0 & 0 & \beta_{tz}(x_{t1}-x_h) & 0 & 0 & \beta_{tz}(x_{t1}-x_h) \\ 0 & \beta_{tgy}(x_{t1}-x_h) & 0 & 0 & \beta_{tgy}(x_{t1}-x_h) & 0 & 0 & \beta_{tgy}(x_{t1}-x_h) & 0 \end{matrix} \rightarrow$$

$$\rightarrow \begin{matrix} \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 \\ 0 & \beta_{ty} & 0 & 0 & \beta_{ty} & 0 & 0 & \beta_{ty} & 0 \\ 0 & 0 & \beta_{tz} & 0 & 0 & \beta_{tz} & 0 & 0 & \beta_{tz} \\ 0 & \beta_{ty}(z_t-z_h) & 0 & 0 & \beta_{ty}(z_t-z_h) & 0 & 0 & \beta_{ty}(z_t-z_h) & 0 \\ 0 & 0 & \beta_{tz}(x_{t1}-x_h) & 0 & 0 & \beta_{tz}(x_{t2}-x_h) & 0 & 0 & \beta_{tz}(x_{t3}-x_h) \\ 0 & \beta_{tgy}(x_{t1}-x_h) & 0 & 0 & \beta_{tgy}(x_{t2}-x_h) & 0 & 0 & \beta_{tgy}(x_{t3}-x_h) & 0 \end{matrix}]. \tag{20}$$

Rectangular sub-matrix $[\mathbf{B}]_{mt}$ of size 3×18 (eqn. 21):

$$[B]_{mt}=-\begin{bmatrix} \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 \\ 0 & \beta_{tgy} & 0 & 0 & \beta_{tgy} & 0 & 0 & \beta_{tgy} & 0 & 0 & \beta_{tgy} & 0 & 0 & \beta_{tgy} & 0 & 0 & \beta_{tgy} & 0 \\ 0 & 0 & 0 & 0 & 0 & \beta_{tz} & 0 & 0 & \beta_{tz} & 0 & 0 & 0 & 0 & 0 & \beta_{tz} & 0 & 0 & \beta_{tz} \end{bmatrix} \quad . \quad (21)$$

Rectangular sub-matrix $[\mathbf{B}]_{hht}$ of size 4×18 (eqn. 22):

$$[B]_{hht}= -\begin{bmatrix} \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 \\ 0 & 0 & 0 & 0 & \beta_{tz} & 0 & 0 & \beta_{tz} & 0 & 0 & \beta_{tz} & 0 & 0 & \beta_{tz} & 0 & 0 & \beta_{tz} & 0 \\ 0 & 0 & 0 & 0 & 0 & \beta_{tz} & 0 & 0 & \beta_{tz} & 0 & 0 & 0 & 0 & 0 & \beta_{tz} & 0 & 0 & \beta_{tz} \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \quad . \quad (22)$$

Rectangular sub-matrix $[\mathbf{B}]_{ast}$ of size 3×18 (eqn. 23):

$$[B]_{ast}=-\begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 \\ \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 & \beta_{tx} & 0 & 0 \end{bmatrix}. \quad (23)$$

Rectangular sub-matrices $[\mathbf{B}]_{has}$ of size 6×3 and $[\mathbf{B}]_{as}$ of size 3×3 (eqn. 24):

$$[B]_{has}= -\begin{bmatrix} 0 & 0 & \beta_{at} \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}; \qquad [B]_{as}= -\begin{bmatrix} 6\beta_{tx} & 0 & \beta_{at} \\ 0 & 0 & \beta_{at} \\ 0 & 0 & \beta_{at} \end{bmatrix}. \quad (24)$$

A rectangular matrix $[\mathbf{C}]$ consisting of coefficients for the projections of operational forces of size 34×3 is formed from the rectangular sub-matrices $[\mathbf{C}]_h$, $[\mathbf{C}]_m$, $[\mathbf{C}]_{hh}$, and $[\mathbf{C}]_{as}$ (eqn. 25):

$$[\mathbf{C}]=\begin{bmatrix} [\mathbf{C}]_h \\ [\mathbf{0}]_{18-3} \\ [\mathbf{C}]_m \\ [\mathbf{C}]_{hh} \\ [\mathbf{C}]_{as} \end{bmatrix}. \quad (25)$$

Rectangular sub-matrix $[\mathbf{C}]_h$ of size 6×3 (eqn. 26):

$$[C]_h = \begin{bmatrix} -\cos q_{m1} & 0 & \sin q_{m1} \\ 0 & -1 & 0 \\ \sin q_{m1} & 0 & -\cos q_{m1} \\ 0 & z_{hh}-z_h & y_{hh}-y_h \\ (x_{hh}+x_h)\cos q_{m1}-(z_{hh}-z_h)\sin q_{m1} & 0 & (x_{hh}+x_h)\sin q_{m1}-(z_{hh}-z_h)\cos q_{m1} \\ y_{hh}-y_h & x_{hh}+x_h & 0 \end{bmatrix}. \tag{26}$$

Rectangular sub-matrix $[\mathbf{C}]_m$ of size 3×3 (eqn. 27):

$$[C]_m = \begin{bmatrix} -\cos q_{m1} & 0 & \sin q_{m1} \\ 0 & -\dfrac{x_{t1}+x_{hh}}{x_{t1}+x_m} & 0 \\ \dfrac{x_{t1}+x_{hh}}{x_{t1}+x_m}\sin q_{m1} & 0 & \dfrac{x_{t1}+x_{hh}}{x_{t1}+x_m}\cos q_{m1} \end{bmatrix}. \tag{27}$$

Rectangular sub-matrices $[\mathbf{C}]_{hh}$ of size 4×3 and $[\mathbf{C}]_{as}$ of size 3×3 (eqn. 28):

$$[C]_{hh} = \begin{bmatrix} -\cos q_{m1} & 0 & \sin q_{m1} \\ 0 & -1 & 0 \\ \sin q_{m1} & 0 & \cos q_{m1} \\ l_G\cos\alpha_s & -l_G & 0 \end{bmatrix};$$

$$[C]_{as} = \begin{bmatrix} -1 & -(\sin\alpha_s+\mu_{gr}\cos\alpha_s) & 0 \\ -\cos q_{m1} & 0 & \sin q_{m1} \\ -\cos q_{m1} & 0 & \sin q_{m1} \end{bmatrix}. \tag{28}$$

A diagonal matrix $[\mathbf{E}]$ of coefficients for generalized accelerations of size 34×34 is formed as (eqn. 29):

$$[\mathbf{E}] = \begin{bmatrix} [\mathbf{E}]_h & [\mathbf{0}]_{6-18} & [\mathbf{0}]_{6-3} & [\mathbf{0}]_{6-4} & [\mathbf{0}]_{6-3} \\ [\mathbf{0}]_{18-6} & [\mathbf{E}]_t & [\mathbf{0}]_{18-3} & [\mathbf{0}]_{18-4} & [\mathbf{0}]_{18-3} \\ [\mathbf{0}]_{3-6} & [\mathbf{0}]_{3-18} & [\mathbf{E}]_m & [\mathbf{0}]_{3-4} & [\mathbf{0}]_{3-3} \\ [\mathbf{0}]_{4-6} & [\mathbf{0}]_{4-18} & [\mathbf{0}]_{3-6} & [\mathbf{E}]_{hh} & [\mathbf{0}]_{3-3} \\ [\mathbf{0}]_{3-6} & [\mathbf{0}]_{3-18} & [\mathbf{0}]_{3-3} & [\mathbf{0}]_{3-4} & [\mathbf{E}]_{as} \end{bmatrix}. \tag{29}$$

Elements of the main diagonal of the diagonal sub-matrices $[\mathbf{E}]_h$ of size 6×6, $[\mathbf{E}]_t$ of size 18×18, $[\mathbf{E}]_m$ of size 3×3, $[\mathbf{E}]_{hh}$ of size 4×4 и $[\mathbf{E}]_{as}$ of size 3×3 (eqn. 30, eqn. 31, eqn. 32, eqn. 33, eqn. 34):

$$[E]_h = diag\left[M_{h,sum}+M_w;\quad M_{h,sum}+M_w;\quad M_{h,sum}+M_w;\quad J_{hmx};\quad J_{hmy};\quad J_{hmz}\right]; \tag{30}$$

$$[E]_t = diag\ \left[M_t;\ M_t;\ M_t;\ M_t;\ M_t;\ M_t;\ M_t;\ M_t;\ M_t;\ M_t;\ M_t;\ M_t;\ M_t;\ M_t;\ M_t;\ M_t;\ M_t;\ M\right. \tag{31}$$

$$[E]_m = diag\ \left[M_m+M_G;\quad M_m+M_G;\quad M_m+M_G\right]; \tag{32}$$

$$[E]_{hh} = diag\ \left[M_G;\quad M_G;\quad M_G;\quad J_{Gz}\right]; \tag{33}$$

$$[E]_{as} = diag\ \left[M_w;\quad M_r;\quad M_{at}\right], \tag{34}$$

where $M_{h,sum}$ is the total mass of the simulated system, including the harvester, manipulator, anchor system and log (excluding the anchor tree mass), J_{hmx}, J_{hmy}, J_{hmz} are the total inertia moments of the harvester and manipulator when turning relative to the axes x, y, z.

The vector of the right-hand sides of the motion equations of size 34 has the following form (eqn. 35):

$$\{G\}^T = \{g_1\ g_2\ \dots\ g_i\ \dots\ g_{34}\} = \{Q_1/e_{1,1}\ Q_2/e_{2,2}\ \dots\ Q_i/e_{i,i}\ \dots\ Q_{34}/e_{34,34}\}, \tag{35}$$

where $e_{i,i}$ is the i-th diagonal element of the matrix $[\mathbf{E}]$.

Fig. S1 – Geometric model.

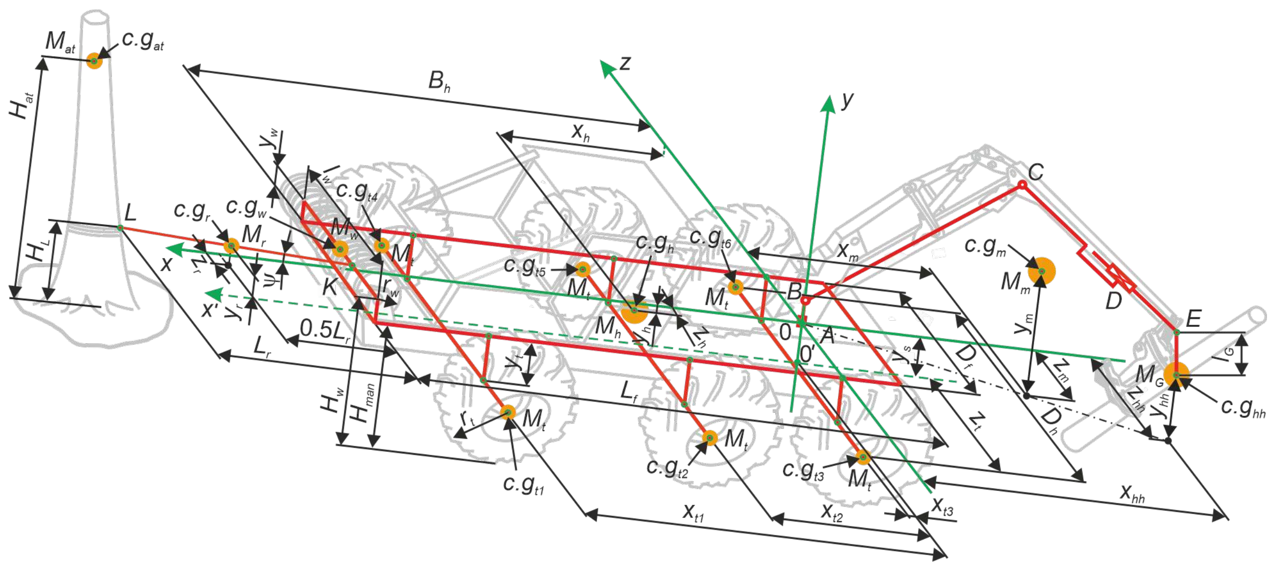

Fig. S2 – Generalized coordinates of the dynamic mathematical model.

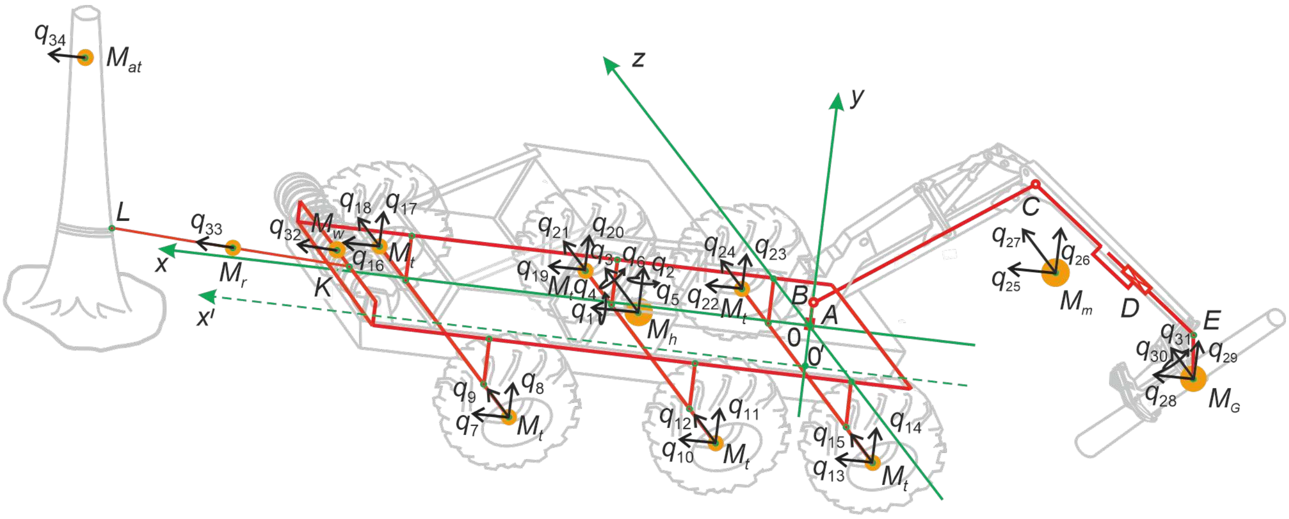

Fig. S3 – The dynamics of the mass center movement of an anchor tree.

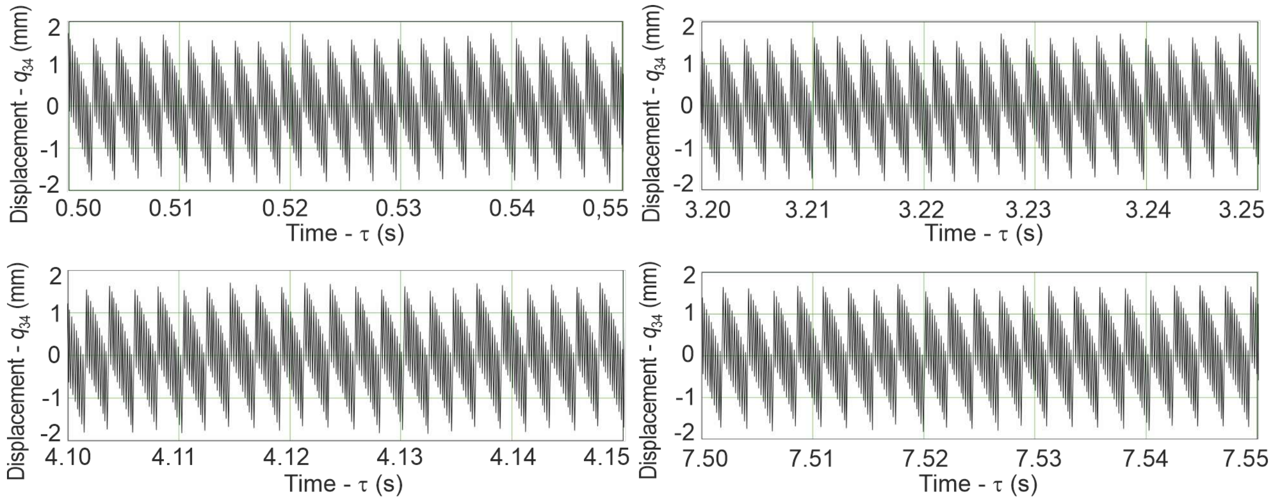

Fig. S4 – The dynamics of the anchor winch drum's movement.

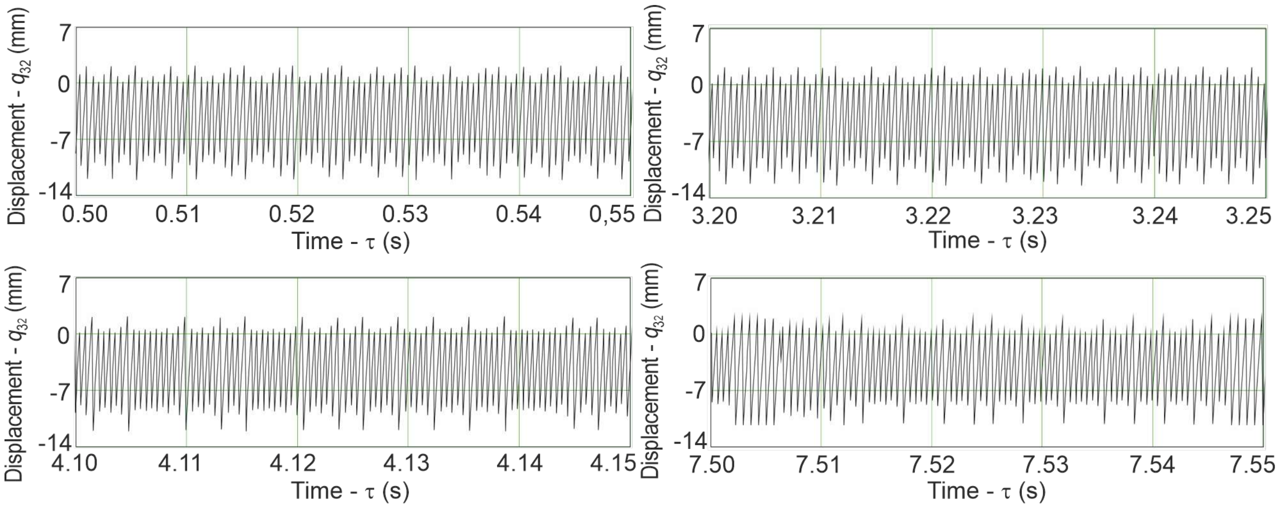

Fig. S5 – Dynamics of the mass center movement of the harvester head and the log along the *x*-axis.

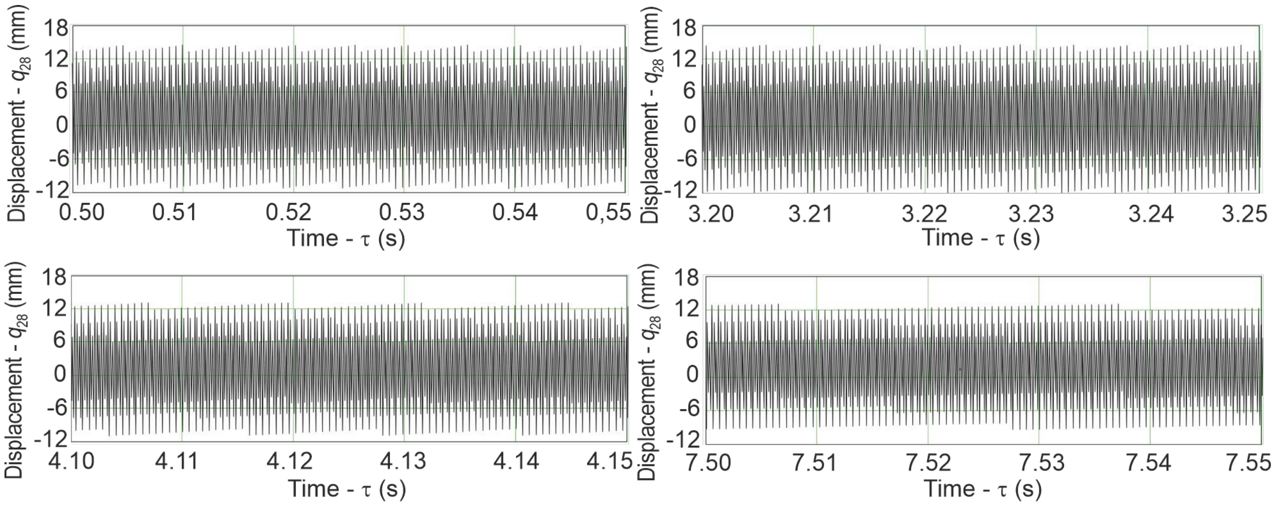

Fig. S6 – Histograms of the distribution of the ranges of relative share for the anchor's rope tensile force (a), the mass center movement of the harvester head and the log along the *x*-axis (b), the anchor winch drum's movement (c), and the mass center movement of an anchor tree (d).