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CORRECTION

Correction to: Analysis on the Evolution of Rock Block Behavior During TBM Tunneling Considering the TBM–Block Interaction

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1. Correction to equations

Equations 3, 4, 5, 11, 13, 15, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27 and 31 are reported incorrectly. The correct equations are given below.

1. The cross products in Eqs. 3, 4, 13, 15, 17, 22, 23 should be dot products.

   Equation 3:

$$\begin{cases} \mathbf{r}^n = \mathbf{r}^{n\prime} \cdot \mathbf{M}^T \\ \mathbf{F}^n = \mathbf{r}^n \cdot \sum F_i^n. \end{cases} \tag{3}$$

   Equation 4:

$$\begin{cases} \mathbf{r}^t = \mathbf{r}^{t\prime} \cdot \mathbf{M}^T \\ \mathbf{F}^t = \sum F_i^t \cdot \mathbf{r}_i^t. \end{cases} \tag{4}$$

   Equation 13:

$$\mathbf{r}^a \cdot \mathbf{v}_i > 0 \tag{13}$$

   Equation 15:

$$\begin{cases} \mathbf{v}_i \cdot \mathbf{r}^a \le 0 \\ \mathbf{v}_j \cdot \mathbf{s} > 0 \quad \text{for } (j \ne i) \end{cases} \tag{15}$$

   Equation 17:

$$\begin{cases} \mathbf{v}_i \cdot \mathbf{s}_j \le 0 \\ \mathbf{v}_j \cdot \mathbf{s}_i \le 0 \\ \mathbf{v}_k \cdot \mathbf{s} > 0 \quad \text{for } (k \ne i, j) \end{cases} \tag{17}$$

   Equation 22:

$$F = \mathbf{F}^a \cdot \mathbf{s} - N_i \tan \phi_i \tag{22}$$

   Equation 23:

$$F = \mathbf{F}^a \cdot \mathbf{s} - \left(N_i \tan \phi_i + N_j \tan \phi_j\right) \tag{23}$$

2. The second cross product of both sub-equations in Eq. 5 should be dot product.

   Equation 5:

$$\begin{cases} \mathbf{M}^n = \sum \vec{PC_i} \times \mathbf{r}_i^n \cdot F_i^n \\ \mathbf{M}^t = \sum \vec{PC_i} \times \mathbf{r}_i^t \cdot F_i^t. \end{cases} \tag{5}$$

3. The moment symbols in Eq. 11 should be in bold.

   Equation 11:

$$\mathbf{M}^e = \mathbf{M}^a = \mathbf{M}^G + \mathbf{M}^n + \mathbf{M}^t \tag{11}$$

4. The cross product in Eq. 18 should be dot product; the moment symbol should be in bold.

   Equation 18:

$$\begin{cases} m \cdot \mathbf{a} = \mathbf{F}^a \\ \mathbf{E}^G \cdot \dot{\boldsymbol{\omega}} = \mathbf{M}^a. \end{cases} \tag{18}$$

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5. The first and the third cross products of each sub-equation in Eqs. 19 and 20 should be dot products.

Equation 19:

$$\begin{cases} \Delta\vec{V}_i \cdot \mathbf{v}_m < 0; \text{ i.e., } \left(\mathbf{a} + \dot{\boldsymbol{\omega}} \times \vec{GV}_i\right) \cdot \mathbf{v}_m < 0 \\ \Delta\vec{V}_i \cdot \mathbf{v}_n < 0; \text{ i.e., } \left(\mathbf{a} + \dot{\boldsymbol{\omega}} \times \vec{GV}_i\right) \cdot \mathbf{v}_n < 0 \\ \Delta\vec{V}_i \cdot \mathbf{v}_f > 0; \text{ i.e., } \left(\mathbf{a} + \dot{\boldsymbol{\omega}} \times \vec{GV}_j\right) \cdot \mathbf{v}_f > 0 \\ \Delta\vec{V}_j \cdot \mathbf{v}_f < 0; \text{ i.e., } \left(\mathbf{a} + \dot{\boldsymbol{\omega}} \times \vec{GV}_j\right) \cdot \mathbf{v}_f < 0, \quad \text{for } (j \neq i). \end{cases} \tag{19}$$

Equation 20:

$$\begin{cases} \Delta\vec{V}_i \cdot \mathbf{v}_m < 0; \text{ i.e., } \left(\mathbf{a} + \dot{\boldsymbol{\omega}} \times \vec{GV}_i\right) \cdot \mathbf{v}_m < 0 \\ \Delta\vec{V}_j \cdot \mathbf{v}_m < 0; \text{ i.e., } \left(\mathbf{a} + \dot{\boldsymbol{\omega}} \times \vec{GV}_j\right) \cdot \mathbf{v}_m < 0 \\ \Delta\vec{V}_i \cdot \mathbf{v}_f > 0; \text{ i.e., } \left(\mathbf{a} + \dot{\boldsymbol{\omega}} \times \vec{GV}_i\right) \cdot \mathbf{v}_f > 0 \\ \Delta\vec{V}_j \cdot \mathbf{v}_f > 0; \text{ i.e., } \left(\mathbf{a} + \dot{\boldsymbol{\omega}} \times \vec{GV}_j\right) \cdot \mathbf{v}_f > 0 \\ \Delta\vec{V}_k \cdot \mathbf{v}_f < 0; \text{ i.e., } \left(\mathbf{a} + \dot{\boldsymbol{\omega}} \times \vec{GV}_k\right) \cdot \mathbf{v}_f < 0, \ for\ (k \neq i, j) \end{cases} \tag{20}$$

6. The cross product between two brackets in the member of both sub-equations in Eq. 24 should be dot product.

Equation 24:

$$\begin{cases} N_i = |\mathbf{F}^a| \dfrac{\left(\mathbf{r}^a \times \mathbf{n}_j\right) \cdot \left(\mathbf{n}_i \times \mathbf{n}_j\right)}{\left|\mathbf{n}_i \times \mathbf{n}_j\right|^2} \\ N_j = |\mathbf{F}^a| \dfrac{\left(\mathbf{r}^a \times \mathbf{n}_i\right) \cdot \left(\mathbf{n}_i \times \mathbf{n}_j\right)}{\left|\mathbf{n}_i \times \mathbf{n}_j\right|^2} \end{cases} \tag{24}$$

7. The cross product in the second sub-equation of Eq. 25 should be dot product; the moment symbols in Eq. 25 should be in bold.

Equation 25:

$$\begin{cases} \mathbf{M}^{V_i} = \mathbf{M}^G + \vec{V_i G} \times \mathbf{F}^a \\ \mathbf{E}^{V_i} \cdot \dot{\boldsymbol{\omega}} = \mathbf{M}^{V_i} \end{cases} \tag{25}$$

8. The second cross product in Eq. 26 should be dot product.

Equation 26:

$$\dot{\boldsymbol{\omega}} \times \vec{V_i V_j} \cdot \mathbf{n}_q \geq 0, \quad \text{for } (j \neq i) \tag{26}$$

9. The second cross products in both sub-equations of Eq. 27 should be dot products.

Equation 27:

$$\begin{cases} \dot{\boldsymbol{\omega}} \times \vec{V_i V_k} \cdot \mathbf{n}_q \geq 0 \\ \dot{\boldsymbol{\omega}} \times \vec{V_j V_k} \cdot \mathbf{n}_q \geq 0 \quad \text{for } (k \neq i, j) \end{cases} \tag{27}$$

10. The two cross products in the second sub-equation of Eq. 31 should be dot products.

Equation 31:

$$\begin{cases} \mathbf{s} = \mathbf{r}^a = \dfrac{\mathbf{F}^a}{|\mathbf{F}^a|} = (-0.0095, 0.9682, -0.2499) \\ \mathbf{s} \cdot \mathbf{v}_1 = \mathbf{s} \cdot \mathbf{n}_1 = -0.9024 < 0 \end{cases} \tag{31}$$

2. Correction to the main text

1. The moment symbols in the paragraph under Eq. 11 in Sect. 3.2.2 should be in bold. The correct expression is shown.

   "…where $\mathbf{M}^e$ is the resultant moment induced by all the external forces, $\mathbf{M}^a$ is the resultant moment induced by active forces, $\mathbf{M}^G$is gravity-induced moment, $\mathbf{M}^n$ and $\mathbf{M}^t$ are moments induced by the normal cutterhead-block interaction force and by the tangential cutterhead-block interaction force, respectively."
2. The moment symbol in the paragraph under Eq. 25 in Sect. 3.4.2 should be in bold. The correct expression is shown.

   "…in which $\mathbf{E}^{V_i}$ is the inertia operator relative to the vertex V_i and $\mathbf{M}^{V_i}$ is the resultant moment at vertex V_i…"
3. The second cross product in the equation of the second-to-the-last paragraph of Sect. 4.2.4 should be dot product. The correct expression is shown.

   "… Due to the $o'y'$ component of the active force induced by the cutterhead–block interaction, the solutions of Eq. (18) satisfy $\mathbf{a} + \dot{\boldsymbol{\omega}} \times \vec{GV}_i \cdot \mathbf{n}_f < 0$ for all vertexes of Block 3. …"

Table 3 Kinematic analysis results for single-plane sliding scenario

Plane no.	Sliding direction **s**	$\mathbf{v}_i \cdot \mathbf{r}^a$	$\mathbf{v}_j \cdot \mathbf{s}\ (j \neq i)$
1	(− 0.022, 0.6426, 0.7659)	−0.9024	$\begin{cases}\mathbf{v}_2 \cdot \mathbf{s} = 0.2105\\ \mathbf{v}_3 \cdot \mathbf{s} = 0.1747\\ \mathbf{v}_4 \cdot \mathbf{s} = -0.9395\end{cases}$
2	(− 0.3698, 0.9276, − 0.0524)	−0.404	$\begin{cases}\mathbf{v}_1 \cdot \mathbf{s} = -0.7443\\ \mathbf{v}_3 \cdot \mathbf{s} = -0.6019\\ \mathbf{v}_4 \cdot \mathbf{s} = -0.7772\end{cases}$
3	(0.3656, 0.9297, − 0.0443)	−0.4195	$\begin{cases}\mathbf{v}_1 \cdot \mathbf{s} = -0.7407\\ \mathbf{v}_2 \cdot \mathbf{s} = -0.5951\\ \mathbf{v}_4 \cdot \mathbf{s} = -0.783\end{cases}$
4	(− 0.0135, 0.5, 0.8659)	−0.7135	$\begin{cases}\mathbf{v}_1 \cdot \mathbf{s} = -0.9396\\ \mathbf{v}_2 \cdot \mathbf{s} = -0.57\\ \mathbf{v}_3 \cdot \mathbf{s} = -0.5921\end{cases}$

Table 4 Kinematic analysis results for double-plane sliding scenario

Plane no.	Sliding direction **s**	$\mathbf{v}_i \cdot \mathbf{s}_j$ and $\mathbf{v}_j \cdot \mathbf{s}_i$	$\mathbf{v}_k \cdot \mathbf{s}\ (k \neq i, j)$
1 and 2	$(0.2303, 0.6255, 0.7454)$	$\begin{cases}\mathbf{v}_1 \cdot \mathbf{s}_2 = -0.7443\\ \mathbf{v}_2 \cdot \mathbf{s}_1 = 0.2105\end{cases}$	$\begin{cases}\mathbf{v}_3 \cdot \mathbf{s} = 0.3749\\ \mathbf{v}_4 \cdot \mathbf{s} = -0.9144\end{cases}$
1 and 3	$(-0.2303, 0.6255, 0.7454)$	$\begin{cases}\mathbf{v}_1 \cdot \mathbf{s}_3 = -0.7407\\ \mathbf{v}_3 \cdot \mathbf{s}_1 = 0.1747\end{cases}$	$\begin{cases}\mathbf{v}_2 \cdot \mathbf{s} = 0.3749\\ \mathbf{v}_4 \cdot \mathbf{s} = -0.9114\end{cases}$
1 and 4	$(-1, 0, 0)$	$\begin{cases}\mathbf{v}_1 \cdot \mathbf{s}_4 = -0.9396\\ \mathbf{v}_4 \cdot \mathbf{s}_1 = -0.9395\end{cases}$	$\begin{cases}\mathbf{v}_2 \cdot \mathbf{s} = 0.8138\\ \mathbf{v}_3 \cdot \mathbf{s} = -0.8138\end{cases}$
2 and 3	$(0, 0.8604, 0.5097)$	$\begin{cases}\mathbf{v}_2 \cdot \mathbf{s}_3 = -0.5951\\ \mathbf{v}_3 \cdot \mathbf{s}_2 = -0.6019\end{cases}$	$\begin{cases}\mathbf{v}_1 \cdot \mathbf{s} = -0.3315\\ \mathbf{v}_4 \cdot \mathbf{s} = -0.9999\end{cases}$
2 and 4	$(-0.5811, 0.4069, -0.7048)$	$\begin{cases}\mathbf{v}_2 \cdot \mathbf{s}_4 = -0.57\\ \mathbf{v}_4 \cdot \mathbf{s}_2 = -0.7772\end{cases}$	$\begin{cases}\mathbf{v}_1 \cdot \mathbf{s} = -0.7647\\ \mathbf{v}_3 \cdot \mathbf{s} = -0.9458\end{cases}$
3 and 4	$(0.5811, 0.4069, -0.7048)$	$\begin{cases}\mathbf{v}_3 \cdot \mathbf{s}_4 = -5921\\ \mathbf{v}_3 \cdot \mathbf{s}_2 = -0.783\end{cases}$	$\begin{cases}\mathbf{v}_1 \cdot \mathbf{s} = -0.7647\\ \mathbf{v}_2 \cdot \mathbf{s} = -0.9458\end{cases}$

3. Correction to tables

1. All the cross products in Tables 3 and 4 should be dot products. The correct tables are given below.