

I. Couple dans une liaison

$$\overrightarrow{\mathcal{M}_{O_i(j \rightarrow i)}} = \overrightarrow{O_i A_i} \wedge \overrightarrow{F_{(j \rightarrow i)}} \quad (1)$$

$$= (a_i \vec{x}_i + b_i \vec{y}_i) \wedge (\mathbf{K}_L \overrightarrow{A_i A_j}) \quad (2)$$

$$= (a_i \vec{x}_i + b_i \vec{y}_i) \wedge (\mathbf{K}_L (\overrightarrow{A_i O_i} + \overrightarrow{O_i O_j} + \overrightarrow{O_j A_j})) \quad (3)$$

$$= \mathbf{K}_L (a_i \vec{x}_i + b_i \vec{y}_i) \wedge (-\vec{X}_i \vec{x}_0 - \vec{Y}_i \vec{y}_0 + \vec{X}_j \vec{x}_0 + \vec{Y}_j \vec{y}_0 + a_j \vec{x}_j + b_j \vec{y}_j) \quad (4)$$

$$= \mathbf{K}_L [-a_i (\vec{X}_j - \vec{X}_i) \sin(\Theta_i) - b_i (\vec{X}_j - \vec{X}_i) \cos(\Theta_i) + a_i (\vec{Y}_j - \vec{Y}_i) \cos(\Theta_i) - b_i (\vec{Y}_j - \vec{Y}_i) \sin(\Theta_i) \quad (5)$$

$$+ a_i a_j \sin(\Theta_j - \Theta_i) - b_i a_j \cos(\Theta_j - \Theta_i) + a_i b_j \cos(\Theta_j - \Theta_i) + b_i b_j \sin(\Theta_j - \Theta_i)] \vec{z}_0 \quad (6)$$

• Linéarisation de la trigo

$$\sin(\Theta_i) \approx \sin(\Theta_i^p) + (\Theta_i - \Theta_i^p) \cos(\Theta_i^p) \quad (7)$$

$$\cos(\Theta_i) \approx \cos(\Theta_i^p) - (\Theta_i - \Theta_i^p) \sin(\Theta_i^p) \quad (8)$$

$$\sin(\Theta_j) \approx \sin(\Theta_j^p) + (\Theta_j - \Theta_j^p) \cos(\Theta_j^p) \quad (9)$$

$$\cos(\Theta_j) \approx \cos(\Theta_j^p) - (\Theta_j - \Theta_j^p) \sin(\Theta_j^p) \quad (10)$$

$$\sin(\Theta_j - \Theta_i) \approx \sin(\Theta_j^p - \Theta_i^p) + (\Theta_j - \Theta_i - \Theta_j^p + \Theta_i^p) \cos(\Theta_j^p - \Theta_i^p) \quad (11)$$

$$\cos(\Theta_j - \Theta_i) \approx \cos(\Theta_j^p - \Theta_i^p) - (\Theta_j - \Theta_i - \Theta_j^p + \Theta_i^p) \sin(\Theta_j^p - \Theta_i^p) \quad (12)$$

$$(13)$$

$$\overrightarrow{\mathcal{M}_{O_i(j \rightarrow i)}} = \mathbf{K}_L [-a_i (\vec{X}_j - \vec{X}_i) (\sin(\Theta_i^p) + (\Theta_i - \Theta_i^p) \cos(\Theta_i^p)) \quad (14)$$

$$- b_i (\vec{X}_j - \vec{X}_i) (\cos(\Theta_i^p) - (\Theta_i - \Theta_i^p) \sin(\Theta_i^p)) \quad (15)$$

$$+ a_i (\vec{Y}_j - \vec{Y}_i) (\cos(\Theta_i^p) - (\Theta_i - \Theta_i^p) \sin(\Theta_i^p)) \quad (16)$$

$$- b_i (\vec{Y}_j - \vec{Y}_i) (\sin(\Theta_i^p) + (\Theta_i - \Theta_i^p) \cos(\Theta_i^p)) \quad (17)$$

$$+ a_i a_j (\sin(\Theta_j^p - \Theta_i^p) + (\Theta_j - \Theta_i - \Theta_j^p + \Theta_i^p) \cos(\Theta_j^p - \Theta_i^p)) \quad (18)$$

$$- b_i a_j (\cos(\Theta_j^p - \Theta_i^p) - (\Theta_j - \Theta_i - \Theta_j^p + \Theta_i^p) \sin(\Theta_j^p - \Theta_i^p)) \quad (19)$$

$$+ a_i b_j (\cos(\Theta_j^p - \Theta_i^p) - (\Theta_j - \Theta_i - \Theta_j^p + \Theta_i^p) \sin(\Theta_j^p - \Theta_i^p)) \quad (20)$$

$$+ b_i b_j (\sin(\Theta_j^p - \Theta_i^p) + (\Theta_j - \Theta_i - \Theta_j^p + \Theta_i^p) \cos(\Theta_j^p - \Theta_i^p))] \vec{z}_0 \quad (21)$$

• Posons :

$$s_i = \sin(\Theta_i^p) \quad (22)$$

$$c_i = \cos(\Theta_i^p) \quad (23)$$

$$s_{ji} = \sin(\Theta_j^p - \Theta_i^p) \quad (24)$$

$$c_{ji} = \cos(\Theta_j^p - \Theta_i^p) \quad (25)$$

$$\overrightarrow{\mathcal{M}_{O_i(j \rightarrow i)}} = \mathbf{K}_L [-a_i(\mathbf{X}_j - \mathbf{X}_i)(s_i + (\Theta_i - \Theta_i^p)c_i) \quad (26)$$

$$- b_i(\mathbf{X}_j - \mathbf{X}_i)(c_i - (\Theta_i - \Theta_i^p)s_i) \quad (27)$$

$$+ a_i(\mathbf{Y}_j - \mathbf{Y}_i)(c_i - (\Theta_i - \Theta_i^p)s_i) \quad (28)$$

$$- b_i(\mathbf{Y}_j - \mathbf{Y}_i)(s_i + (\Theta_i - \Theta_i^p)c_i) \quad (29)$$

$$+ a_i a_j (s_{ji} + (\Theta_j - \Theta_i - \Theta_j^p + \Theta_i^p)c_{ji}) \quad (30)$$

$$- b_i a_j (c_{ji} - (\Theta_j - \Theta_i - \Theta_j^p + \Theta_i^p)s_{ji}) \quad (31)$$

$$+ a_i b_j (c_{ji} - (\Theta_j - \Theta_i - \Theta_j^p + \Theta_i^p)s_{ji}) \quad (32)$$

$$+ b_i b_j (s_{ji} + (\Theta_j - \Theta_i - \Theta_j^p + \Theta_i^p)c_{ji})] \vec{z}_0 \quad (33)$$

$$\overrightarrow{\mathcal{M}_{O_i(j \rightarrow i)}} = \mathbf{K}_L [-a_i(s_i - c_i \Theta_i^p) \mathbf{X}_j - a_i c_i \mathbf{X}_j \Theta_i + a_i(s_i - c_i \Theta_i^p) \mathbf{X}_i + a_i c_i \Theta_i^p \quad (34)$$

$$- b_i(c_i + s_i \Theta_i^p) \mathbf{X}_j + b_i s_i \mathbf{X}_j \Theta_i + b_i(c_i + s_i \Theta_i^p) \mathbf{X}_i - b_i s_i \mathbf{X}_i \Theta_i \quad (35)$$

$$+ a_i(c_i + s_i \Theta_i^p) \mathbf{Y}_j - a_i s_i \mathbf{Y}_j \Theta_i - a_i(c_i + s_i \Theta_i^p) \mathbf{Y}_i + a_i s_i \mathbf{Y}_i \Theta_i \quad (36)$$

$$- b_i(s_i - c_i \Theta_i^p) \mathbf{Y}_j - b_i c_i \mathbf{Y}_j \Theta_i + b_i(s_i - c_i \Theta_i^p) \mathbf{Y}_i + b_i c_i \mathbf{Y}_i \Theta_i \quad (37)$$

$$+ a_i a_j c_{ji} \Theta_j - a_i a_j c_{ji} \Theta_i - a_i a_j (s_{ji} - (\Theta_j^p - \Theta_i^p)c_{ji}) \quad (38)$$

$$+ b_i a_j s_{ji} \Theta_j - b_i a_j s_{ji} \Theta_i - b_i a_j (c_{ji} + (\Theta_j^p - \Theta_i^p)s_{ji}) \quad (39)$$

$$- a_i b_j s_{ji} \Theta_j + a_i b_j s_{ji} \Theta_i - a_i b_j (c_{ji} + (\Theta_j^p - \Theta_i^p)s_{ji}) \quad (40)$$

$$+ b_i b_j c_{ji} \Theta_j - b_i b_j c_{ji} \Theta_i + b_i b_j (s_{ji} - (\Theta_j^p - \Theta_i^p)c_{ji})] \vec{z}_0 \quad (41)$$

On remarque que :

$$\mathbf{X}_j \Theta_i \approx \mathbf{X}_j^p \Theta_i + \mathbf{X}_j \Theta_i^p - \mathbf{X}_j^p \Theta_i^p \quad (42)$$

$$\mathbf{X}_i \Theta_i \approx \mathbf{X}_i^p \Theta_i + \mathbf{X}_i \Theta_i^p - \mathbf{X}_i^p \Theta_i^p \quad (43)$$

$$\mathbf{Y}_j \Theta_i \approx \mathbf{Y}_j^p \Theta_i + \mathbf{Y}_j \Theta_i^p - \mathbf{Y}_j^p \Theta_i^p \quad (44)$$

$$\mathbf{Y}_i \Theta_i \approx \mathbf{Y}_i^p \Theta_i + \mathbf{Y}_i \Theta_i^p - \mathbf{Y}_i^p \Theta_i^p \quad (45)$$

$$\overrightarrow{\mathcal{M}_{O_i(j \rightarrow i)}} = \mathbf{K}_L [-a_i(s_i - c_i \Theta_i^p) \mathbf{X}_j - a_i c_i \mathbf{X}_j^p \Theta_i - a_i \mathbf{X}_j \Theta_i^p + a_i \mathbf{X}_j^p \Theta_i^p + a_i(s_i - c_i \Theta_i^p) \mathbf{X}_i + a_i c_i \Theta_i^p \quad (46)$$

$$- b_i(c_i + s_i \Theta_i^p) \mathbf{X}_j + b_i s_i \mathbf{X}_j^p \Theta_i + b_i \mathbf{X}_j \Theta_i^p - b_i \mathbf{X}_j^p \Theta_i^p + b_i(c_i + s_i \Theta_i^p) \mathbf{X}_i - b_i s_i \mathbf{X}_i^p \Theta_i - b_i \mathbf{X}_i \Theta_i^p + b_i \mathbf{X}_i^p \Theta_i^p \quad (47)$$

$$+ a_i(c_i + s_i \Theta_i^p) \mathbf{Y}_j - a_i s_i \mathbf{X}_i^p \Theta_i - a_i \mathbf{X}_i \Theta_i^p + a_i \mathbf{X}_i^p \Theta_i^p - a_i(c_i + s_i \Theta_i^p) \mathbf{Y}_i + a_i s_i \mathbf{Y}_i^p \Theta_i + a_i \mathbf{Y}_i \Theta_i^p - a_i \mathbf{Y}_i^p \Theta_i^p \quad (48)$$

$$- b_i(s_i - c_i \Theta_i^p) \mathbf{Y}_j - b_i c_i \mathbf{X}_i^p \Theta_i - b_i \mathbf{X}_i \Theta_i^p + b_i \mathbf{X}_i^p \Theta_i^p + b_i(s_i - c_i \Theta_i^p) \mathbf{Y}_i + b_i c_i \mathbf{Y}_i^p \Theta_i + b_i \mathbf{Y}_i \Theta_i^p - b_i \mathbf{Y}_i^p \Theta_i^p \quad (49)$$

$$+ a_i a_j c_{ji} \Theta_j - a_i a_j c_{ji} \Theta_i - a_i a_j (s_{ji} - (\Theta_j^p - \Theta_i^p)c_{ji}) \quad (50)$$

$$+ b_i a_j s_{ji} \Theta_j - b_i a_j s_{ji} \Theta_i - b_i a_j (c_{ji} + (\Theta_j^p - \Theta_i^p)s_{ji}) \quad (51)$$

$$- a_i b_j s_{ji} \Theta_j + a_i b_j s_{ji} \Theta_i - a_i b_j (c_{ji} + (\Theta_j^p - \Theta_i^p)s_{ji}) \quad (52)$$

$$+ b_i b_j c_{ji} \Theta_j - b_i b_j c_{ji} \Theta_i + b_i b_j (s_{ji} - (\Theta_j^p - \Theta_i^p)c_{ji})] \quad (53)$$

Posons :

$$s_{ici} = s_i - c_i \Theta_i^p \quad (54)$$

$$c_{isi} = c_i + s_i \Theta_i^p \quad (55)$$

$$(56)$$

$$\overrightarrow{\mathcal{M}_{O_i(j \rightarrow i)}} = \mathbf{K}_L [(a_i s_{ici} + b_i c_{isi} - b_i \Theta_i^p - a_i \Theta_i^p - b_i \Theta_i^p) \mathbf{X}_i \quad (57)$$

$$+ (-a_i c_{isi} + a_i \Theta_i^p + b_i s_{ici} + b_i \Theta_i^p) \mathbf{Y}_i \quad (58)$$

$$+ (-a_i c_i X_j^p + b_i s_i X_j^p - b_i s_i X_i^p - a_i s_i X_i^p + a_i s_i Y_i^p - b_i c_i X_i^p \quad (59)$$

$$+ b_i c_i Y_i^p - a_i a_j c_{ji} - b_i a_j s_{ji} + a_i b_j s_{ji} - b_i b_j c_{ji}) \Theta_i \quad (60)$$

$$+ (-a_i s_{ici} - a_i \Theta_i^p - b_i c_{isi} + b_i \Theta_i^p) \mathbf{X}_j \quad (61)$$

$$+ (+a_i c_{isi} - b_i s_{ici}) \mathbf{Y}_j \quad (62)$$

$$+ (a_i a_j c_{ji} + b_i a_j s_{ji} - a_i b_j s_{ji} + b_i b_j c_{ji}) \Theta_j \quad (63)$$

$$+ a_i X_j^p \Theta_i^p + a_i c_i \Theta_i^p \quad (64)$$

$$- b_i X_j^p \Theta_i^p + b_i X_i^p \Theta_i^p + a_i X_i^p \Theta_i^p - a_i Y_i^p Y_i^p + b_i X_i^p \Theta_i^p - b_i Y_i^p Y_i^p \quad (65)$$

$$- a_i a_j (s_{ji} - (\Theta_j^p - \Theta_i^p) c_{ji}) - b_i a_j (c_{ji} + (\Theta_j^p - \Theta_i^p) s_{ji}) \quad (66)$$

$$- a_i b_j (c_{ji} + (\Theta_j^p - \Theta_i^p) s_{ji}) + b_i b_j (s_{ji} - (\Theta_j^p - \Theta_i^p) c_{ji}) \quad (67)$$

II. Couple de la souris
