6 Non overconstrained *T3*-type TPMs with uncoupled motions

Equation (1.15) indicates that *non overconstrained* solutions of *T3*-type TPMs with *uncoupled motions* and q independent loops meet the condition $\sum_{1}^{p} f_i = 3 + 6q$ along with $S_F = 3$, $(R_F) = (\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$ and $N_F = 0$. They could have identical limbs or limbs with different structures and could be actuated by linear or rotating motors. Each operational velocity given by Eq. (1.19) depends on just one actuated joint velocity: $v_i = v_i(\dot{q}_i)$, $i = 1,2,3$. The Jacobian matrix in Eq. (1.19) is a diagonal matrix.

They can be actuated by linear or rotating actuators which can be mounted on the fixed base or on a moving link. In the solutions presented in this section, the actuators are associated with a revolute joint mounted on the fixed base.

6.1 Basic solutions with rotating actuators

In the *basic* non overconstrained TPMs with *rotating actuators* and uncoupled motions $F \leftarrow G_1–G_2–G_3$, the moving platform $n \equiv n_{Gi}$ ($i = 1, 2, 3$) is connected to the reference platform $1 \equiv 1_{Gi} \equiv 0$ by three limbs with five degrees of connectivity. No idle mobilities exist in these basic solutions.

The various types of limbs with five degrees of connectivity and no idle mobilities are systematized in Fig. 6.1. They are simple kinematic chains actuated by rotating motors mounted on the fixed base.

Various solutions of TPMs with uncoupled motions and no idle mobilities can be obtained by using three limbs with identical or different topologies presented in Fig. 6.1. We only show solutions with identical limb type as illustrated in Figs. 6.2–6.4. The actuated revolute joints adjacent to the fixed base in the three limbs have orthogonal directions (Figs. 6.2–6.4). The structural parameters of these solutions are presented in Table 6.1.

G. Gogu, *Structural Synthesis of Parallel Robots: Part 2: Translational Topologies with Two and Three Degrees of Freedom,* Solid Mechanics and Its Applications 159, 615–685.

Table 6.1. Structural parameters[a] of translational parallel mechanisms in Figs. 6.2–6.4

No.	Structural parameter	Solution 3-<u>R</u>RRRP, 3-<u>R</u>RPRR (Fig. 6.2a, b)	3-<u>R</u>CRR (Fig. 6.3a)	3-<u>R</u>RPRR (Fig. 6.3b) 3-<u>R</u>RRPR, 3-<u>R</u>RRRR (Fig. 6.4a, b)
1	m	14	11	14
2	p_1	5	4	5
3	p_2	5	4	5
4	p_3	5	4	5
5	p	15	12	15
6	q	2	2	2
7	k_1	3	3	3
8	k_2	0	0	0
9	k	3	3	3
10	(R_{G1})	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3,\boldsymbol{\omega}_\alpha,\boldsymbol{\omega}_\beta)$	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3,\boldsymbol{\omega}_\alpha,\boldsymbol{\omega}_\beta)$	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3,\boldsymbol{\omega}_\alpha,\boldsymbol{\omega}_\delta)$
11	(R_{G2})	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3,\boldsymbol{\omega}_\beta,\boldsymbol{\omega}_\delta)$	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3,\boldsymbol{\omega}_\beta,\boldsymbol{\omega}_\delta)$	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3,\boldsymbol{\omega}_\alpha,\boldsymbol{\omega}_\beta)$
12	(R_{G3})	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3,\boldsymbol{\omega}_\alpha,\boldsymbol{\omega}_\delta)$	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3,\boldsymbol{\omega}_\alpha,\boldsymbol{\omega}_\delta)$	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3,\boldsymbol{\omega}_\beta,\boldsymbol{\omega}_\delta)$
13	S_{G1}	5	5	5
14	S_{G2}	5	5	5
15	S_{G3}	5	5	5
16	r_{G1}	0	0	0
17	r_{G2}	0	0	0
18	r_{G3}	0	0	0
19	M_{G1}	5	5	5
20	M_{G2}	5	5	5
21	M_{G3}	5	5	5
22	(R_F)	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3)$	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3)$	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3)$
23	S_F	3	3	3
24	r_l	0	0	0
25	r_F	12	12	12
26	M_F	3	3	3
27	N_F	0	0	0
28	T_F	0	0	0
29	$\sum_{j=1}^{p_1} f_j$	5	5	5
30	$\sum_{j=1}^{p_2} f_j$	5	5	5
31	$\sum_{j=1}^{p_3} f_j$	5	5	5
32	$\sum_{j=1}^{p} f_j$	15	15	15

[a]See footnote of Table 2.1 for the nomenclature of structural parameters

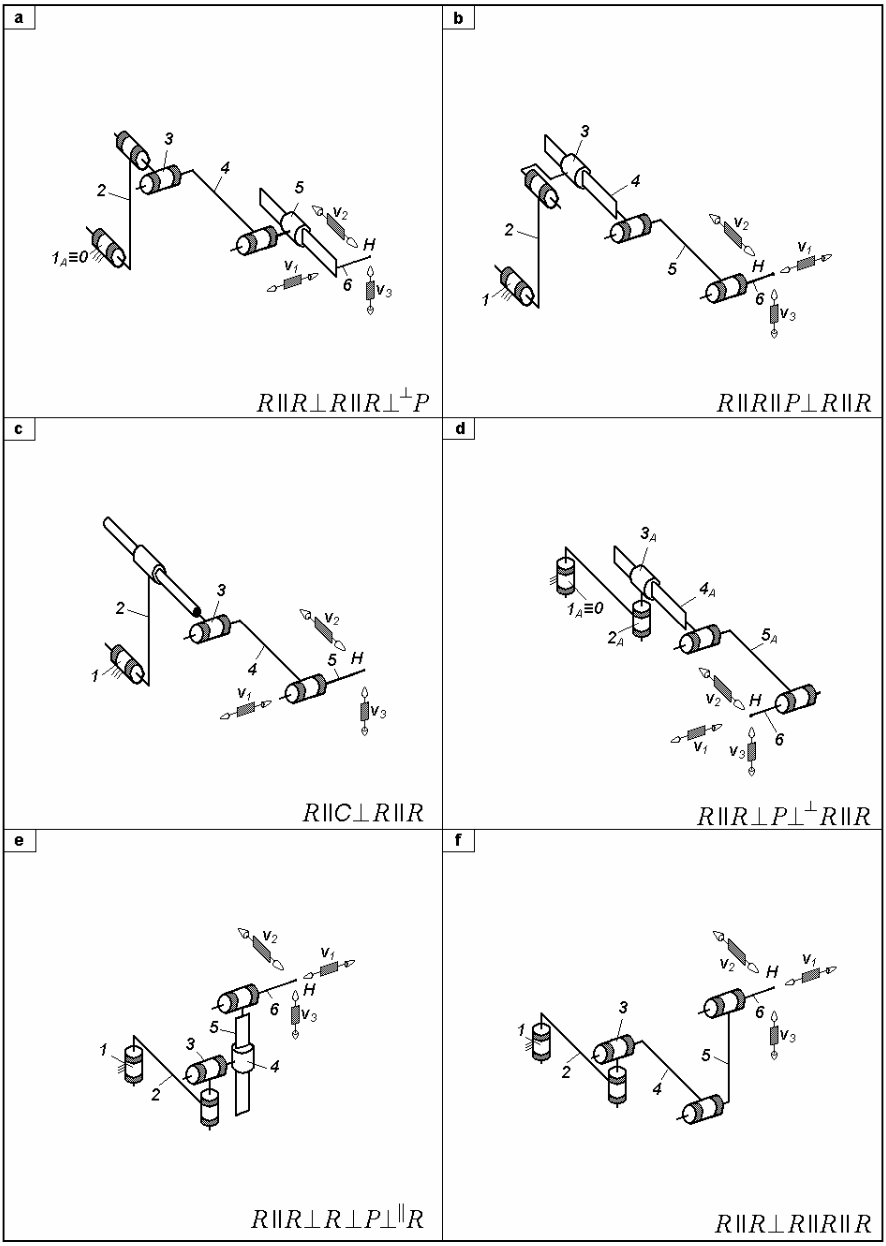


Fig. 6.1. Simple limbs for non overconstrained TPMs with uncoupled motions defined by $M_G = S_G = 5$, $(R_G) = (\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3, \boldsymbol{\omega}_1, \boldsymbol{\omega}_2)$ and actuated by rotating motors mounted on the fixed base

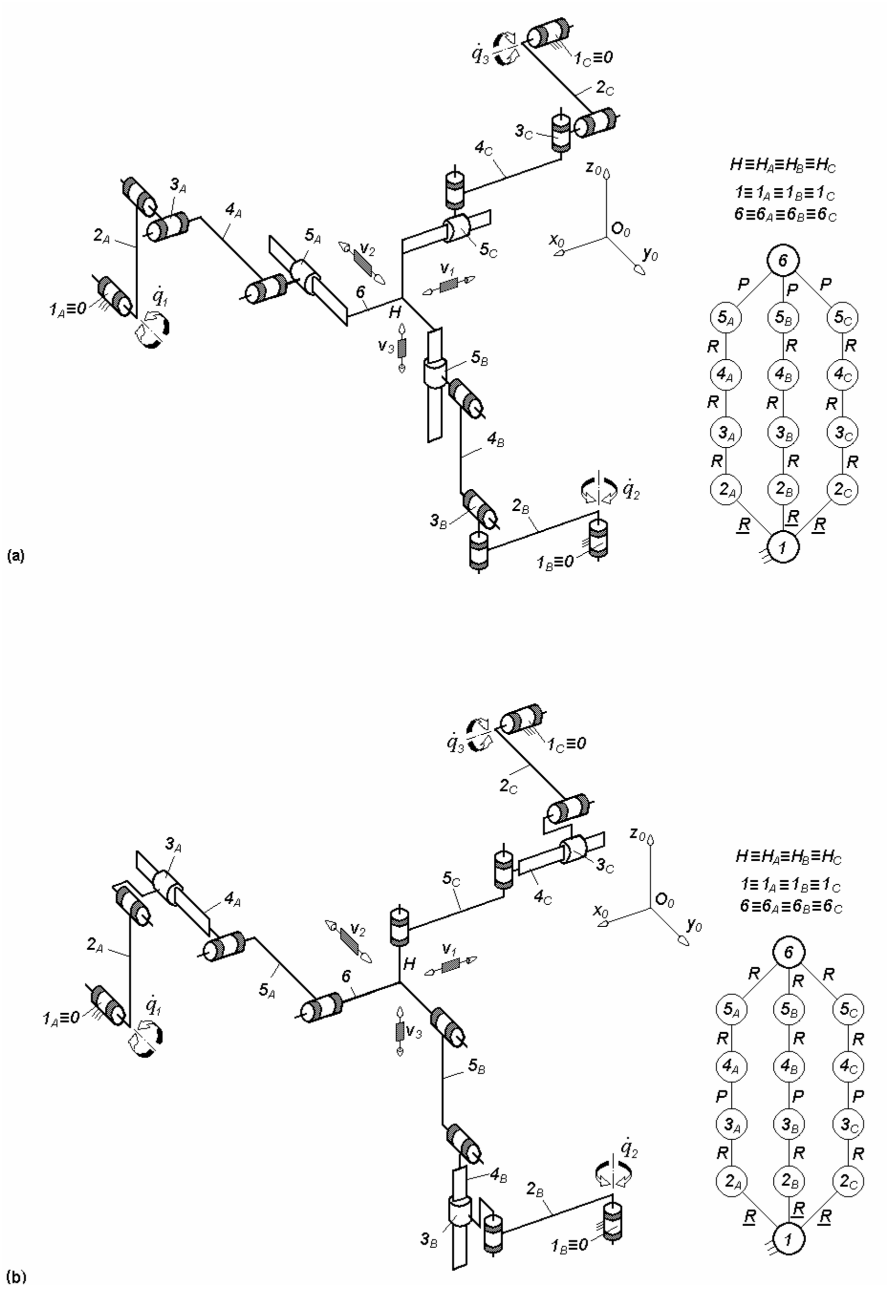


Fig. 6.2. Non overconstrained TPMs with uncoupled motions of types *3-*$\underline{R}RRRP$ (**a**) and *3-*$\underline{R}RPRR$ (**b**), limb topology $\underline{R}||R\perp R||R\perp{}^{||}P$ (**a**) and $\underline{R}||R||P\perp R||R$ (**b**)

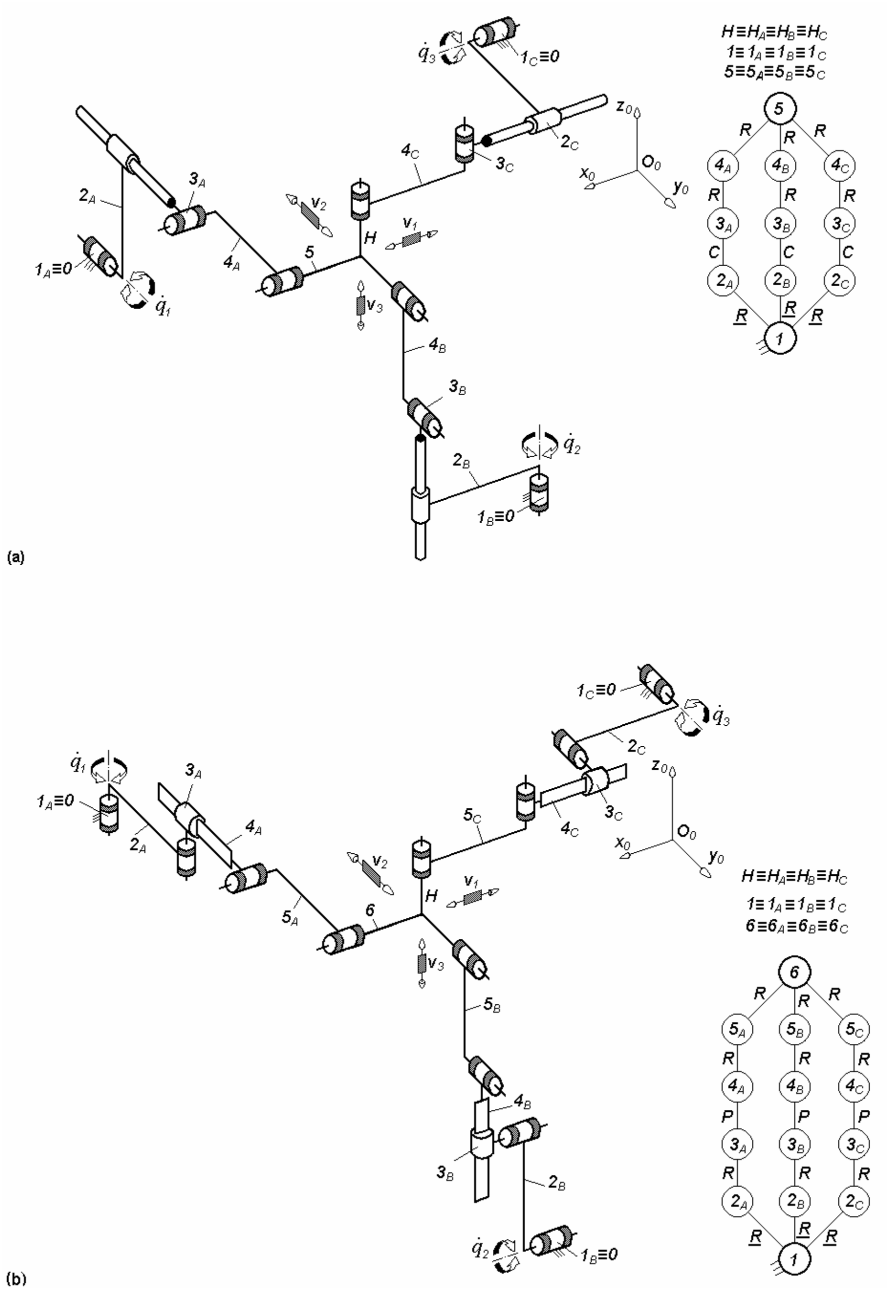


Fig. 6.3. Non overconstrained TPMs with uncoupled motions of types *3-$\underline{R}$CRR* (**a**) and *3-$\underline{R}$RPRR* (**b**), limb topology $\underline{R}||C \perp R||R$ (**a**) and $\underline{R}||R \perp P \perp^{\perp} R||R$ (**b**)

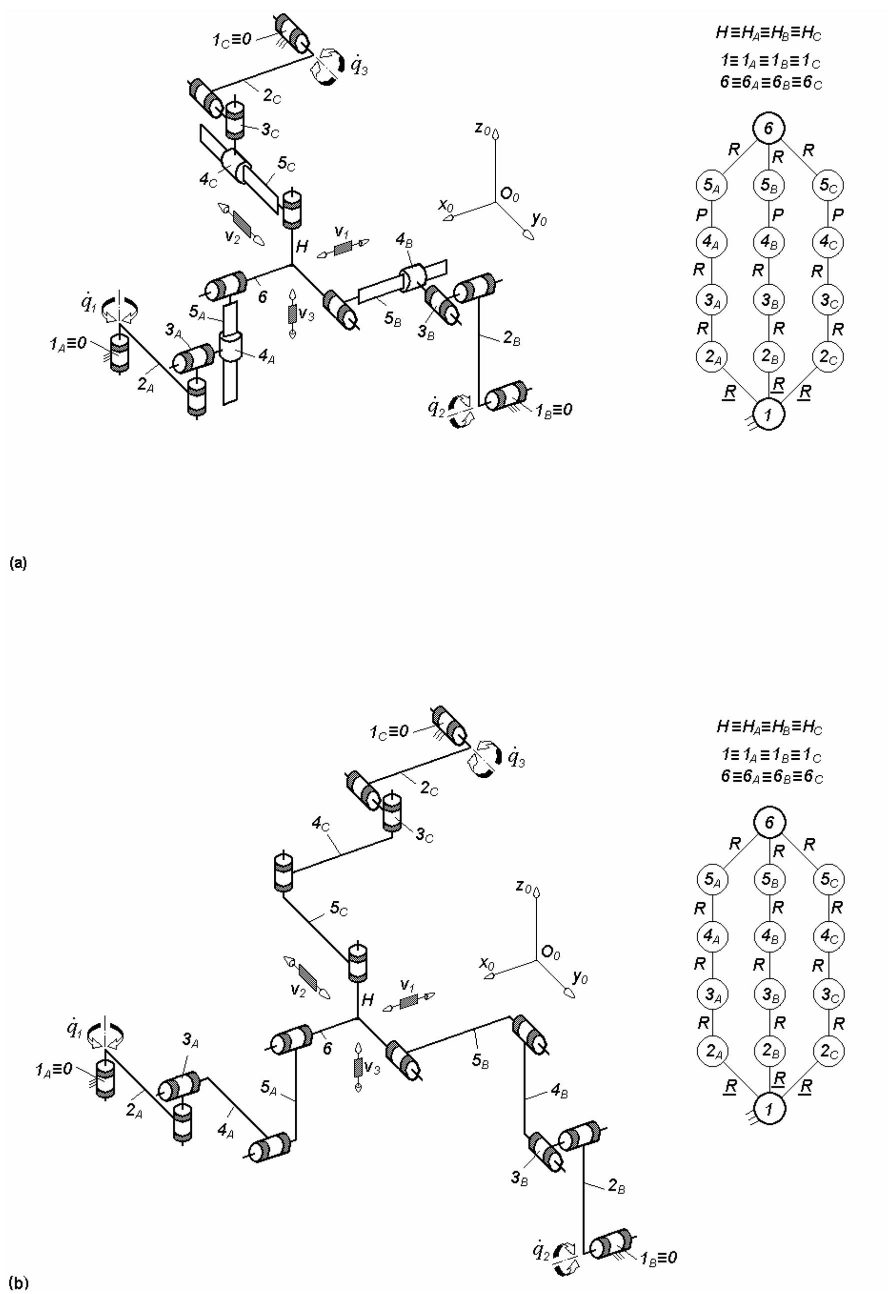


Fig. 6.4. Non overconstrained TPMs with uncoupled motions of types *3-$\underline{R}$RRPR* (**a**) and *3-$\underline{R}$RRRR* (**b**), limb topology $\underline{R}||R \perp R \perp P \perp^{||}R$ (**a**) and $\underline{R}||R \perp R||R||R$ (**b**)

6.2 Derived solutions with rotating actuators

Non overconstrained solutions $F \leftarrow G_1–G_2–G_2$ with rotating actuators and uncoupled motions can be derived from the overconstrained solutions presented in Figs. 5.6–5.48 by introducing the required *idle mobilities* to obtain $S_F = 3$, $(R_F) = (\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$ and $N_F = 0$.

For example, the non overconstrained solution in Fig. 6.5a is derived from the overconstrained solution in Fig. 5.6a by replacing, in each limb, two revolute joints by spherical joints in the parallelogram loop and a prismatic joint by a cylindrical joint. We note that the two spherical joints adjacent to link 4 make the parallelogram loop non overconstrained and provide an idle rotational mobility of link 4. An idle mobility of rotation is combined in each cylindrical joint denoted by C*.

The limb topology and connecting conditions of the solutions Figs. 6.5–6.54 are systematized in Table 6.2 and the structural parameters of these solutions are presented in Tables 6.3–6.13.

Table 6.2. Limb topology of the derived non overconstrained TPMs with idle mobilities and linear actuators mounted on the fixed base presented in Figs. 6.5–6.54

No.	Basic TPM type	N_F	Derived TPM with $N_F = 0$ type	Limb topology
1	$3\text{-}\underline{Pa}PP$ (Fig. 5.6)	15	$3\text{-}\underline{Pa}^{ss}PC^*$ (Fig. 6.5a)	$\underline{Pa}^{ss}\|P\perp C^*$
2			$3\text{-}\underline{Pa}^{cs}C^*C^*$ (Fig. 6.5b)	$\underline{Pa}^{cs}\|C^*\perp^{\perp} C^*$
3	$3\text{-}\underline{Pa}PP$ (Fig. 5.7)	15	$\underline{Pa}^{ss}PC^*$ (Fig. 6.6a)	$\underline{Pa}^{ss}\perp P\perp^{\|}C^*$
4			$3\text{-}\underline{Pa}^{cs}C^*C^*$ (Fig. 6.6b)	$\underline{Pa}^{cs}\perp C^*\perp^{\|}C^*$
5	$3\text{-}\underline{Pa}PaP$ (Fig. 5.8a)	24	$3\text{-}\underline{Pa}^{ss}Pa^{ss}P$ (Fig. 6.7a)	$\underline{Pa}^{ss}\perp Pa^{ss}\perp^{\|}P$
6			$3\text{-}\underline{Pa}^{cs}Pa^{cs}PR^*R^*$ (Fig. 6.7b)	$\underline{Pa}^{cs}\perp Pa^{cs}\perp^{\|}P\perp^{\perp} R\perp^{\|}R$
7	$3\text{-}\underline{Pa}PaP$ (Fig. 5.9)	24	$3\text{-}\underline{Pa}^{ss}Pa^{ss}P$ (Fig. 6.8a)	$\underline{Pa}^{ss}\perp Pa^{ss}\perp^{\perp} P$
8			$3\text{-}\underline{Pa}^{cs}Pa^{cs}PR^*R^*$ (Fig. 6.8b)	$\underline{Pa}^{cs}\perp Pa^{cs}\perp^{\perp} P\perp^{\perp} R^*\perp^{\|}R^*$
9	$3\text{-}\underline{Pa}PPa$ (Fig. 5.10)	24	$3\text{-}\underline{Pa}^{ss}PPa^{ss}$ (Fig. 6.9a)	$\underline{Pa}^{ss}\|P\perp^{\perp} Pa^{ss}$
10			$3\text{-}\underline{Pa}^{cs}PPa^{cs}R^*R^*$ (Fig. 6.9b)	$\underline{Pa}^{cs}\|P\perp Pa^{cs}\perp^{\|}R^*\perp^{\perp} R^*$
11	$3\text{-}\underline{Pa}PPa$ (Fig. 5.11)	24	$3\text{-}\underline{Pa}^{ss}PPa^{ss}$ (Fig. 6.10a)	$\underline{Pa}^{ss}\perp P\perp^{\perp} Pa^{ss}$
12			$3\text{-}\underline{Pa}^{cs}PPa^{cs}R^*R^*$ (Fig. 6.10b)	$\underline{Pa}^{cs}\perp P\perp^{\perp} Pa^{cs}\perp^{\|}R^*\perp^{\perp} R^*$
13	$3\text{-}\underline{Pa}PaPa$ (Fig. 5.12)	33	$3\text{-}\underline{Pa}^{ss}Pa^{cs}Pa^{ss}$ (Fig. 6.11)	$\underline{Pa}^{ss}\perp Pa^{cs}\|Pa^{ss}$
14			$3\text{-}\underline{Pa}^{cs}Pa^{cs}Pa^{cs}R^*R^*$ (Fig. 6.12)	$\underline{Pa}^{cs}\perp Pa^{cs}\|Pa^{cs}\perp^{\|}R^*\perp^{\perp} R^*$
15	$3\text{-}\underline{Pa}Pa^{t}P$ (Fig. 5.14)	24	$3\text{-}\underline{Pa}^{cs}Pa^{tcs}C^*$ (Fig. 6.13a)	$\underline{Pa}^{cs}\|Pa^{tss}\|C^*$
16			$3\text{-}\underline{Pa}^{cs}Pa^{tcs}C^*R^*$ (Fig. 6.13b)	$3\ \underline{Pa}^{cs}\|Pa^{tcs}\|C^*\perp R^*$
17	$3\text{-}\underline{Pa}^{cc}P$ (Fig. 5.16)	12	$3\text{-}\underline{Pa}^{scc}C^*R^*$ (Fig. 6.14a)	$\underline{Pa}^{scc}\perp C^*\perp^{\perp} R^*$
18			$3\text{-}\underline{Pa}^{scc}C^*R^*$ (Fig. 6.14b)	$3\text{-}\underline{Pa}^{scc}\perp C^*\perp^{\|}R^*$
19	$3\text{-}\underline{Pa}^{cc}Pa$ (Fig. 5.17)	21	$3\text{-}\underline{Pa}^{scc}Pa^{ss}R^*$ (Fig. 6.15)	$\underline{Pa}^{scc}\perp Pa^{ss}\|R^*$
20			$3\text{-}\underline{Pa}^{scc}Pa^{cs}R^*R^*$ (Fig. 6.16)	$\underline{Pa}^{scc}\perp Pa^{cs}\|R^*\perp^{\perp} R^*$

Table 6.2. (cont.)

21	$3\text{-}\underline{R}RPP$ (Fig. 5.18a)	*3*	$3\text{-}\underline{R}RC^*P$ (Fig. 6.17)	$\underline{R}\parallel R\perp C^*\perp^{\parallel}P$
22	$3\text{-}\underline{R}CP$ (Fig. 5.19a)	*3*	$3\text{-}\underline{R}CC^*$ (Fig. 6.18)	$\underline{R}\parallel C\perp C^*$
23	$3\text{-}\underline{Pa}RRP$ (Fig. 5.20)	*12*	$3\text{-}\underline{Pa}^{cs}RRC^*$ (Fig. 6.19a)	$\underline{Pa}^{cs}\perp R\parallel R\perp^{\parallel}C^*$
24			$3\text{-}\underline{Pa}^{cs}RRC^*$ (Fig. 6.19b)	$\underline{Pa}^{cs}\perp R\parallel R\perp^{\perp}C^*$
25	$3\text{-}\underline{Pa}RRP$ (Fig. 5.21)	*12*	$3\text{-}\underline{Pa}^{ss}RC^*$ (Fig. 6.20a)	$\underline{Pa}^{ss}\perp R\perp^{\parallel}C^*$
26			$3\text{-}\underline{Pa}^{ss}RC^*$ (Fig. 6.20b)	$\underline{Pa}^{ss}\perp R\perp^{\perp}C^*$
27	$3\text{-}\underline{Pa}RPR$ (Fig. 5.22)	*12*	$3\text{-}\underline{Pa}^{cs}RC^*R$ (Fig. 6.21a)	$\underline{Pa}^{cs}\perp R\perp C^*\perp^{\parallel}R$
28			$3\text{-}\underline{Pa}^{cs}RC^*R$ (Fig. 6.21b)	$\underline{Pa}^{ss}\parallel C^*\perp R$
29			$3\text{-}\underline{Pa}^{cs}RPRR^*$ (Fig. 6.22)	$\underline{Pa}^{cs}\perp R\perp P\perp^{\parallel}R\perp R^*$
30	$3\text{-}\underline{Pa}RRR$ (Fig. 5.23)	*12*	$3\text{-}\underline{Pa}^{cs}RRRR^*$ (Fig. 6.23)	$\underline{Pa}^{cs}\perp R\parallel R\parallel R\perp R^*$
31			$3\text{-}\underline{Pa}^{ss}RRR^*$ (Fig. 6.24)	$\underline{Pa}^{ss}\perp R\parallel R\perp R^*$
32	$3\text{-}\underline{Pa}PRR$ (Fig. 5.24)	*12*	$3\text{-}\underline{Pa}^{cs}C^*RR$ (Fig. 6.25a)	$\underline{Pa}^{cs}\parallel C^*\perp R\parallel R$
33			$3\text{-}\underline{Pa}^{cs}PRRR^*$ (Fig. 6.26)	$\underline{Pa}^{cs}\parallel P\perp R\parallel R\perp R^*$
34	$3\text{-}\underline{Pa}PRR$ (Fig. 5.25)	*12*	$3\text{-}\underline{Pa}^{cs}C^*RR$ (Fig. 6.25b)	$\underline{Pa}^{cs}\perp C^*\perp^{\perp}R\parallel R$
35			$3\text{-}\underline{Pa}^{cs}PRRR^*$ (Fig. 6.27)	$\underline{Pa}^{cs}\perp P\perp^{\perp}R\parallel R\perp R^*$
36	$3\text{-}\underline{Pa}PaRR$ (Fig. 5.26)	*21*	$3\text{-}\underline{Pa}^{cs}Pa^{cs}RRR^*$ (Fig. 6.28)	$\underline{Pa}^{cs}\perp Pa^{cs}\parallel R\parallel R\perp^{\parallel}R^*$
37			$3\text{-}\underline{Pa}^{cs}Pa^{cs}RRR^*$ (Fig. 6.29)	$\underline{Pa}^{cs}\perp Pa^{cs}\parallel R\parallel R\perp R^*$
38	$3\text{-}\underline{Pa}RRPa$ (Fig. 5.27)	*21*	$3\text{-}\underline{Pa}^{cs}RRPa^{ss}$ (Fig. 6.30a)	$\underline{Pa}^{cs}\perp R\parallel R\parallel Pa^{ss}$
39			$3\text{-}\underline{Pa}^{ss}RPa^{ss}$ (Fig. 6.30b)	$\underline{Pa}^{ss}\perp R\parallel Pa^{ss}$
40	$3\text{-}\underline{Pa}RRbR$ (Fig. 5.28)	*21*	$3\text{-}\underline{Pa}^{ss}Rb^{cs}RR^*$ (Fig. 6.31)	$\underline{Pa}^{ss}\perp Rb^{cs}\parallel R\perp R^*$
41			$3\text{-}\underline{Pa}^{cs}R^*RRb^{cs}R$ (Fig. 6.32)	$\underline{Pa}^{cs}\parallel R^*\perp R\parallel Rb^{cs}\parallel R$

Table 6.2. (cont.)

42	$3\text{-}\underline{Pa}RRbRbR$ (Fig. 5.29)	*30*	$3\text{-}\underline{Pa}^{ss}Rb^{cs}Rb^{cs}RR^*$ (Fig. 6.33)	$\underline{Pa}^{ss}\perp Rb^{cs}\vert\vert Rb^{cs}\vert\vert R\perp R^*$
43			$3\text{-}\underline{Pa}^{cs}R^*RRb^{cs}Rb^{cs}R$ (Fig. 6.34)	$\underline{Pa}^{cs}\vert\vert R\perp R\vert\vert Rb^{cs}\vert\vert Rb^{cs}\vert\vert R$
44	$3\text{-}\underline{Pa}Pn2R$ (Fig. 5.30)	*21*	$3\text{-}\underline{Pa}^{cs}Pn2^{cs}RR^*$ (Fig. 6.35)	$\underline{Pa}^{cs}\perp Pn2^{cs}\vert\vert R\perp R^*$
45	$3\text{-}\underline{Pa}Pn2R$ (Fig. 5.31)	*21*	$3\text{-}\underline{Pa}^{cs}Pn2^{cs}RR^*$ (Fig. 6.36)	$\underline{Pa}^{cs}\perp Pn2^{cs}\vert\vert R\perp R^*$
46	$3\text{-}\underline{Pa}Pn3$ (Fig. 5.32)	*21*	$3\text{-}\underline{Pa}^{cs}Pn3^{cs}R^*$ (Fig. 6.37)	$\underline{Pa}^{cs}\perp Pn3^{cs}\perp R^*$
47	$3\text{-}\underline{Pa}Pn3$ (Fig. 5.32)	*21*	$3\text{-}\underline{Pa}^{cs}Pn3^{cs}R^*$ (Fig. 6.38)	$\underline{Pa}^{cs}\perp Pn3^{cs}\perp R^*$
48	$3\text{-}\underline{Pa^{cc}}RR$ (Fig. 5.34)	*9*	$3\text{-}\underline{Pa}^{scc}RRR^*$ (Fig. 6.39)	$\underline{Pa}^{scc}\perp R\vert\vert R\perp R^*$
49	$3\text{-}\underline{R}RPaP$ (Fig. 5.35)	*12*	$3\text{-}\underline{R}Pa^{ss}C^*$ (Fig. 6.40)	$\underline{R}\perp Pa^{ss}\perp^{\perp} C^*$
50			$3\text{-}\underline{RR}Pa^{ss}P$ (Fig. 6.41)	$\underline{R}\vert\vert R\perp Pa^{ss}\perp^{\vert\vert}P$
51	$3\text{-}\underline{R}RPPa$ (Fig. 5.38)	*12*	$3\text{-}\underline{R}CPa^{ss}$ (Fig. 6.42)	$\underline{R}\vert\vert C\perp Pa^{ss}$
52			$3\text{-}\underline{R}RC^*Pa^{cs}$ (Fig. 6.43)	$\underline{R}\vert\vert R\perp C^*\perp^{\perp} Pa^{cs}$
53	$3\text{-}\underline{R}RPaPa$ (Fig. 5.39)	*21*	$3\text{-}\underline{R}RPa^{ss}Pa^{cs}$ (Fig. 6.44)	$\underline{R}\vert\vert R\perp Pa^{ss}\vert\vert Pa^{cs}$
54	$3\text{-}\underline{R}RPaPa$ (Fig. 5.40)	*21*	$3\text{-}\underline{R}RPa^{cs}Pa^{ss}$ (Fig. 6.45)	$\underline{R}\vert\vert R\perp Pa^{cs}\vert\vert Pa^{ss}$
55			$3\text{-}\underline{R}Pa^{ss}Pa^{ss}$ (Fig. 6.46)	$\underline{R}\perp Pa^{ss}\vert\vert Pa^{ss}$
56	$3\text{-}\underline{R}RRRbR$ (Fig. 5.41)	*9*	$3\text{-}\underline{R}RRRb^{cs}R$ (Fig. 6.47)	$\underline{R}\vert\vert R\perp R\vert\vert Rb^{cs}\vert\vert R$
57	$3\text{-}\underline{R}RRRbRbR$ (Fig. 5.42)	*18*	$3\text{-}\underline{R}RRRb^{cs}Rb^{cs}R$ (Fig. 6.48)	$\underline{R}\vert\vert R\perp R\vert\vert Rb^{cs}\vert\vert Rb^{cs}\vert\vert R$
58	$3\text{-}\underline{R}RPn2R$ (Figs. 5.43, 5.44)	*9*	$3\text{-}\underline{R}RPn2^{cs}R$ (Figs. 6.49, 6.50)	$\underline{R}\vert\vert R\perp Pn2^{cs}\vert\vert R$
59	$3\text{-}\underline{R}RPn3$ (Figs. 5.45, 5.46)	*9*	$3\text{-}\underline{R}RPn3^{cs}$ (Figs. 6.51, 6.52)	$\underline{R}\vert\vert R\perp Pn3^{cs}$
60	$3\text{-}\underline{R}RRRPa$ (Fig. 5.47)	*9*	$3\text{-}\underline{R}RRRPa^{cs}$ (Fig. 6.53)	$\underline{R}\vert\vert R\perp R\vert\vert R\vert\vert Pa^{cs}$
61	$3\text{-}\underline{R}RPaRR$ (Fig. 5.48a)	*9*	$3\text{-}\underline{R}RPa^{cs}RR$ (Fig. 6.54a)	$\underline{R}\vert\vert R\perp Pa^{cs}\vert\vert R\vert\vert R$
62	$3\text{-}\underline{R}RPaRR$ (Fig. 5.48b)	*9*	$3\text{-}\underline{R}Pa^{ss}RR$ (Fig. 6.54b)	$\underline{R}\perp Pa^{ss}\vert\vert R\vert\vert R$

Table 6.3. Bases of the operational velocities spaces of the limbs isolated from the parallel mechanisms presented in Figs. 6.5–6.54

No.	Parallel mechanism	Basis (R_{G1})	(R_{G2})	(R_{G3})
1	Figs. 6.5a, 6.6a, 6.9a, 6.10a, 6.11, 6.14a, 6.21, 6.30, 6.47, 6.48, 6.53, 6.54a	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3, \boldsymbol{\omega}_\alpha, \boldsymbol{\omega}_\delta)$	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3, \boldsymbol{\omega}_\alpha, \boldsymbol{\omega}_\beta)$	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3, \boldsymbol{\omega}_\beta, \boldsymbol{\omega}_\delta)$
2	Figs. 6.5b, 6.6b, 6.7b, 6.8b, 6.9b, 6.10b, 6.12, 6.13b, 6.14b, 6.17, 6.18, 6.40–6.46	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3, \boldsymbol{\omega}_\beta, \boldsymbol{\omega}_\delta)$	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3, \boldsymbol{\omega}_\alpha, \boldsymbol{\omega}_\delta)$	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3, \boldsymbol{\omega}_\alpha, \boldsymbol{\omega}_\beta)$
3	Fig. 6.7a, 6.8a, 6.13a, 6.15, 6.16, 6.19, 6.20, 6.22–6.29, 6.31–6.39, 6.49–6.52, 6.54b	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3, \boldsymbol{\omega}_\alpha, \boldsymbol{\omega}_\beta)$	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3, \boldsymbol{\omega}_\beta, \boldsymbol{\omega}_\delta)$	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3, \boldsymbol{\omega}_\alpha, \boldsymbol{\omega}_\delta)$

Table 6.4. Structural parameters[a] of translational parallel mechanisms in Figs. 6.5–6.10

No.	Structural parameter	Solution *3-<u>Pa</u>^{ss}PC** *3-<u>Pa</u>^{cs}C*C** (Fig. 6.5a, b) *3-<u>Pa</u>^{ss}PC** *3-<u>Pa</u>^{cs}C*C** (Fig. 6.6a, b)	*3-<u>Pa</u>^{ss}Pa^{ss}P* (Figs. 6.7a, 6.8a) *3-<u>Pa</u>^{ss}PPa^{ss}* (Figs. 6.9a, 6.10a)	*3-<u>Pa</u>^{cs}Pa^{cs}PR*R** (Figs. 6.7b, 6.8b) *3-<u>Pa</u>^{cs}PPa^{cs}R*R** (Figs. 6.9b, 6.10b)
1	m	14	20	26
2	p_1	6	9	11
3	p_2	6	9	11
4	p_3	6	9	11
5	p	18	27	33
6	q	5	8	8
7	k_1	0	0	0
8	k_2	3	3	3
9	k	3	3	3
10	(R_{Gi}) $(i = 1,2,3)$	See Table 6.3	See Table 6.3	See Table 6.3
11	S_{G1}	5	5	5
12	S_{G2}	5	5	5
13	S_{G3}	5	5	5
14	r_{G1}	6	12	12
15	r_{G2}	6	12	12
16	r_{G3}	6	12	12
17	M_{G1}	5	5	5
18	M_{G2}	5	5	5
19	M_{G3}	5	5	5
20	(R_F)	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$
21	S_F	3	3	3
22	r_l	18	36	36
23	r_F	30	48	48
24	M_F	3	3	3
25	N_F	0	0	0
26	T_F	0	0	0
27	$\sum_{j=1}^{p_1} f_j$	11	17	17
28	$\sum_{j=1}^{p_2} f_j$	11	17	17
29	$\sum_{j=1}^{p_3} f_j$	11	17	17
30	$\sum_{j=1}^{p} f_j$	33	51	51

[a]See footnote of Table 2.1 for the nomenclature of structural parameters

Table 6.5. Structural parameters[a] of translational parallel mechanisms in Figs. 6.11 and 6.12

No.	Structural parameter	Solution $3\text{-}\underline{Pa}^{ss}Pa^{cs}Pa^{ss}$ (Fig. 6.11)	$3\text{-}\underline{Pa}^{cs}Pa^{cs}Pa^{cs}R^{*}R^{*}$ (Fig. 6.12)
1	m	26	32
2	p_1	12	14
3	p_2	12	14
4	p_3	12	14
5	p	36	42
6	q	11	11
7	k_1	0	0
8	k_2	3	3
9	k	3	3
10	(R_{Gi}) $(i = 1,2,3)$	See Table 6.3	See Table 6.3
11	S_{G1}	5	5
12	S_{G2}	5	5
13	S_{G3}	5	5
14	r_{G1}	18	18
15	r_{G2}	18	18
16	r_{G3}	18	18
17	M_{G1}	5	5
18	M_{G2}	5	5
19	M_{G3}	5	5
20	(R_F)	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3)$	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3)$
21	S_F	3	3
22	r_l	54	54
23	r_F	66	66
24	M_F	3	3
25	N_F	0	0
26	T_F	0	0
27	$\sum_{j=1}^{p_1} f_j$	23	23
28	$\sum_{j=1}^{p_2} f_j$	23	23
29	$\sum_{j=1}^{p_3} f_j$	23	23
30	$\sum_{j=1}^{p} f_j$	69	69

[a]See footnote of Table 2.1 for the nomenclature of structural parameters

Table 6.6. Structural parameters[a] of translational parallel mechanisms in Figs. 6.13–6.16

No.	Structural parameter	Solution $\underline{Pa}^{cs}Pa^{tss}C^*$ (Fig. 6.13a) $3\text{-}\underline{Pa}^{scc}Pa^{ss}R^*$ (Fig. 6.15)	$3\text{-}\underline{Pa}^{cs}Pa^{tss}C^*R^*$ (Fig. 6.13b) $3\text{-}\underline{Pa}^{scc}Pa^{cs}R^*R^*$ (Fig. 6.16)	$3\text{-}\underline{Pa}^{scc}C^*R^*$ (Fig. 6.14)
1	m	20	23	14
2	p_1	9	10	6
3	p_2	9	10	6
4	p_3	9	10	6
5	p	27	30	18
6	q	8	8	5
7	k_1	0	0	0
8	k_2	3	3	3
9	k	3	3	3
10	(R_{Gi}) $(i = 1,2,3)$	See Table 6.3	See Table 6.3	See Table 6.3
11	S_{G1}	5	5	5
12	S_{G2}	5	5	5
13	S_{G3}	5	5	5
14	r_{G1}	12	12	6
15	r_{G2}	12	12	6
16	r_{G3}	12	12	6
17	M_{G1}	5	5	5
18	M_{G2}	5	5	5
19	M_{G3}	5	5	5
20	(R_F)	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3)$	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3)$	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3)$
21	S_F	3	3	3
22	r_l	36	36	18
23	r_F	48	48	30
24	M_F	3	3	3
25	N_F	0	0	0
26	T_F	0	0	0
27	$\sum_{j=1}^{p_1} f_j$	17	17	11
28	$\sum_{j=1}^{p_2} f_j$	17	17	11
29	$\sum_{j=1}^{p_3} f_j$	17	17	11
30	$\sum_{j=1}^{p} f_j$	51	51	33

[a]See footnote of Table 2.1 for the nomenclature of structural parameters

Table 6.7. Structural parameters[a] of translational parallel mechanisms in Figs. 6.17–6.19

No.	Structural parameter	Solution *3-<u>R</u>RC*P* (Fig. 6.17)	*3-<u>R</u>CC** (Fig. 6.18)	*3-<u>Pa</u>^{cs}RRC** (Fig. 6.19)
1	m	11	8	17
2	p_1	4	3	7
3	p_2	4	3	7
4	p_3	4	3	7
5	p	12	9	21
6	q	2	2	5
7	k_1	3	3	0
8	k_2	0	0	3
9	k	3	3	3
10	(R_{Gi}) $(i = 1,2,3)$	See Table 6.3	See Table 6.3	See Table 6.3
11	S_{G1}	5	5	5
12	S_{G2}	5	5	5
13	S_{G3}	5	5	5
14	r_{G1}	0	0	6
15	r_{G2}	0	0	6
16	r_{G3}	0	0	6
17	M_{G1}	5	5	5
18	M_{G2}	5	5	5
19	M_{G3}	5	5	5
20	(R_F)	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$
21	S_F	3	3	3
22	r_l	0	0	18
23	r_F	12	12	30
24	M_F	3	3	3
25	N_F	0	0	0
26	T_F	0	0	0
27	$\sum_{j=1}^{p_1} f_j$	5	5	11
28	$\sum_{j=1}^{p_2} f_j$	5	5	11
29	$\sum_{j=1}^{p_3} f_j$	5	5	11
30	$\sum_{j=1}^{p} f_j$	15	15	33

[a]See footnote of Table 2.1 for the nomenclature of structural parameters

Table 6.8. Structural parameters[a] of translational parallel mechanisms in Figs. 6.20–6.27

No.	Structural parameter	Solution *3-Pa^ss RC** (Fig. 6.20) *3-Pa^ss C*R* (Fig. 6.21b)	*3-Pa^cs RC*R* (Fig. 6.21a) *3-Pa^ss RRR** (Fig. 6.24) *3-Pa^cs C*RR* (Fig. 6.25)	*3-Pa^cs RPRR** (Fig. 6.22) *3-Pa^cs RRRR** (Fig. 6.23) *3-Pa^cs PRRR** (Figs. 6.26, 6.27)
1	m	14	17	20
2	p_1	6	7	8
3	p_2	6	7	8
4	p_3	6	7	8
5	p	18	21	24
6	q	5	5	5
7	k_1	0	0	0
8	k_2	3	3	3
9	k	3	3	3
10	(R_{Gi}) $(i = 1,2,3)$	See Table 6.3	See Table 6.3	See Table 6.3
11	S_{G1}	5	5	5
12	S_{G2}	5	5	5
13	S_{G3}	5	5	5
14	r_{G1}	6	6	6
15	r_{G2}	6	6	6
16	r_{G3}	6	6	6
17	M_{G1}	5	5	5
18	M_{G2}	5	5	5
19	M_{G3}	5	5	5
20	(R_F)	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$
21	S_F	3	3	3
22	r_l	18	18	18
23	r_F	30	30	30
24	M_F	3	3	3
25	N_F	0	0	0
26	T_F	0	0	0
27	$\sum_{j=1}^{p_1} f_j$	11	11	11
28	$\sum_{j=1}^{p_2} f_j$	11	11	11
29	$\sum_{j=1}^{p_3} f_j$	11	11	11
30	$\sum_{j=1}^{p} f_j$	33	33	33

[a]See footnote of Table 2.1 for the nomenclature of structural parameters

Table 6.9. Structural parameters[a] of translational parallel mechanisms in Figs. 6.28–6.32

No.	Structural parameter	Solution 3-$\underline{Pa}^{cs}Pa^{cs}RRR*$ (Figs. 6.28, 6.29) 3-$\underline{Pa}^{ss}R*RRb^{cs}R$ (Fig. 6.32)	3-$\underline{Pa}^{cs}RRPa^{ss}$ (Fig. 6.30a) 3-$\underline{Pa}^{ss}Rb^{cs}RR*$ (Fig. 6.31)	3-$\underline{Pa}^{ss}RPa^{ss}$ (Fig. 6.30b)
1	m	26	23	20
2	p_1	11	10	9
3	p_2	11	10	9
4	p_3	11	10	9
5	p	33	30	27
6	q	8	8	8
7	k_1	0	0	0
8	k_2	3	3	3
9	k	3	3	3
10	(R_{Gi}) $(i = 1,2,3)$	See Table 6.3	See Table 6.3	See Table 6.3
11	S_{G1}	5	5	5
12	S_{G2}	5	5	5
13	S_{G3}	5	5	5
14	r_{G1}	12	12	12
15	r_{G2}	12	12	12
16	r_{G3}	12	12	12
17	M_{G1}	5	5	5
18	M_{G2}	5	5	5
19	M_{G3}	5	5	5
20	(R_F)	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3)$	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3)$	$(\boldsymbol{v}_1,\boldsymbol{v}_2,\boldsymbol{v}_3)$
21	S_F	3	3	3
22	r_l	36	36	36
23	r_F	48	48	48
24	M_F	3	3	3
25	N_F	0	0	0
26	T_F	0	0	0
27	$\sum_{j=1}^{p_1} f_j$	17	17	17
28	$\sum_{j=1}^{p_2} f_j$	17	17	17
29	$\sum_{j=1}^{p_3} f_j$	17	17	17
30	$\sum_{j=1}^{p} f_j$	51	51	51

[a]See footnote of Table 2.1 for the nomenclature of structural parameters

Table 6.10. Structural parameters[a] of translational parallel mechanisms in Figs. 6.33–6.38

No.	Structural parameter	Solution 3-<u>*Pa*</u>^{ss}*Rb*^{cs}*Rb*^{cs}*RR** (Fig. 6.33)	3-<u>*Pa*</u>^{cs}*R*RRb*^{cs}*Rb*^{cs}*R* (Fig. 6.34)	3-<u>*Pa*</u>^{cs}*Pn2*^{cs}*RR** (Figs. 6.35, 6.36) 3-<u>*Pa*</u>^{cs}*Pn3*^{cs}*R** (Figs. 6.37, 6.38)
1	m	29	32	26
2	p_1	13	14	11
3	p_2	13	14	11
4	p_3	13	14	11
5	p	39	42	33
6	q	11	11	8
7	k_1	0	0	0
8	k_2	3	3	3
9	k	3	3	3
10	(R_{Gi}) $(i = 1,2,3)$	See Table 6.3	See Table 6.3	See Table 6.3
11	S_{G1}	5	5	5
12	S_{G2}	5	5	5
13	S_{G3}	5	5	5
14	r_{G1}	18	18	12
15	r_{G2}	18	18	12
16	r_{G3}	18	18	12
17	M_{G1}	5	5	5
18	M_{G2}	5	5	5
19	M_{G3}	5	5	5
20	(R_F)	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$
21	S_F	3	3	3
22	r_l	54	54	36
23	r_F	66	66	48
24	M_F	3	3	3
25	N_F	0	0	0
26	T_F	0	0	0
27	$\sum_{j=1}^{p_1} f_j$	23	23	17
28	$\sum_{j=1}^{p_2} f_j$	23	23	17
29	$\sum_{j=1}^{p_3} f_j$	23	23	17
30	$\sum_{j=1}^{p} f_j$	69	69	51

[a]See footnote of Table 2.1 for the nomenclature of structural parameters

Table 6.11. Structural parameters[a] of translational parallel mechanisms in Figs. 6.39–6.45

No.	Structural parameter	Solution 3-$\underline{Pa}^{scc}RRR*$ (Fig. 6.39) 3-$\underline{R}RPa^{ss}P$ (Fig. 6.41) 3-$\underline{R}RC*Pa^{cs}$ (Fig. 6.43)	3-$\underline{R}Pa^{ss}C*$ (Fig. 6.40) 3-$\underline{R}CPa^{ss}$ (Fig. 6.42)	3-$\underline{R}RPa^{ss}Pa^{cs}$ (Fig. 6.44) 3-$\underline{R}RPa^{cs}Pa^{ss}$ (Fig. 6.45)
1	m	17	14	23
2	p_1	7	6	10
3	p_2	7	6	10
4	p_3	7	6	10
5	p	21	18	30
6	q	5	5	8
7	k_1	0	0	0
8	k_2	3	3	3
9	k	3	3	3
10	(R_{Gi}) $(i = 1,2,3)$	See Table 6.3	See Table 6.3	See Table 6.3
11	S_{G1}	5	5	5
12	S_{G2}	5	5	5
13	S_{G3}	5	5	5
14	r_{G1}	6	6	12
15	r_{G2}	6	6	12
16	r_{G3}	6	6	12
17	M_{G1}	5	5	5
18	M_{G2}	5	5	5
19	M_{G3}	5	5	5
20	(R_F)	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$
21	S_F	3	3	3
22	r_l	18	18	36
23	r_F	30	30	48
24	M_F	3	3	3
25	N_F	0	0	0
26	T_F	0	0	0
27	$\sum_{j=1}^{p_1} f_j$	11	11	17
28	$\sum_{j=1}^{p_2} f_j$	11	11	17
29	$\sum_{j=1}^{p_3} f_j$	11	11	17
30	$\sum_{j=1}^{p} f_j$	33	33	51

[a]See footnote of Table 2.1 for the nomenclature of structural parameters

Table 6.12. Structural parameters[a] of translational parallel mechanisms in Figs. 6.46–6.52

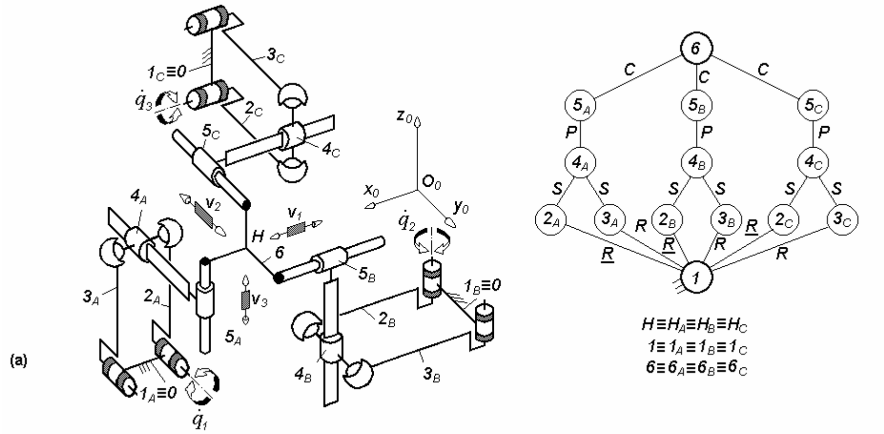
No.	Structural parameter	Solution 3-*<u>R</u>Pa^ss^Pa^ss^* (Fig. 6.46)	3-*<u>R</u>RRRb^cs^R* (Fig. 6.47) 3-*<u>R</u>RPn2^cs^R* (Figs. 6.49, 6.50) 3-*<u>R</u>RPn3^cs^* (Figs. 6.51, 6.52)	3-*<u>R</u>RRRb^cs^Rb^cs^R* (Fig. 6.48)
1	m	20	20	26
2	p_1	9	8	11
3	p_2	9	8	11
4	p_3	9	8	11
5	p	27	24	33
6	q	8	5	8
7	k_1	0	0	0
8	k_2	3	3	3
9	k	3	3	3
10	(R_{Gi}) $(i = 1,2,3)$	See Table 6.3	See Table 6.3	See Table 6.3
11	S_{G1}	5	5	5
12	S_{G2}	5	5	5
13	S_{G3}	5	5	5
14	r_{G1}	12	6	12
15	r_{G2}	12	6	12
16	r_{G3}	12	6	12
17	M_{G1}	5	5	5
18	M_{G2}	5	5	5
19	M_{G3}	5	5	5
20	(R_F)	$(\mathbf{v}_1, \mathbf{v}_2, \mathbf{v}_3)$	$(\mathbf{v}_1, \mathbf{v}_2, \mathbf{v}_3)$	$(\mathbf{v}_1, \mathbf{v}_2, \mathbf{v}_3)$
21	S_F	3	3	3
22	r_l	36	18	36
23	r_F	48	30	48
24	M_F	3	3	3
25	N_F	0	0	0
26	T_F	0	0	0
27	$\sum_{j=1}^{p_1} f_j$	17	11	17
28	$\sum_{j=1}^{p_2} f_j$	17	11	17
29	$\sum_{j=1}^{p_3} f_j$	17	11	17
30	$\sum_{j=1}^{p} f_j$	51	33	51

[a]See footnote of Table 2.1 for the nomenclature of structural parameters

Table 6.13. Structural parameters[a] of translational parallel mechanisms in Figs. 6.53 and 6.54

No.	Structural parameter	Solution *3-RRRRPa^cs^* (Fig. 6.53) *3-RRPa^cs^RR* (Fig. 6.54a)	*3-RPa^ss^RR* (Fig. 6.54b)
1	m	20	17
2	p_1	8	7
3	p_2	8	7
4	p_3	8	7
5	p	24	21
6	q	5	5
7	k_1	0	0
8	k_2	3	3
9	k	3	3
10	(R_{Gi}) $(i = 1,2,3)$	See Table 6.3	See Table 6.3
11	S_{G1}	5	5
12	S_{G2}	5	5
13	S_{G3}	5	5
14	r_{G1}	6	6
15	r_{G2}	6	6
16	r_{G3}	6	6
17	M_{G1}	5	5
18	M_{G2}	5	5
19	M_{G3}	5	5
20	(R_F)	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$	$(\boldsymbol{v}_1, \boldsymbol{v}_2, \boldsymbol{v}_3)$
21	S_F	3	3
22	r_l	18	18
23	r_F	30	30
24	M_F	3	3
25	N_F	0	0
26	T_F	0	0
27	$\sum_{j=1}^{p_1} f_j$	11	11
28	$\sum_{j=1}^{p_2} f_j$	11	11
29	$\sum_{j=1}^{p_3} f_j$	11	11
30	$\sum_{j=1}^{p} f_j$	33	33

[a]See footnote of Table 2.1 for the nomenclature of structural parameters



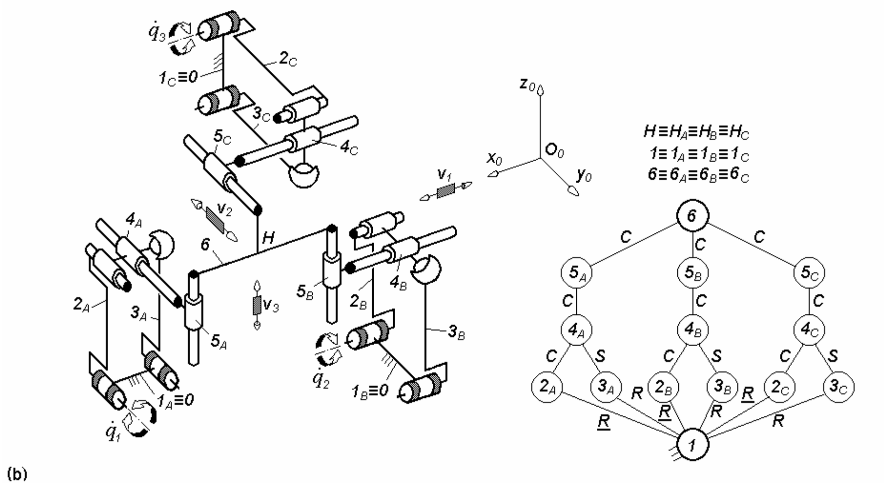


Fig. 6.5. Non overconstrained TPMs with uncoupled motions of types $3\text{-}\underline{Pa}^{ss}PC^*$ (**a**) and $3\text{-}\underline{Pa}^{cs}C^*C^*$ (**b**), limb topology $\underline{Pa}^{ss}||P\perp^{\perp}C^*$ (**a**) and $\underline{Pa}^{cs}||C^*\perp^{\perp}C^*$ (**b**)

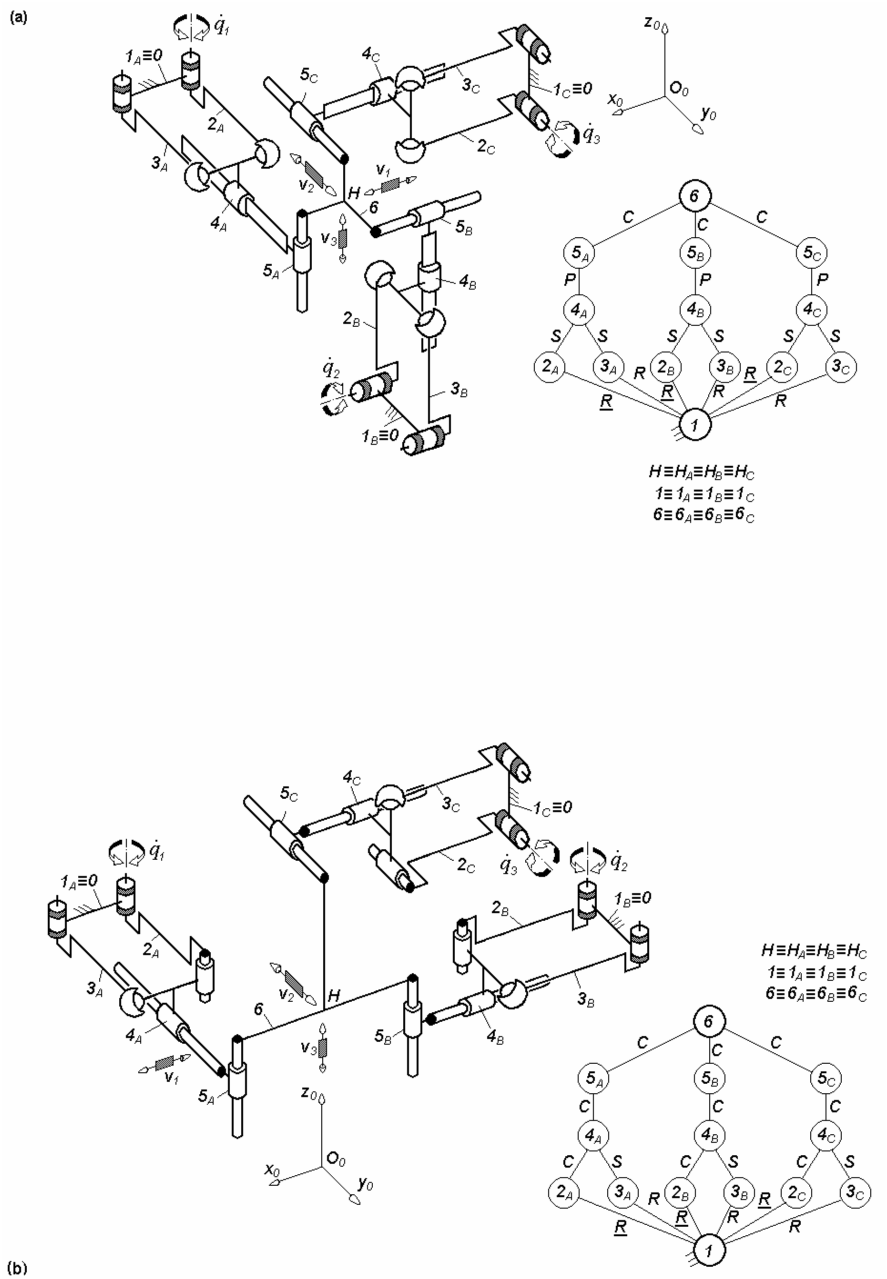


Fig. 6.6. Non overconstrained TPMs with uncoupled motions of types $3\text{-}\underline{Pa}^{ss}PC^*$ (**a**) and $3\text{-}\underline{Pa}^{cs}C^*C^*$ (**b**), limb topology $\underline{Pa}^{ss} \perp P \perp^{\parallel} C^*$ (**a**) and $\underline{Pa}^{cs} \perp C^* \perp^{\parallel} C^*$ (**b**)

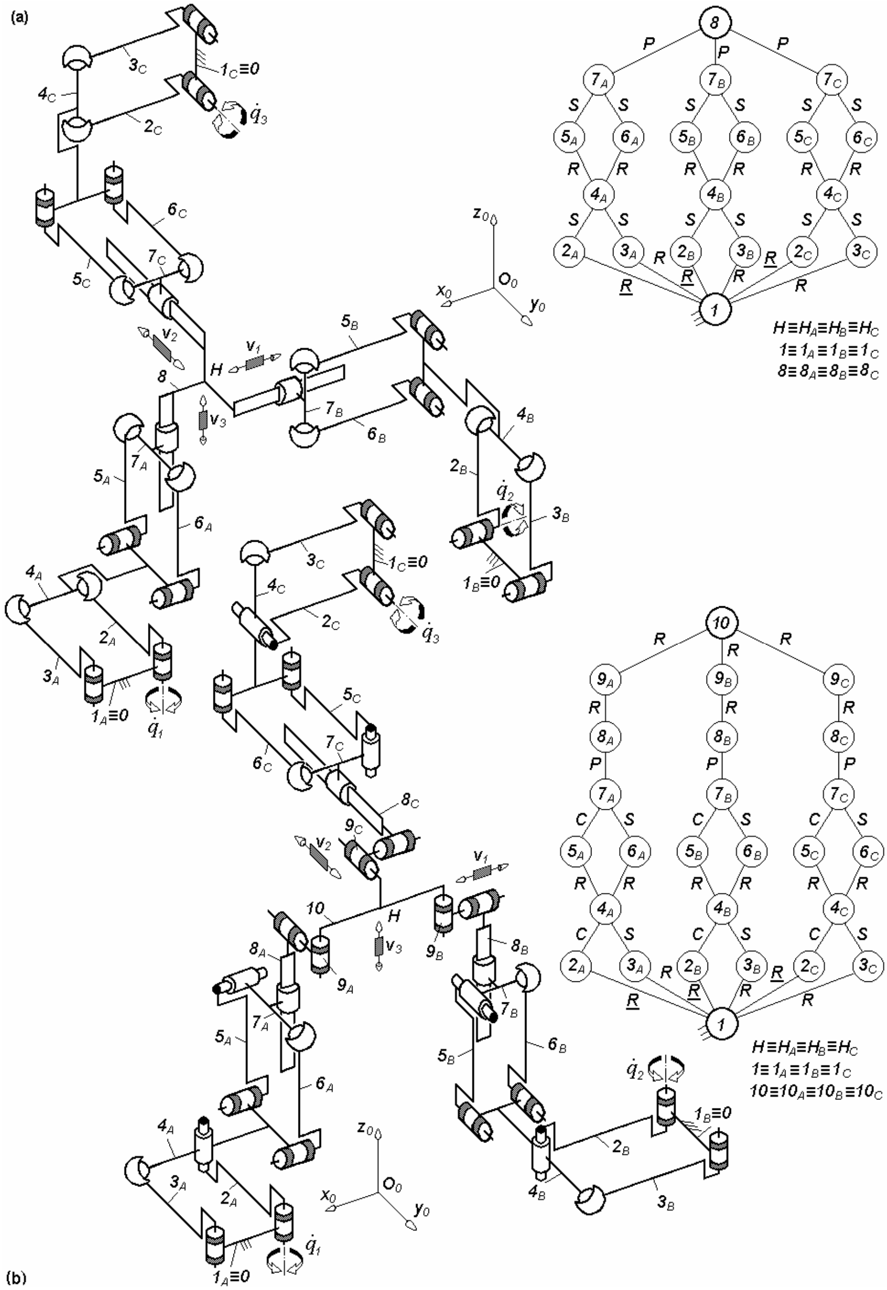


Fig. 6.7. Non overconstrained TPMs with uncoupled motions of types $3\text{-}\underline{Pa}^{ss}Pa^{ss}P$ (**a**) and $3\text{-}\underline{Pa}^{cs}Pa^{cs}PR^{*}R^{*}$ (**b**), limb topology $\underline{Pa}^{ss} \perp Pa^{ss} \perp^{\parallel} P$ (**a**) and $\underline{Pa}^{cs} \perp Pa^{cs} \perp^{\parallel} P \perp^{\perp} R \perp^{\parallel} R$ (**b**)

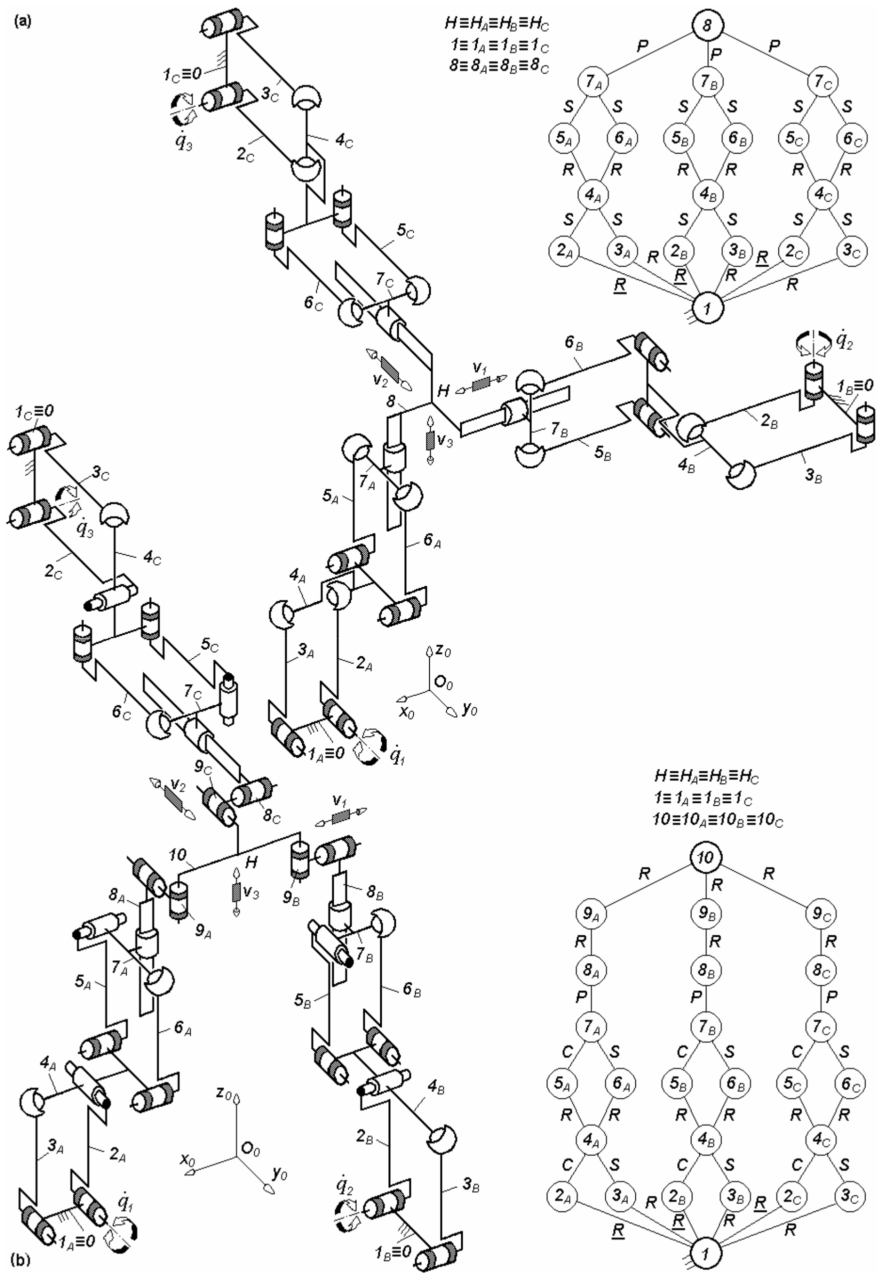


Fig. 6.8. Non overconstrained TPMs with uncoupled motions of types $3\text{-}\underline{Pa}^{ss}Pa^{ss}P$ (**a**) and $3\text{-}\underline{Pa}^{cs}Pa^{cs}PR^{*}R^{*}$ (**b**), limb topology $\underline{Pa}^{ss}\perp Pa^{ss}\perp^{\perp}P$ (**a**) and $\underline{Pa}^{cs}\perp Pa^{cs}\perp^{\perp}P\perp^{\perp}R^{*}\perp^{\parallel}R^{*}$ (**b**)

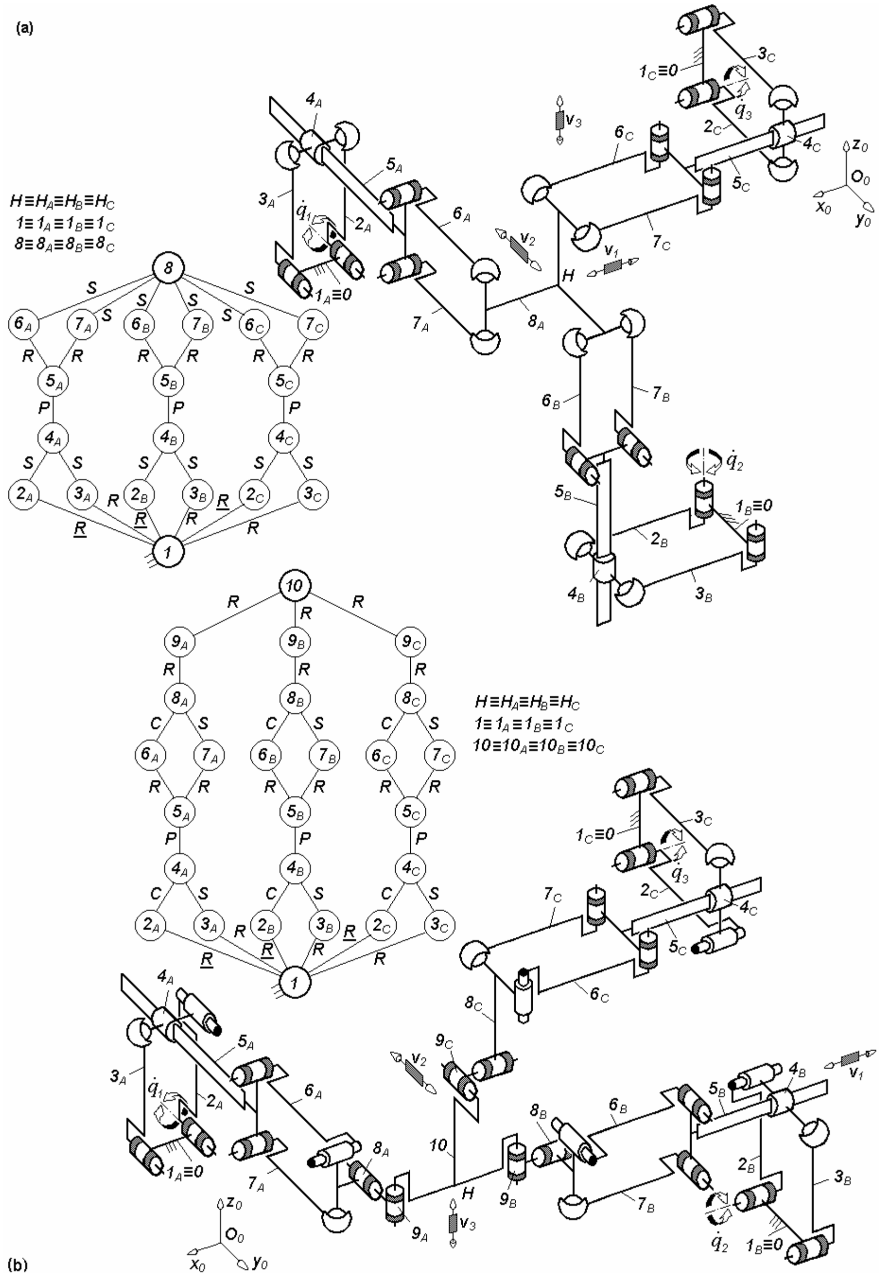


Fig. 6.9. Non overconstrained TPMs with uncoupled motions of types *3-*$\underline{Pa}^{ss}PPa^{ss}$ (**a**) and *3-*$\underline{Pa}^{cs}PPa^{cs}R^*R^*$ (**b**), limb topology $\underline{Pa}^{ss}||P\perp Pa^{ss}$ (**a**) and $\underline{Pa}^{cs}||P\perp Pa^{cs}\perp^{||}R^*\perp^{\perp}R^*$ (**b**)

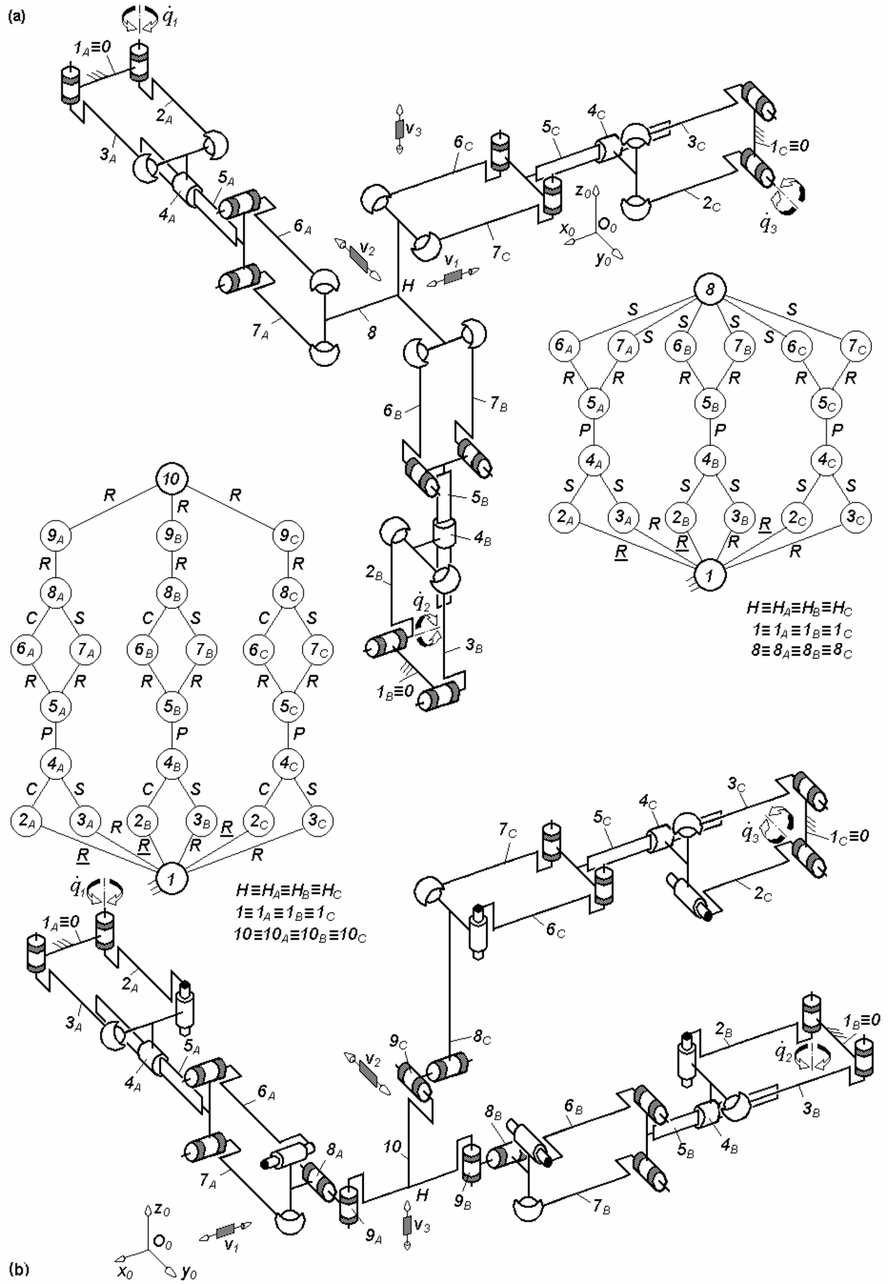


Fig. 6.10. Non overconstrained TPMs with uncoupled motions of types *3-*$\underline{Pa}^{ss}PPa^{ss}$ (**a**) and *3-*$\underline{Pa}^{cs}PPa^{cs}R^*R^*$ (**b**), limb topology $\underline{Pa}^{ss}\perp P\perp^{\perp}Pa^{ss}$ (**a**) and $\underline{Pa}^{cs}\perp P\perp^{\perp}Pa^{cs}\perp^{||}R^*\perp^{\perp}R^*$ (**b**)

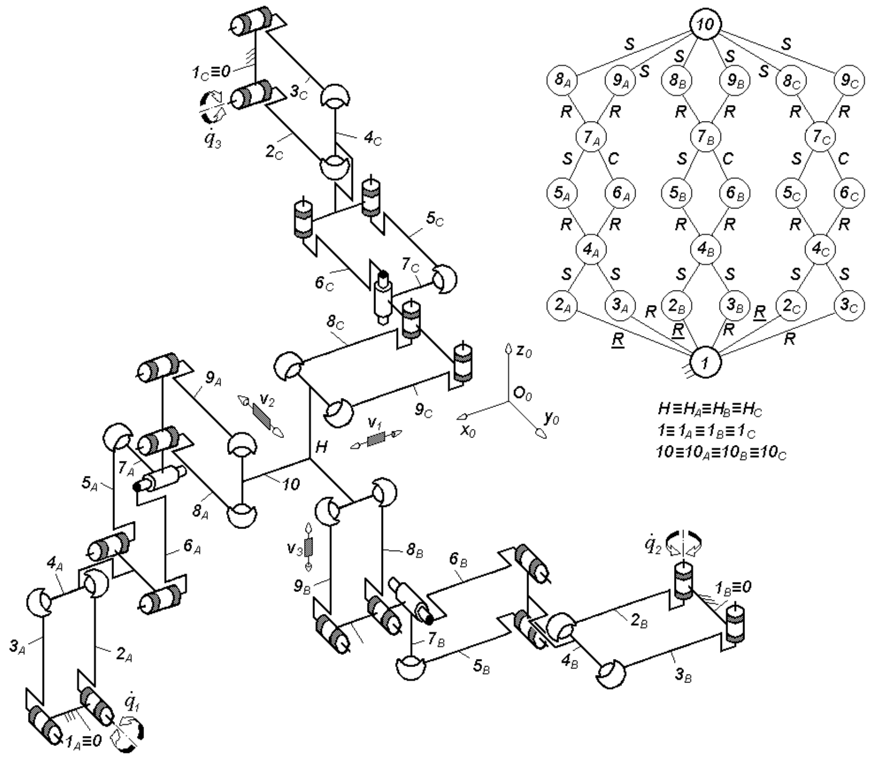


Fig. 6.11. $3\text{-}\underline{Pa}^{ss}Pa^{cs}Pa^{ss}$-type non overconstrained TPM with uncoupled motions, limb topology $\underline{Pa}^{ss} \perp Pa^{cs}||Pa^{ss}$

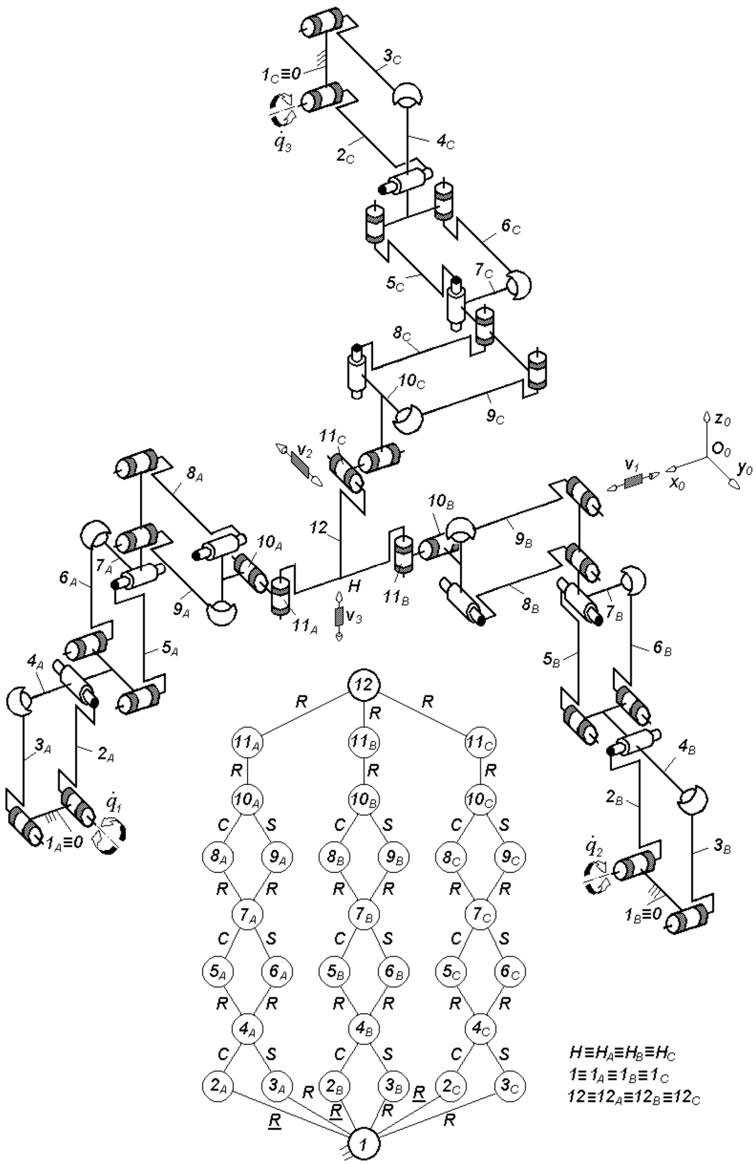


Fig. 6.12. *3-*$\underline{Pa}^{cs}Pa^{cs}Pa^{cs}R^*R^*$-type non overconstrained TPM with uncoupled motions, limb topology $\underline{Pa}^{cs} \perp Pa^{cs} || Pa^{cs} \perp^{||} R^* \perp^{\perp} R^*$

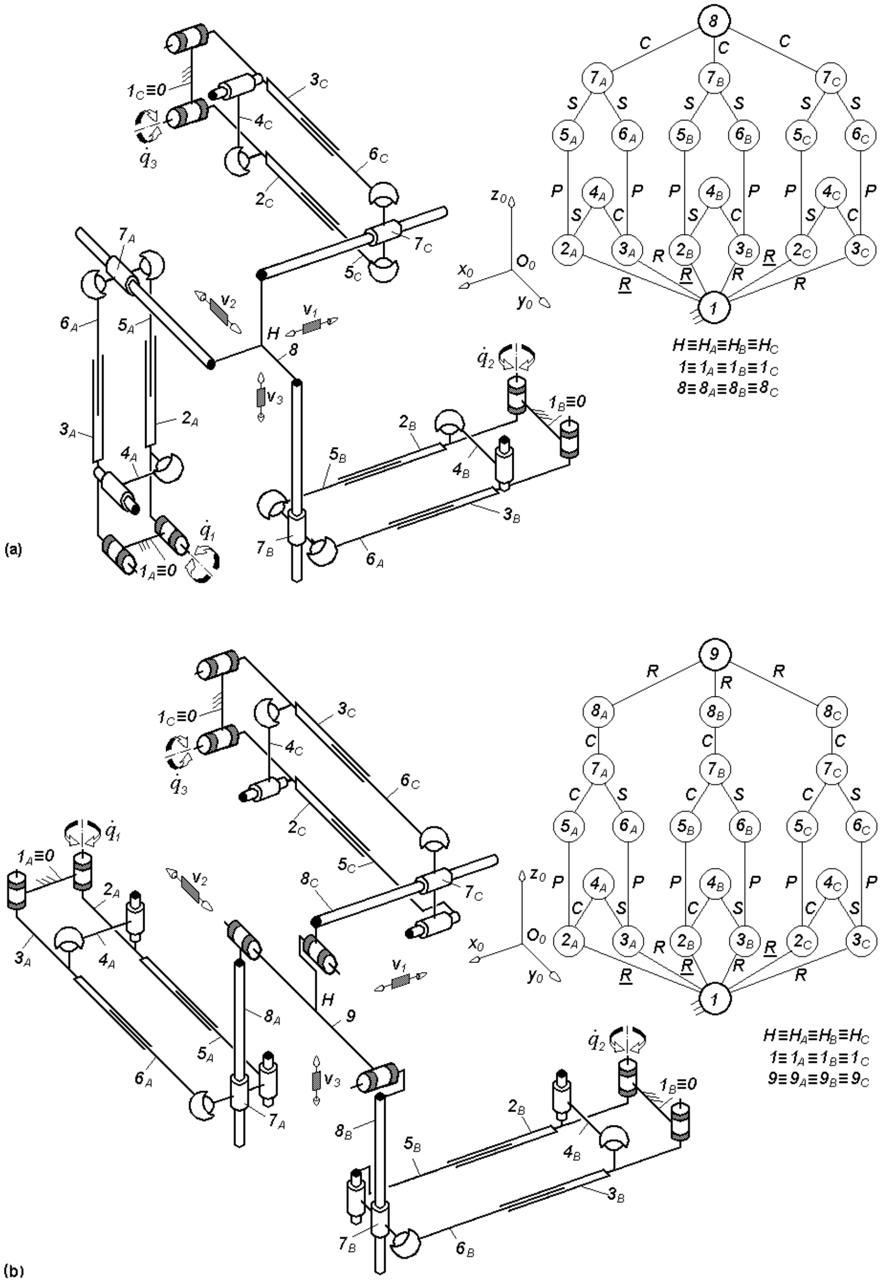


Fig. 6.13. Non overconstrained TPMs with uncoupled motions of types $3\text{-}\underline{Pa}^{cs}Pa^{tss}C^*$ (**a**) and $3\text{-}\underline{Pa}^{cs}Pa^{tcs}C^*R^*$ (**b**), limb topology $\underline{Pa}^{cs}||Pa^{tss}||C^*$ (**a**) and $\underline{Pa}^{cs}||Pa^{tcs}||C^* \perp R^*$ (**b**)

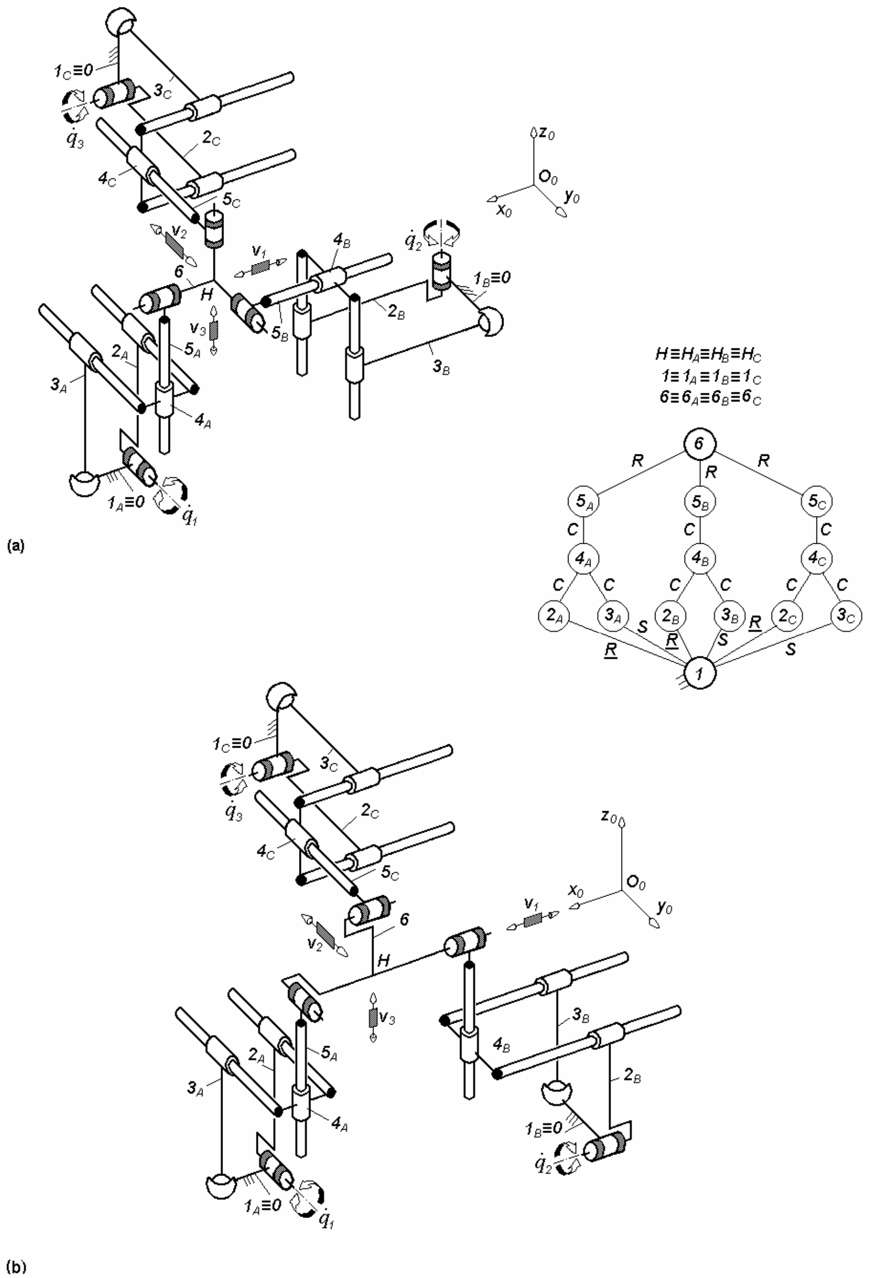


Fig. 6.14. *3-*$\underline{Pa}^{scc}C^*R^*$-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{Pa}^{scc} \perp C^* \perp^{\perp} R^*$ (**a**) and $\underline{Pa}^{scc} \perp C^* \perp^{\parallel} R^*$ (**b**)

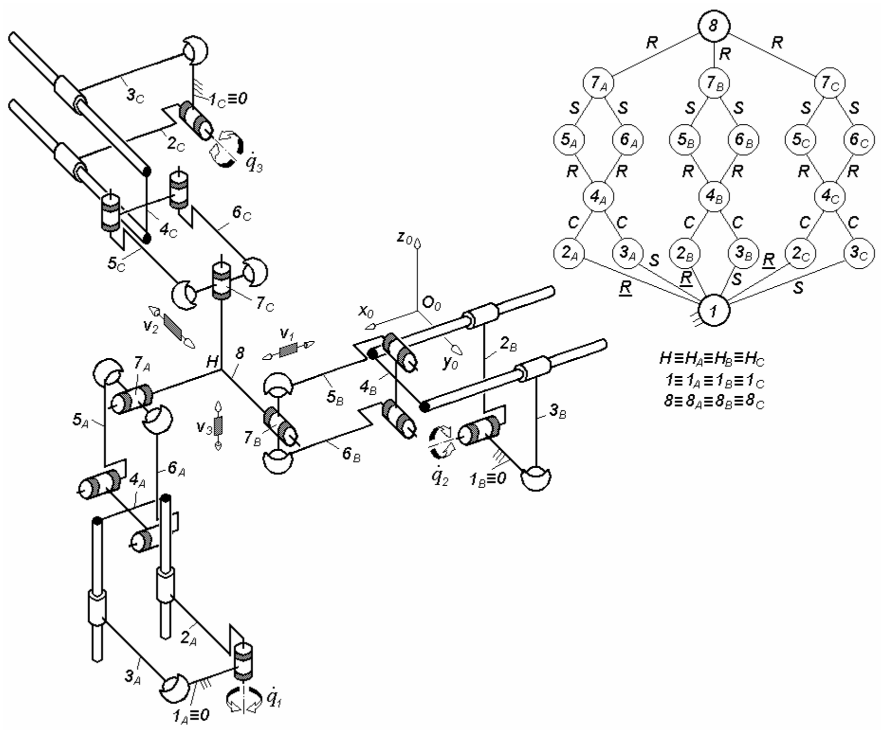


Fig. 6.15. *3-Pa*^{scc}*Pa*^{ss}*R**-type non overconstrained TPM with uncoupled motions, limb topology $\underline{Pa}^{scc} \perp Pa^{ss}||R^*$

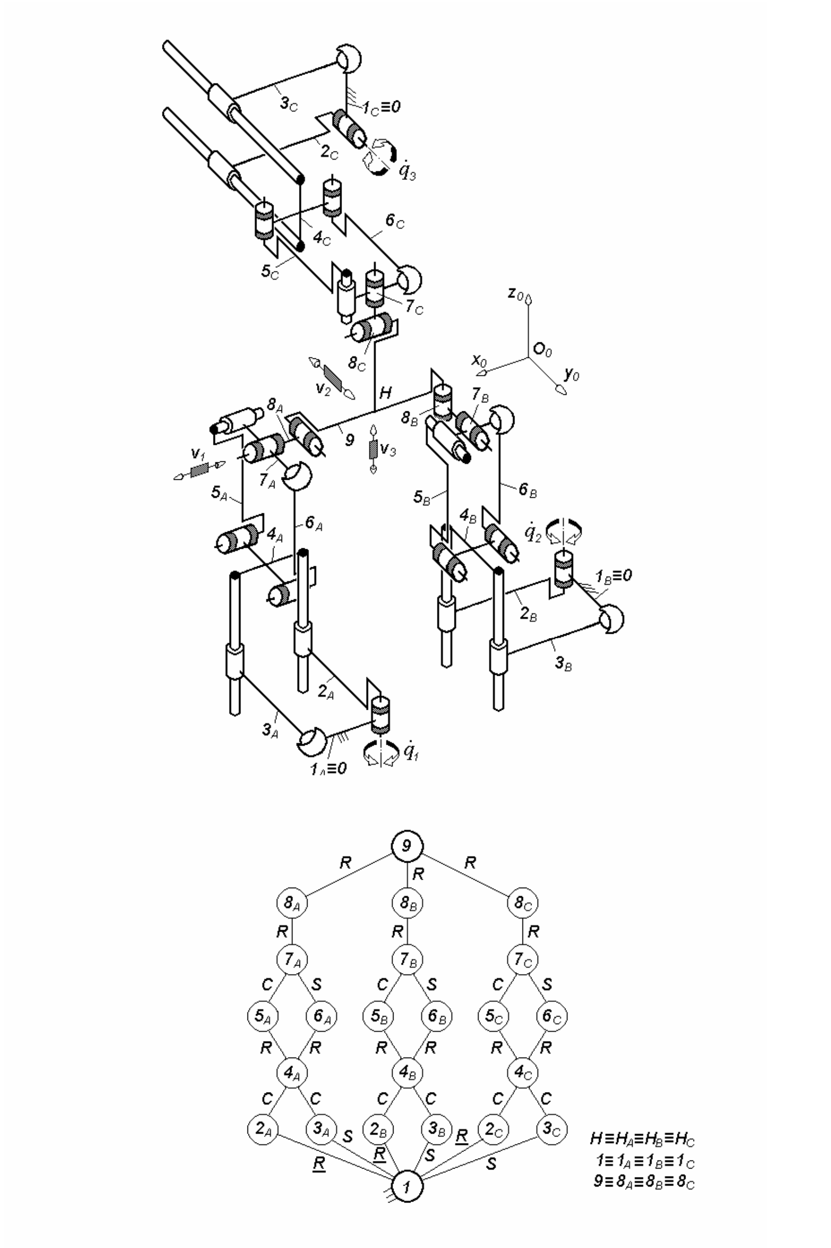


Fig. 6.16. 3-$\underline{Pa}^{scc}Pa^{cs}R^*R^*$-type non overconstrained TPM with uncoupled motions, limb topology $\underline{Pa}^{scc} \perp Pa^{cs} || R^* \perp^{\perp} R^*$

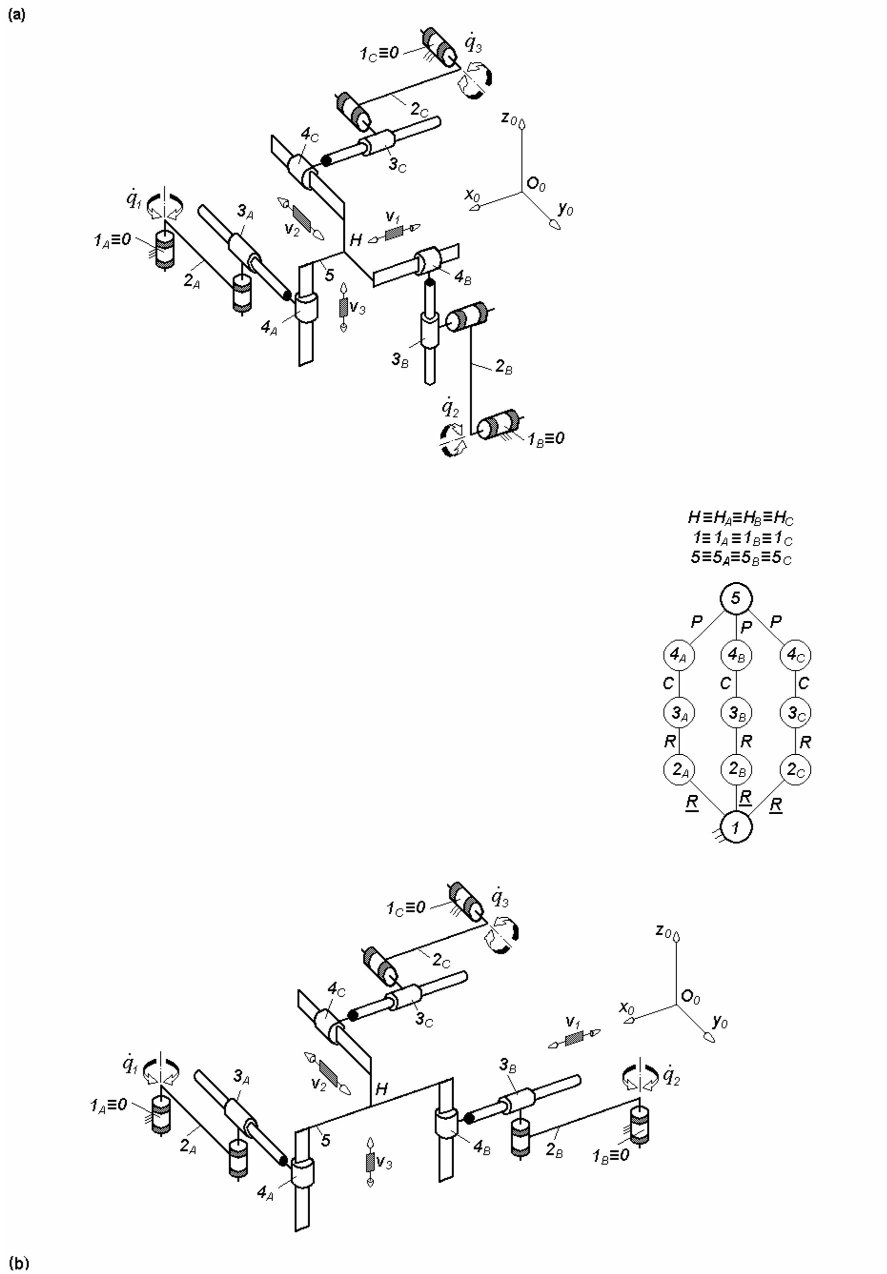


Fig. 6.17. *3-RRC*P*-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{R}||R \perp C^* \perp^{||} P$

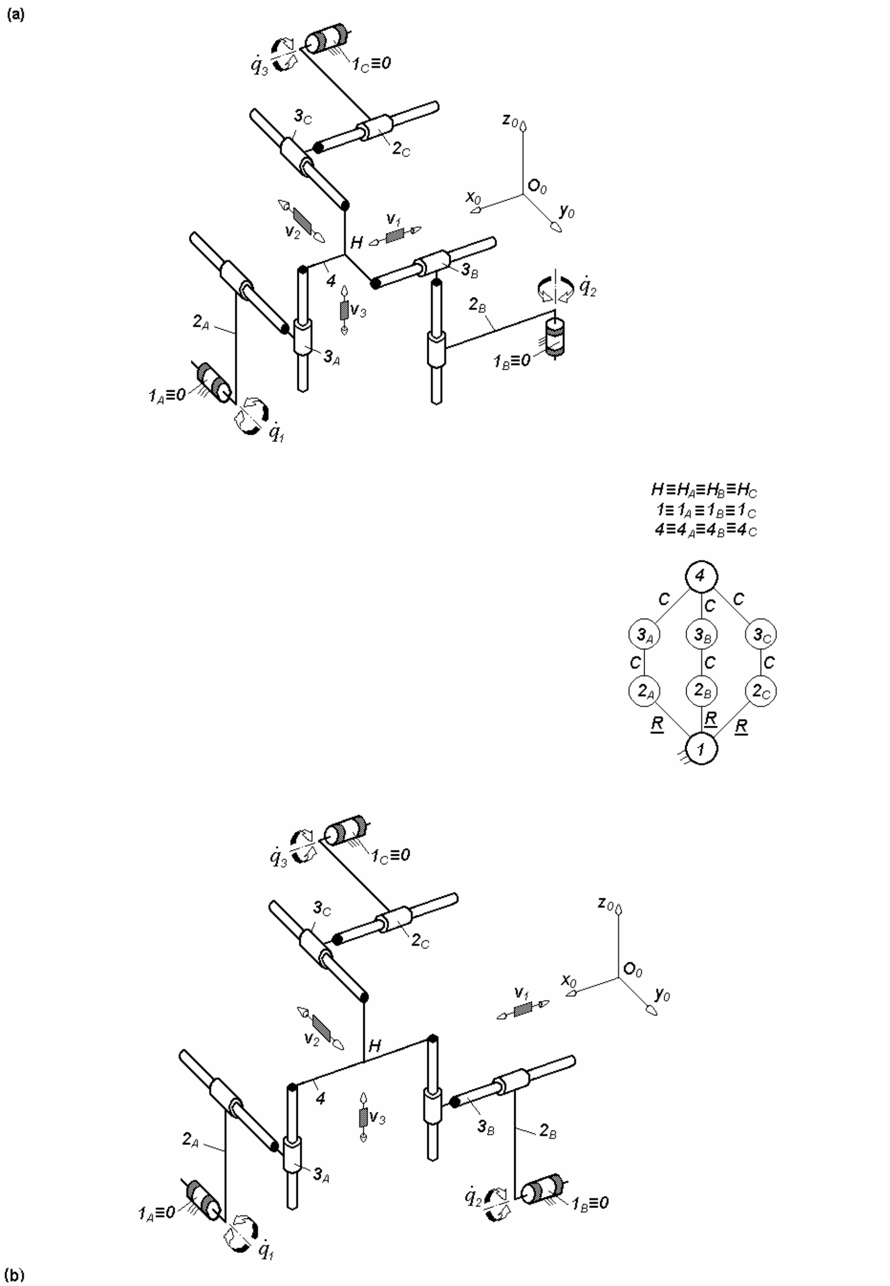


Fig. 6.18. *3-$\underline{R}CC^*$*-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{R}||C \perp C^*$

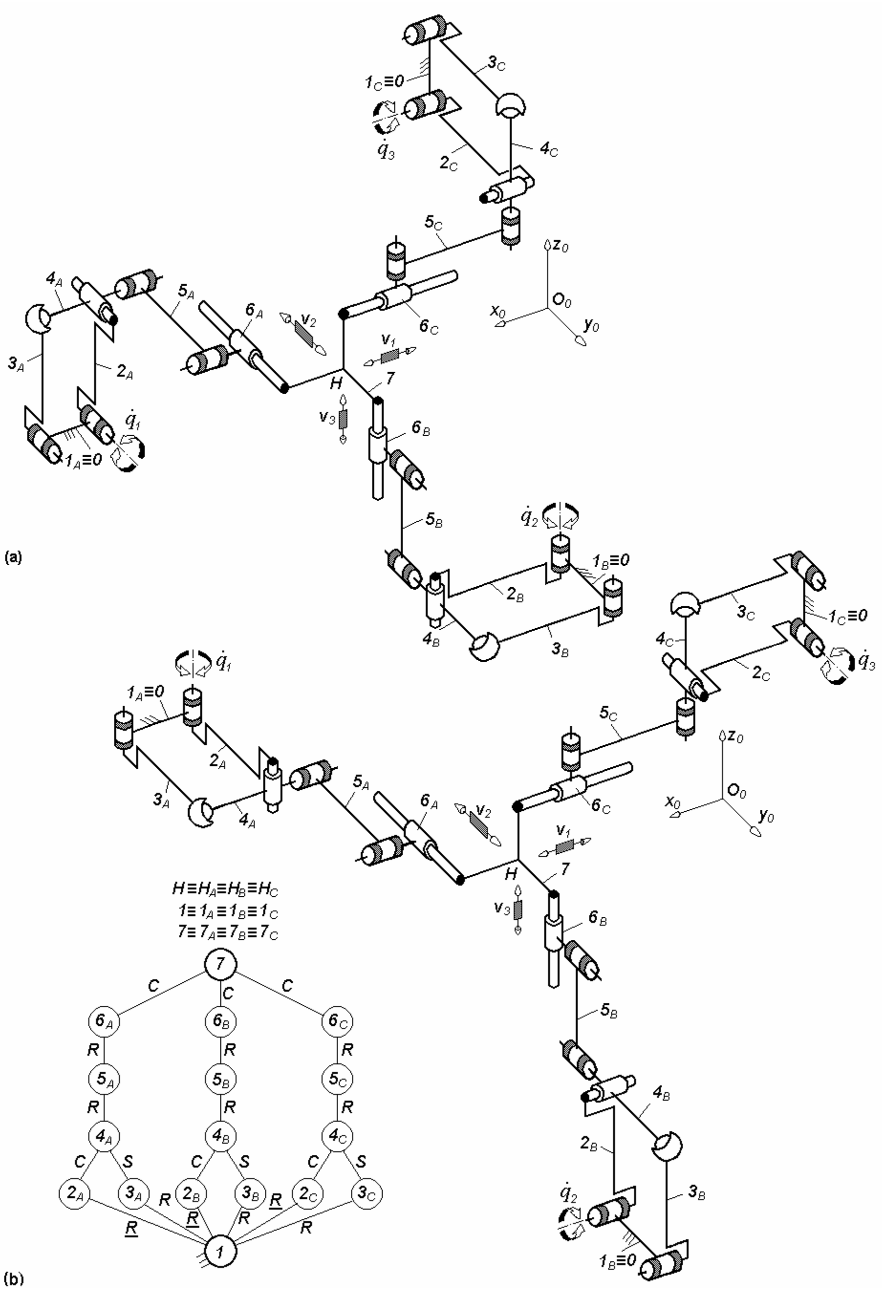


Fig. 6.19. *3-$\underline{Pa}^{cs}RRC^*$*-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{Pa}^{cs} \perp R||R \perp^{||} C^*$ (**a**) and $\underline{Pa}^{cs} \perp R||R \perp^{\perp} C^*$ (**b**)

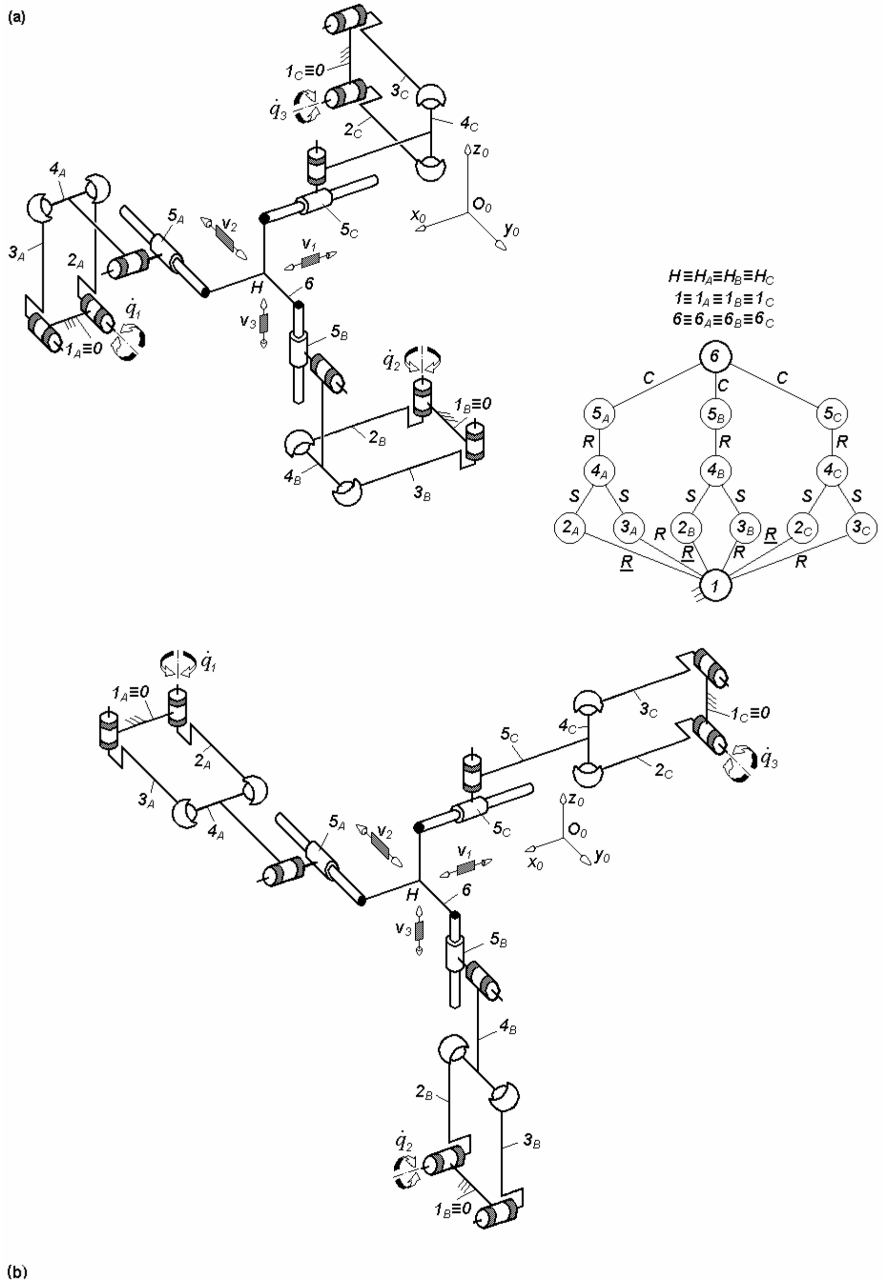


Fig. 6.20. *3-$\underline{Pa}^{ss}RC^*$*-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{Pa}^{ss} \perp R \perp^{\parallel} C^*$ (**a**) and $\underline{Pa}^{ss} \perp R \perp^{\perp} C^*$ (**b**)

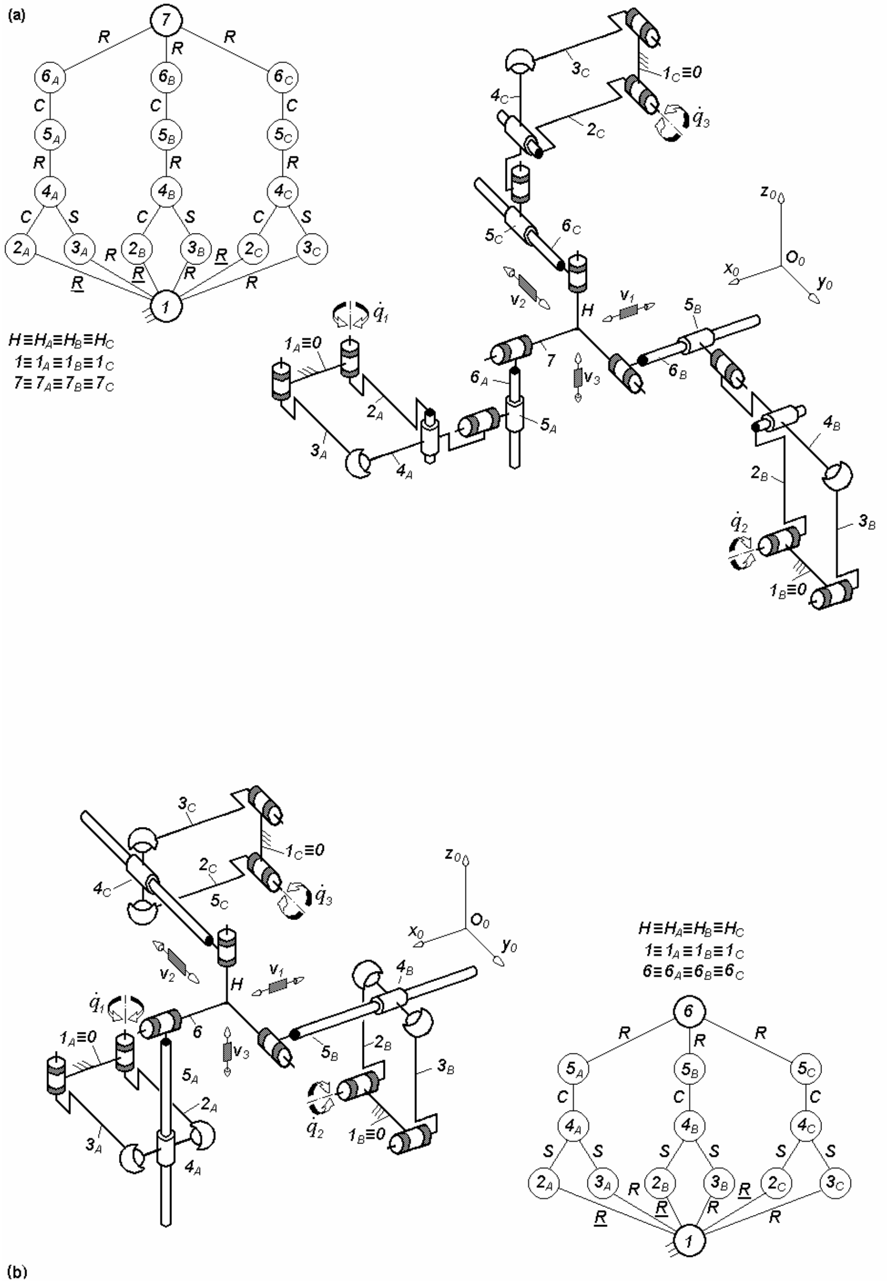


Fig. 6.21. Non overconstrained TPMs with uncoupled motions of types $3\text{-}\underline{Pa}^{cs}RC^{*}R$ (**a**) and $3\text{-}\underline{Pa}^{ss}C^{*}R$ (**b**), limb topology $\underline{Pa}^{cs} \perp R \perp C^{*} \perp^{\parallel} R$ (**a**) and $\underline{Pa}^{ss} \parallel C^{*} \perp R$ (**b**)

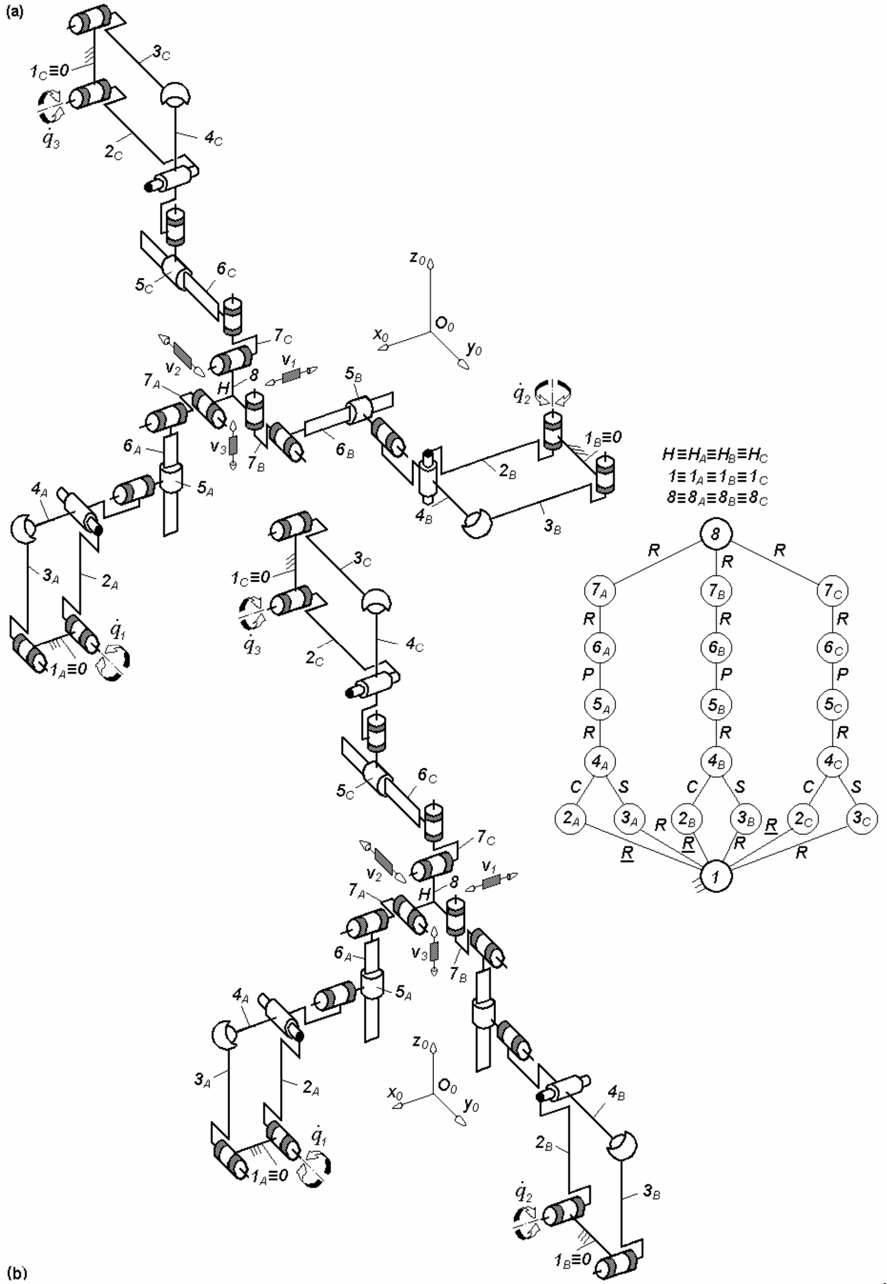


Fig. 6.22. *3-*$\underline{Pa}^{cs}$*RPRR**-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{Pa}^{cs} \perp R \perp P \perp^{\parallel} R \perp R^{*}$

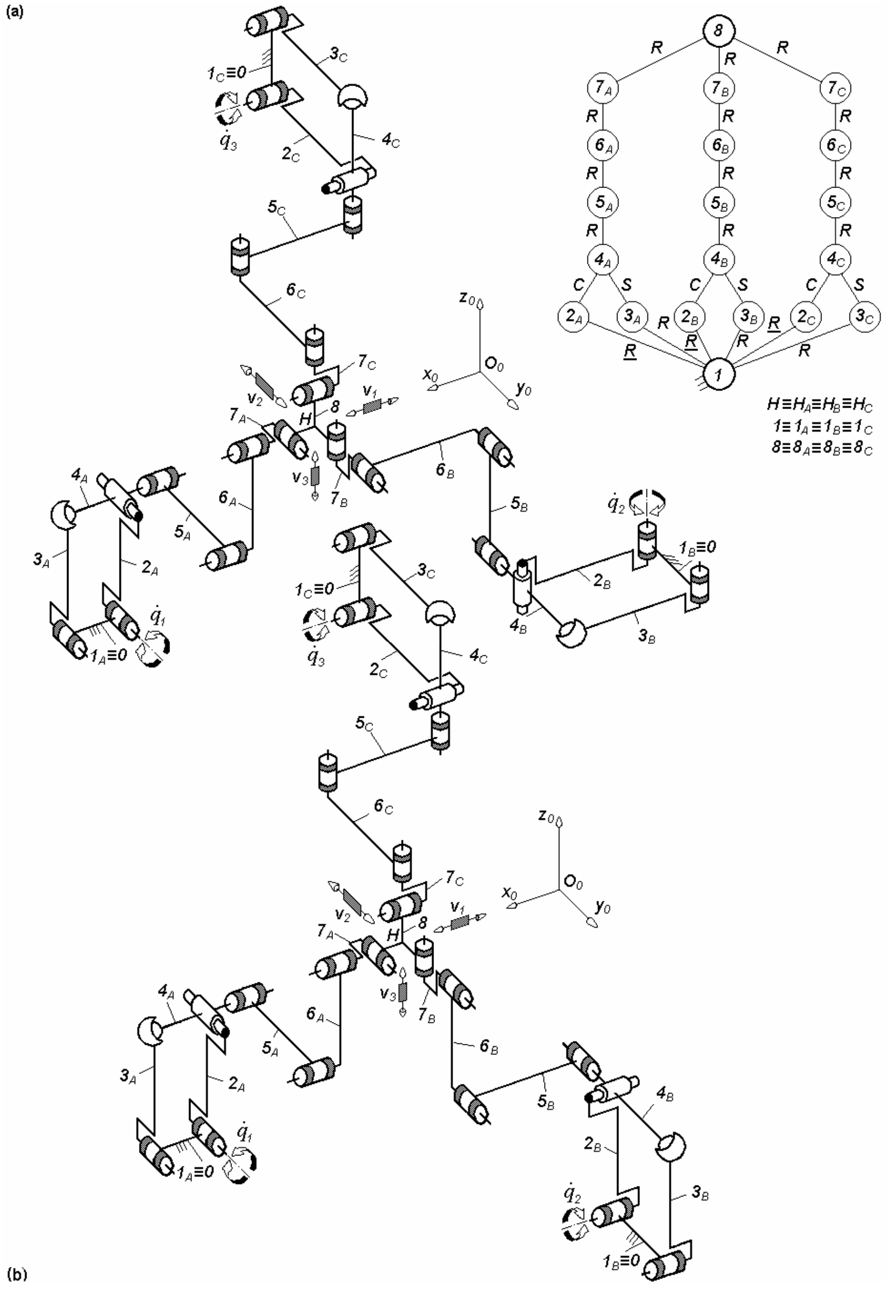


Fig. 6.23. *3-*$\underline{Pa}^{cs}$*RRRR**-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{Pa}^{cs} \perp R||R||R \perp R*$

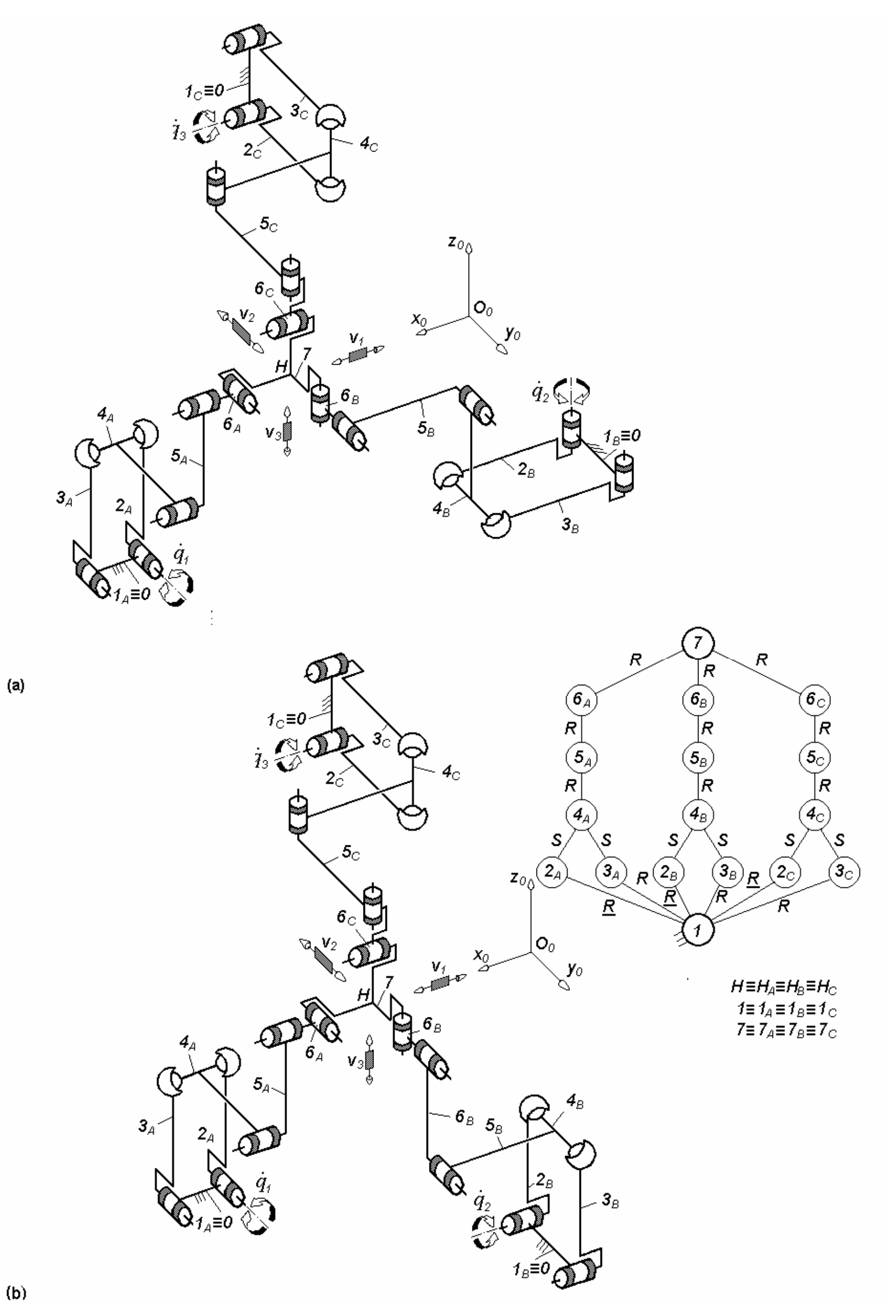


Fig. 6.24. *3-*$\underline{Pa}^{ss}$*RRR**-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{Pa}^{ss} \perp R||R \perp R*$

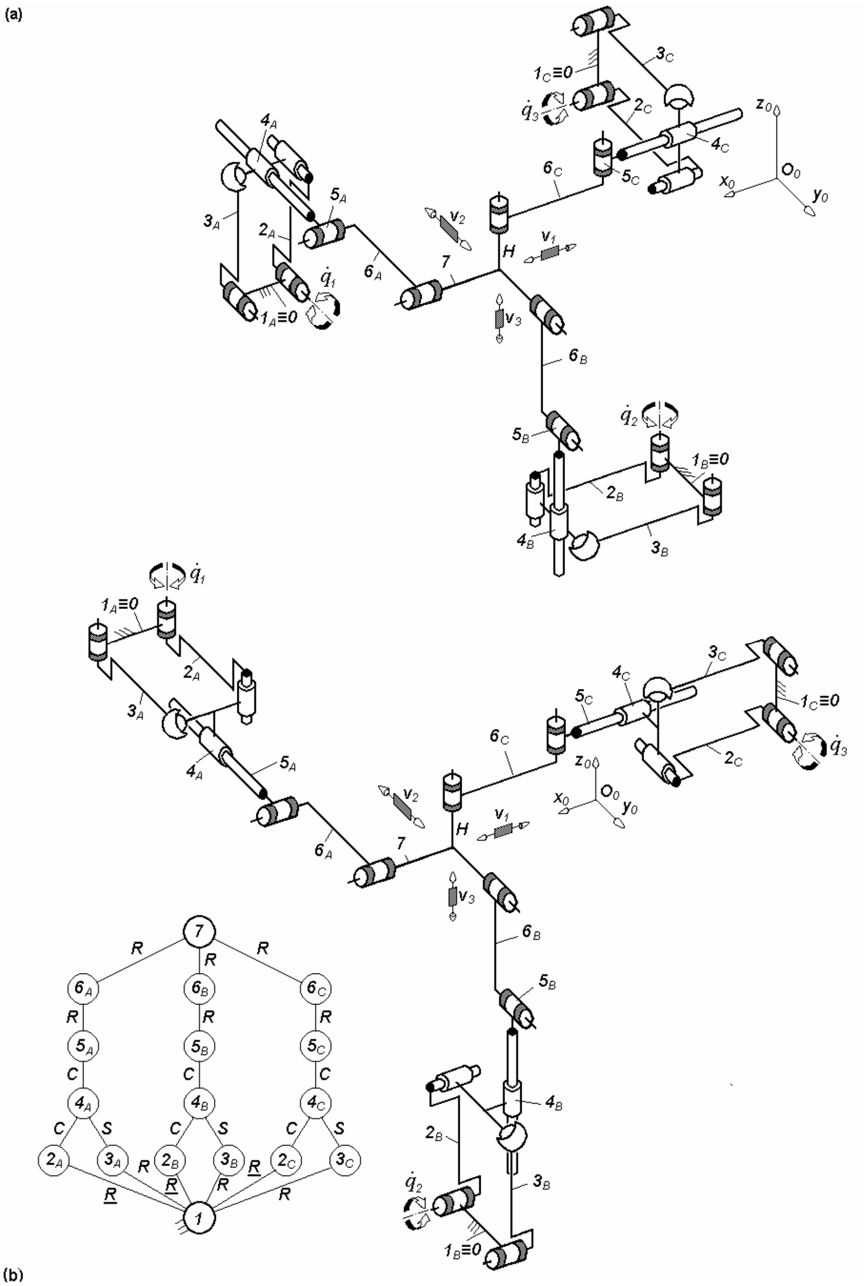


Fig. 6.25. *3-*$\underline{Pa}^{cs}C^*RR$-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{Pa}^{cs}||C^*\perp R||R$ (**a**) and $\underline{Pa}^{cs}\perp C^*\perp^{\perp} R||R$ (**b**)

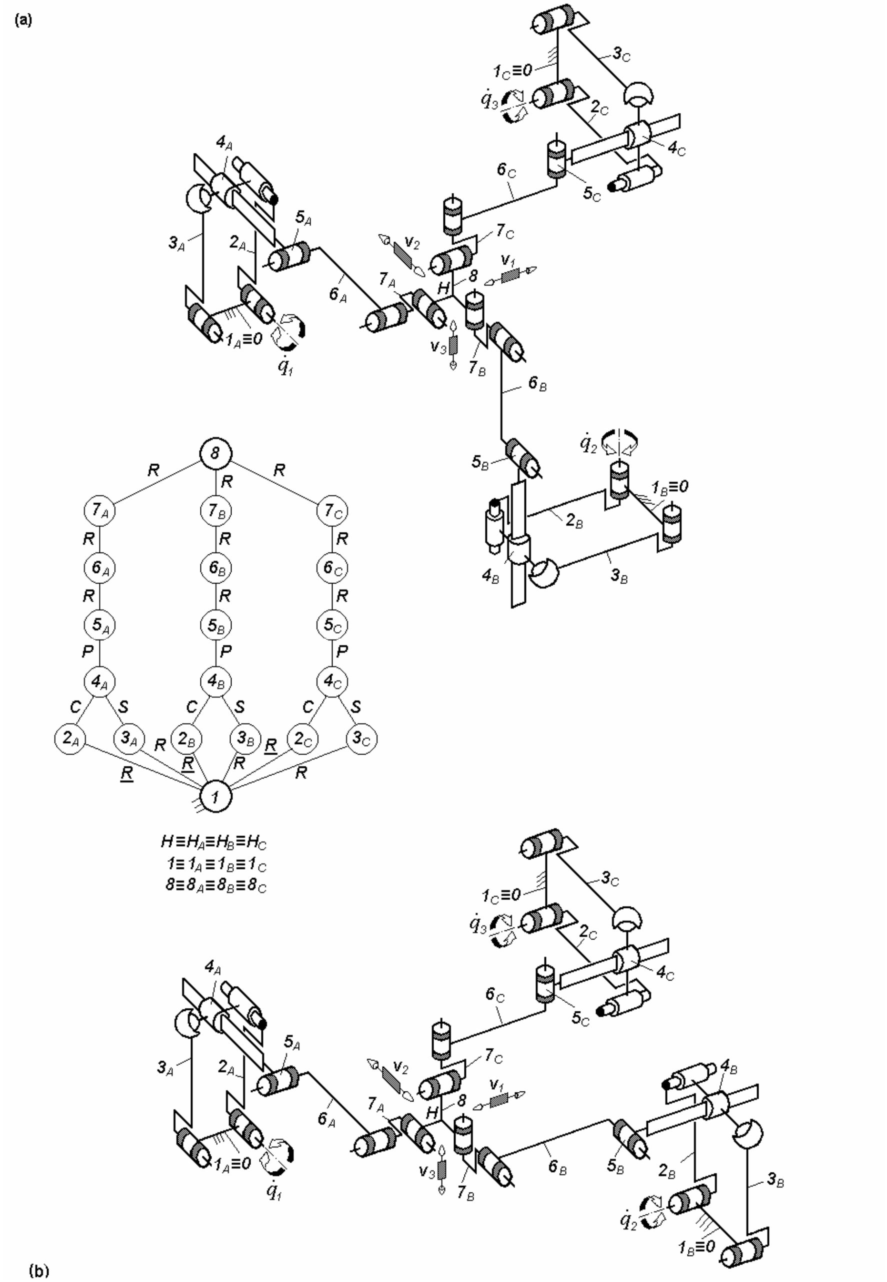


Fig. 6.26. *3-*$\underline{Pa}^{cs}PRRR^*$-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{Pa}^{cs}||P\perp R||R\perp R^*$

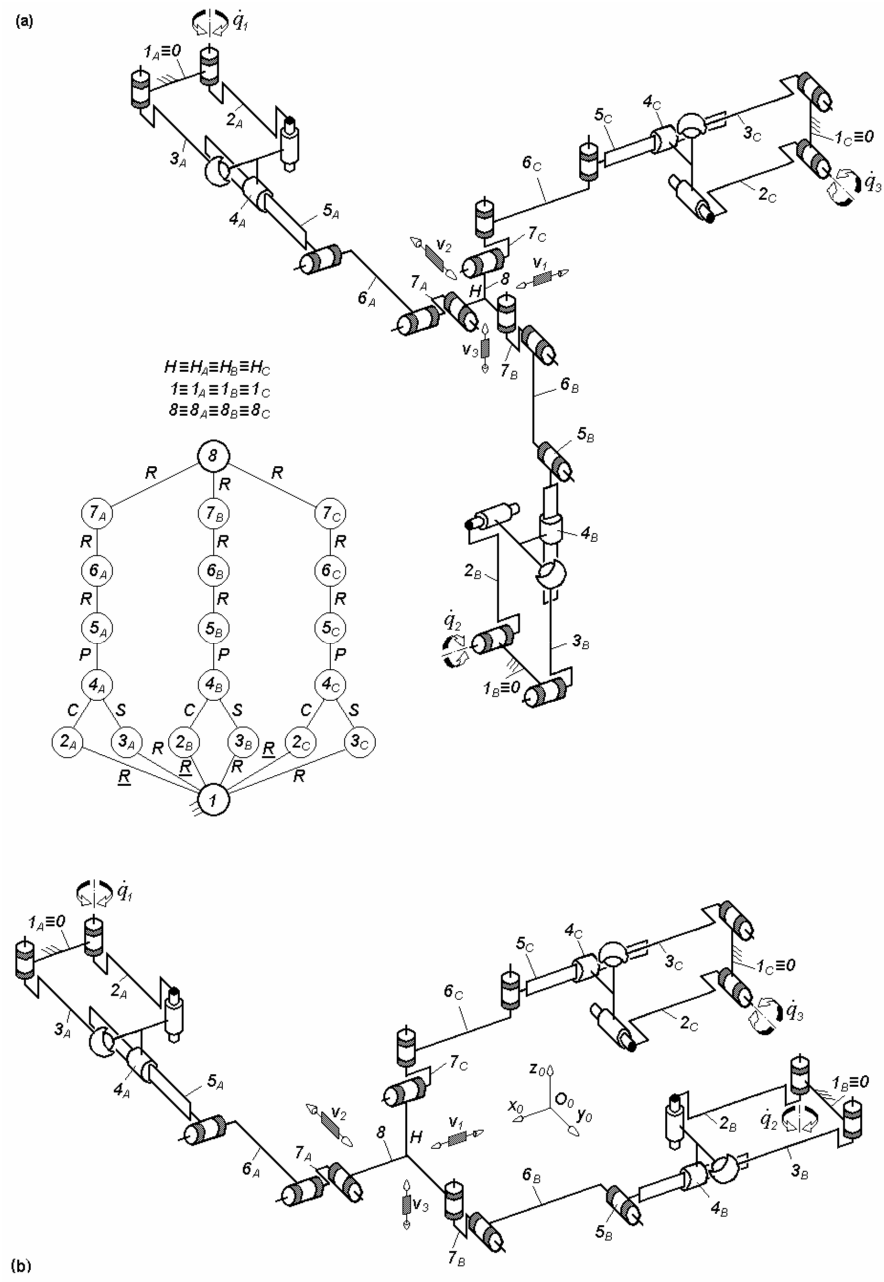


Fig. 6.27. *3-*$\underline{Pa}^{cs}$*PRRR**-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{Pa}^{cs} || P \perp R || R \perp R^*$

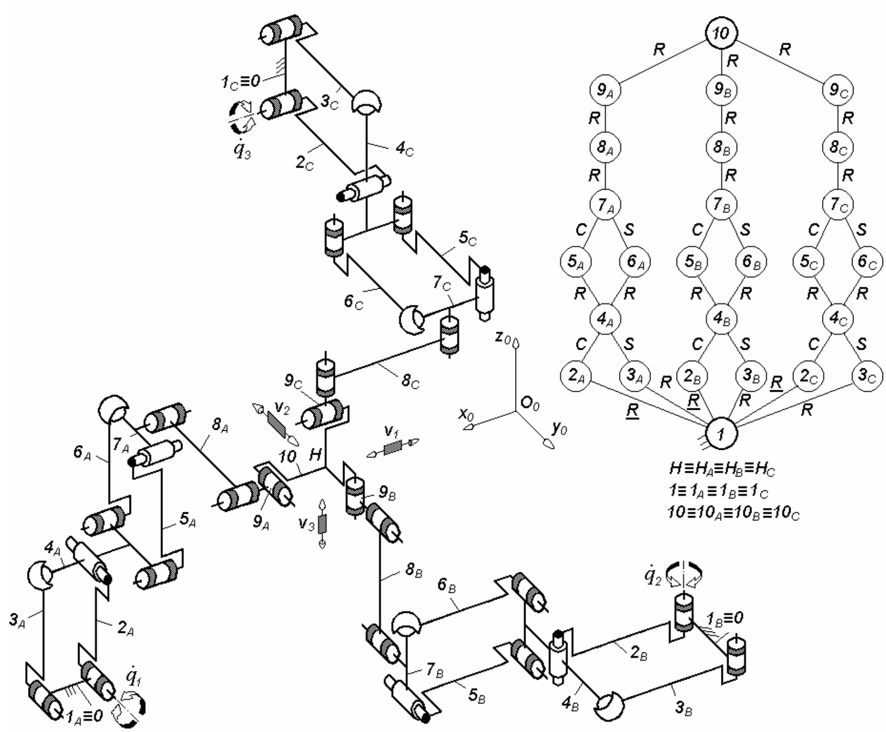


Fig. 6.28. $3\text{-}\underline{Pa}^{cs}Pa^{cs}RRR*$-type non overconstrained TPM with uncoupled motions, limb topology $\underline{Pa}^{cs}\perp Pa^{cs}||R||R\perp{}^{||}R*$ and the actuated joints with orthogonal axes

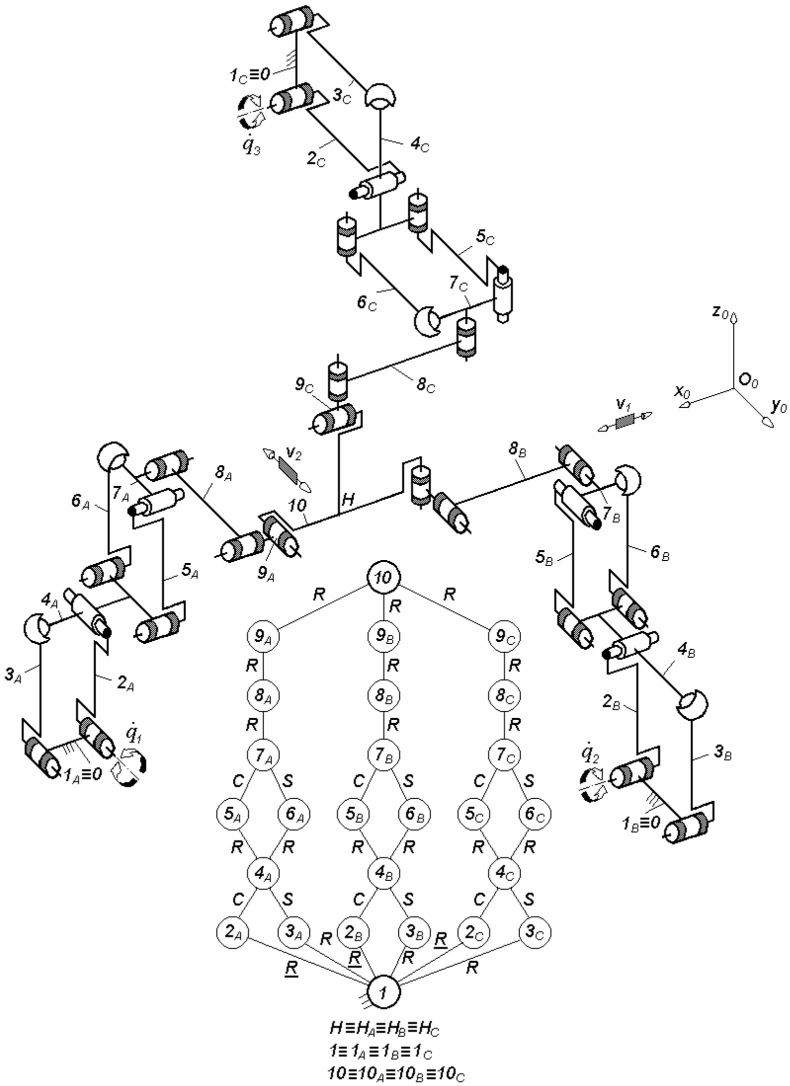


Fig. 6.29. *3-*$\underline{Pa}^{cs}Pa^{cs}RRR^*$-type non overconstrained TPM with uncoupled motions, limb topology $\underline{Pa}^{cs} \perp Pa^{cs}||R||R \perp R^*$ and the axes of the actuated joints parallel to two orthogonal directions

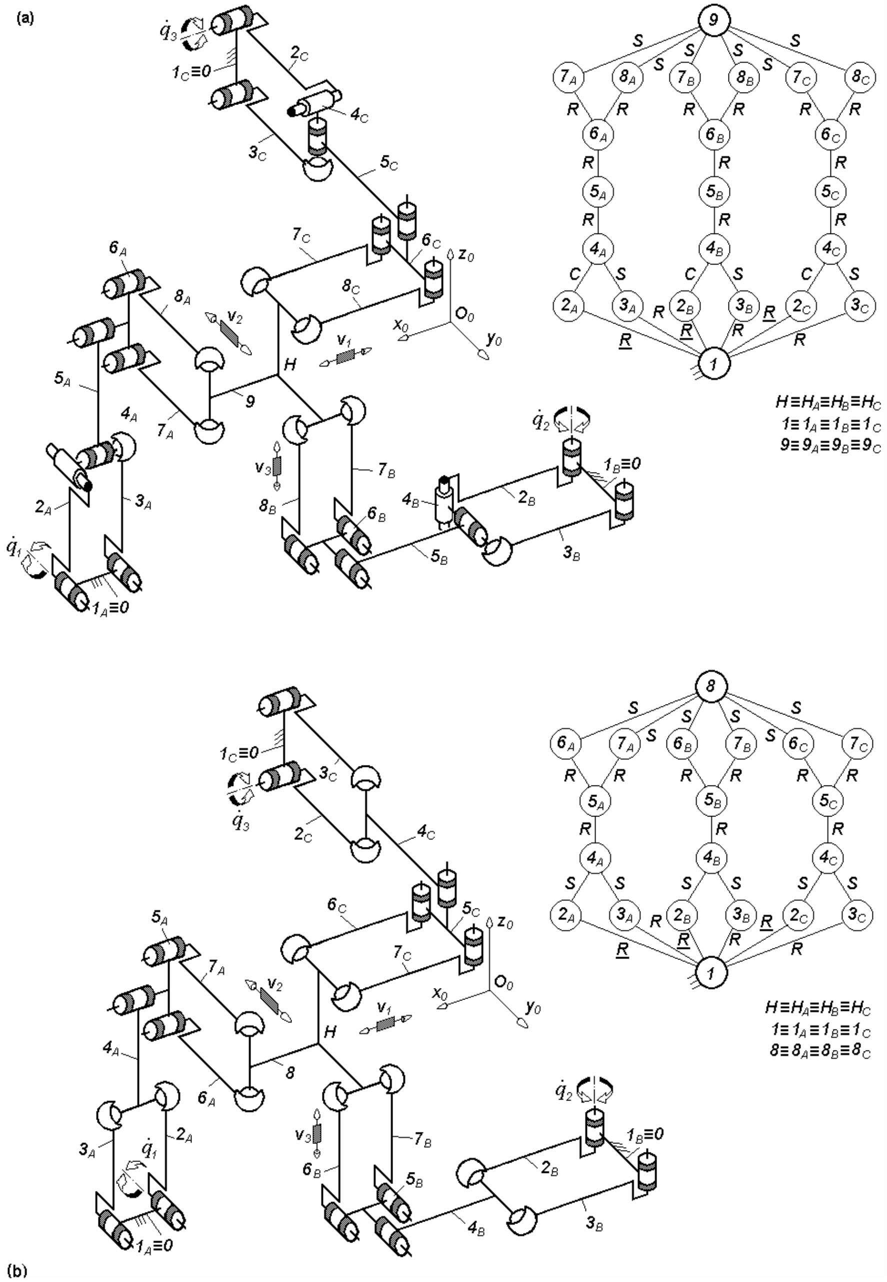


Fig. 6.30 Non overconstrained TPMs with uncoupled motions of types $3\text{-}\underline{Pa}^{cs}RRPa^{ss}$ (**a**) and $3\text{-}\underline{Pa}^{ss}RPa^{ss}$ (**b**), limb topology $\underline{Pa}^{cs} \perp R||R||Pa^{ss}$ (**a**) and $\underline{Pa}^{ss} \perp R||Pa^{ss}$ (**b**)

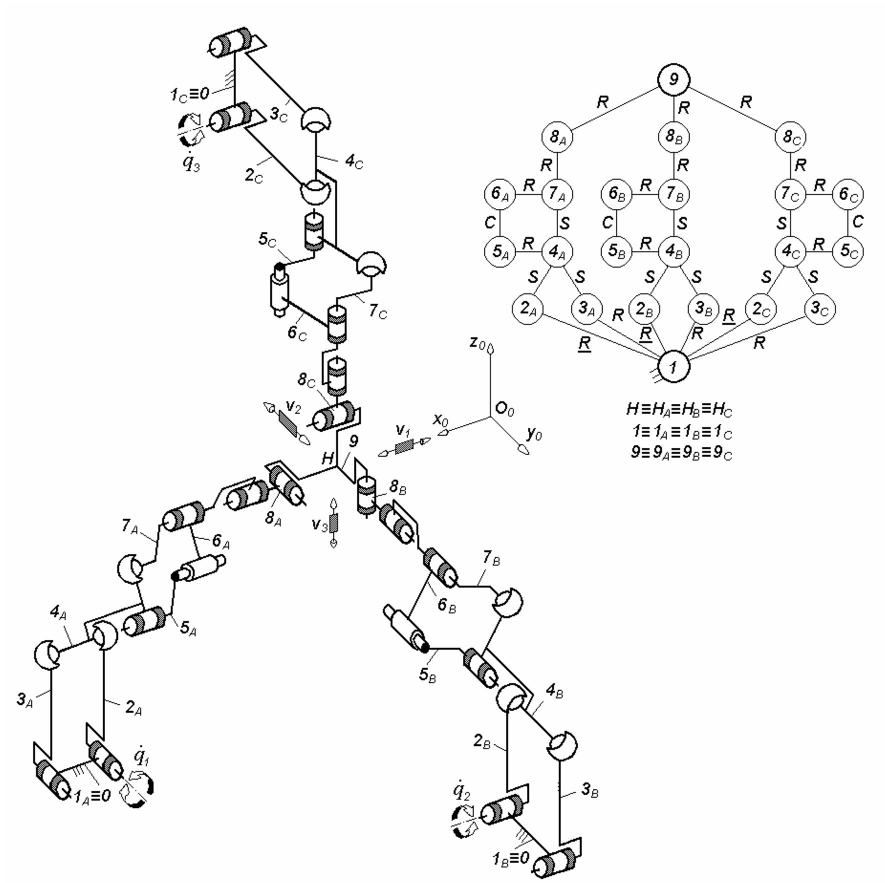


Fig. 6.31. *3-*$\underline{Pa}^{ss}Rb^{cs}RR^*$-type non overconstrained TPM with uncoupled motions, limb topology $\underline{Pa}^{ss} \perp Rb^{cs} || R \perp R^*$

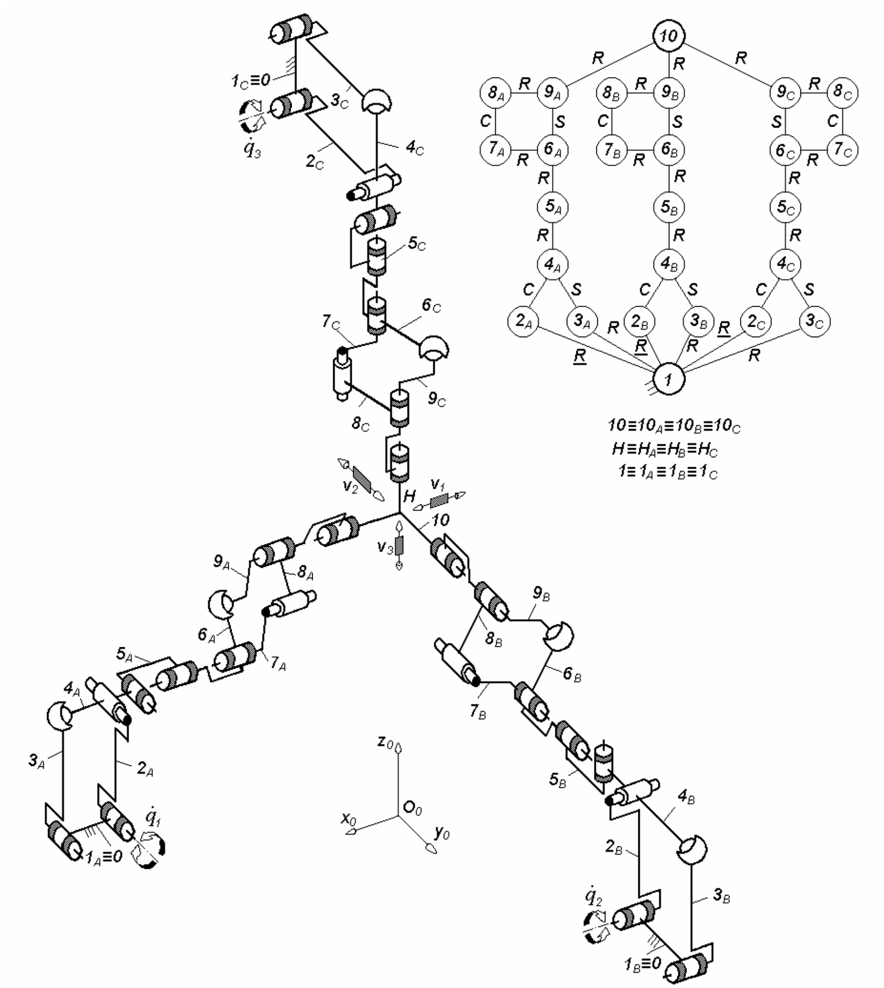


Fig. 6.32. *3-*$\underline{Pa}^{cs}R{*}RRb^{cs}R$-type non overconstrained TPM with uncoupled motions, limb topology $\underline{Pa}^{cs}||R{*}\perp R||Rb^{cs}||R$

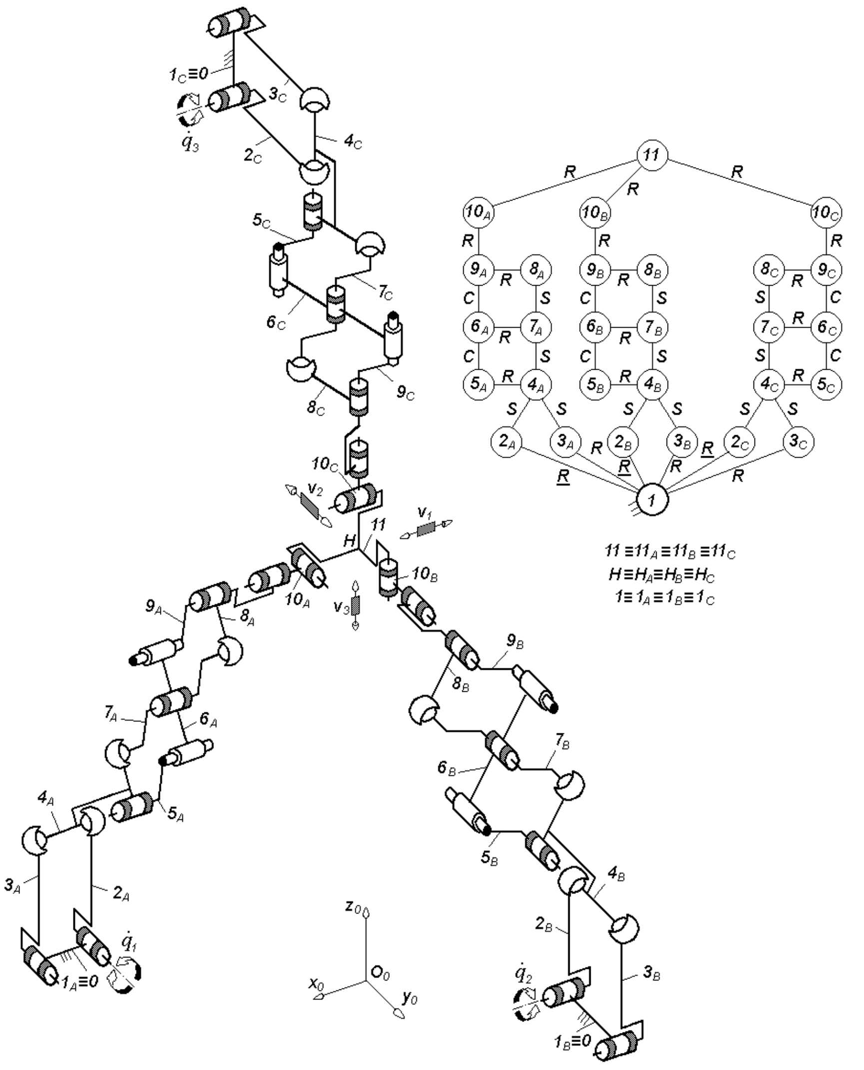


Fig. 6.33. $3\text{-}\underline{Pa}^{ss}Rb^{cs}Rb^{cs}RR^{*}$-type non overconstrained TPM with uncoupled motions, limb topology $\underline{Pa}^{ss} \perp Rb^{cs}||Rb^{cs}||R \perp R^{*}$

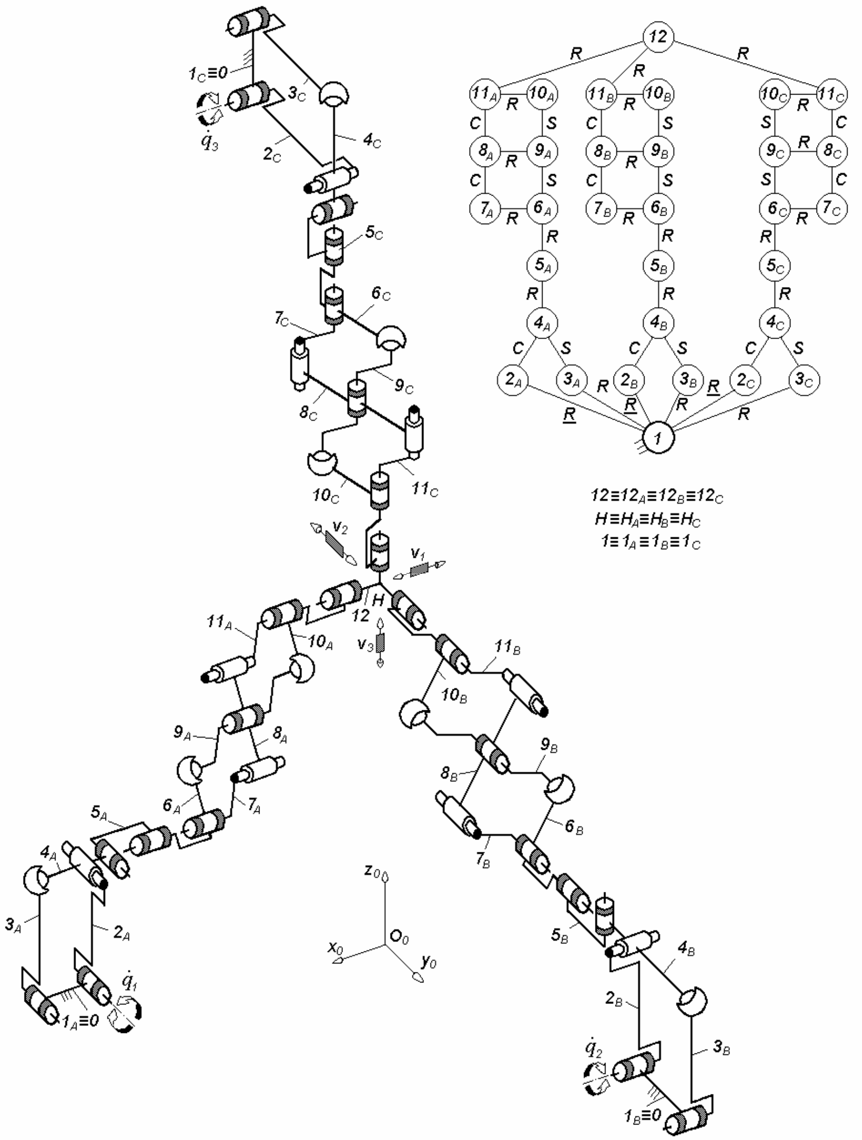


Fig. 6.34. *3-$\underline{Pa}^{cs}R{*}RRb^{cs}Rb^{cs}R$*-type non overconstrained TPM with uncoupled motions, limb topology $\underline{Pa}^{cs}||R\perp R||Rb^{cs}||Rb^{cs}||R$

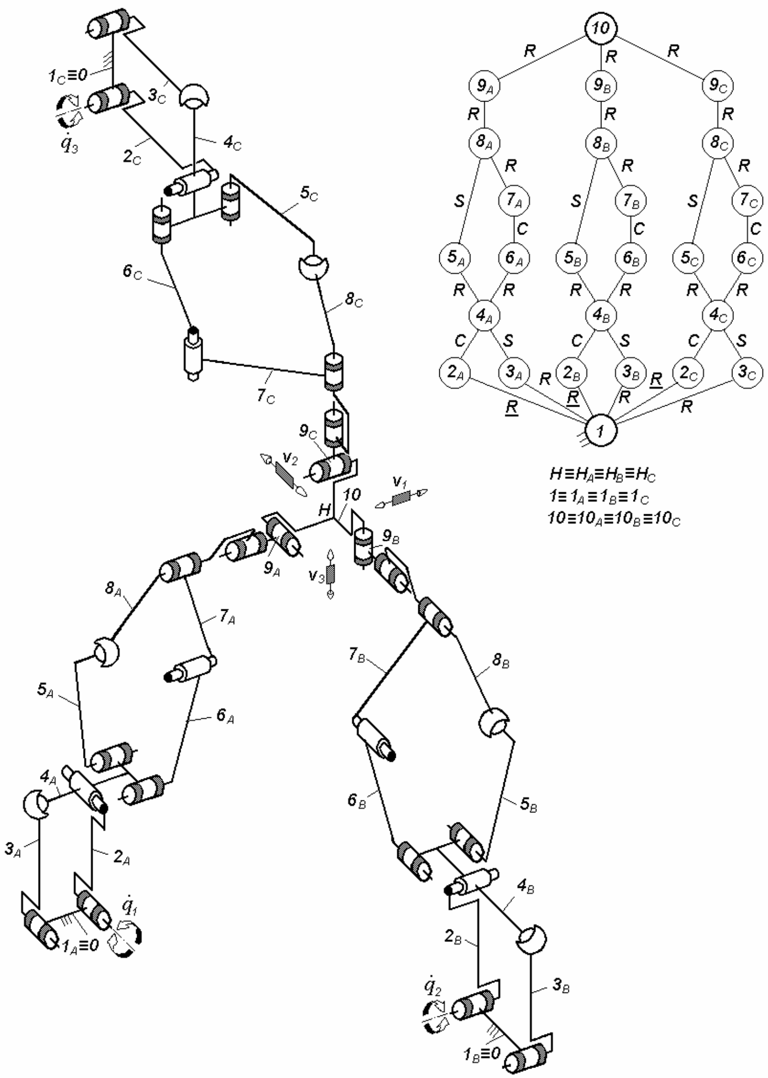


Fig. 6.35. $3\text{-}\underline{Pa}^{cs}Pn2^{cs}RR^{*}$-type non overconstrained TPM with uncoupled motions, limb topology $\underline{Pa}^{cs} \perp Pn2^{cs} || R \perp R^{*}$

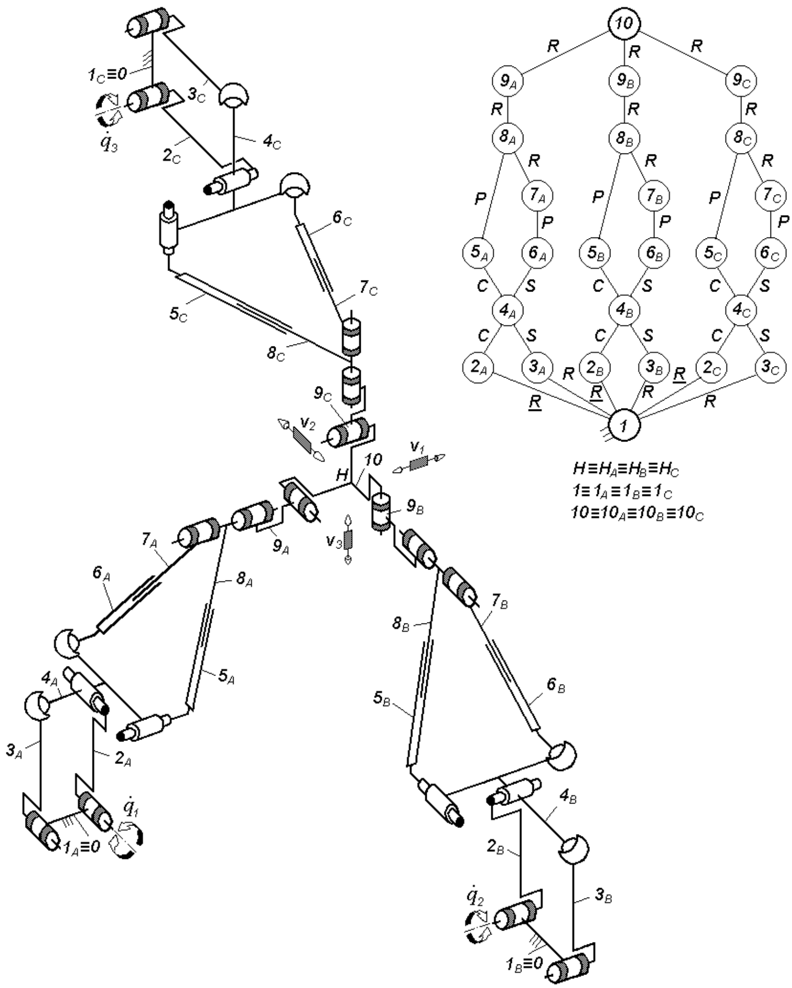


Fig. 6.36. *3-<u>Pa</u>^{cs}Pn2^{cs}RR**-type non overconstrained TPM with uncoupled motions, limb topology <u>*Pa*</u>^{cs} $\perp$ *Pn2*^{cs}||*R* $\perp$ *R**

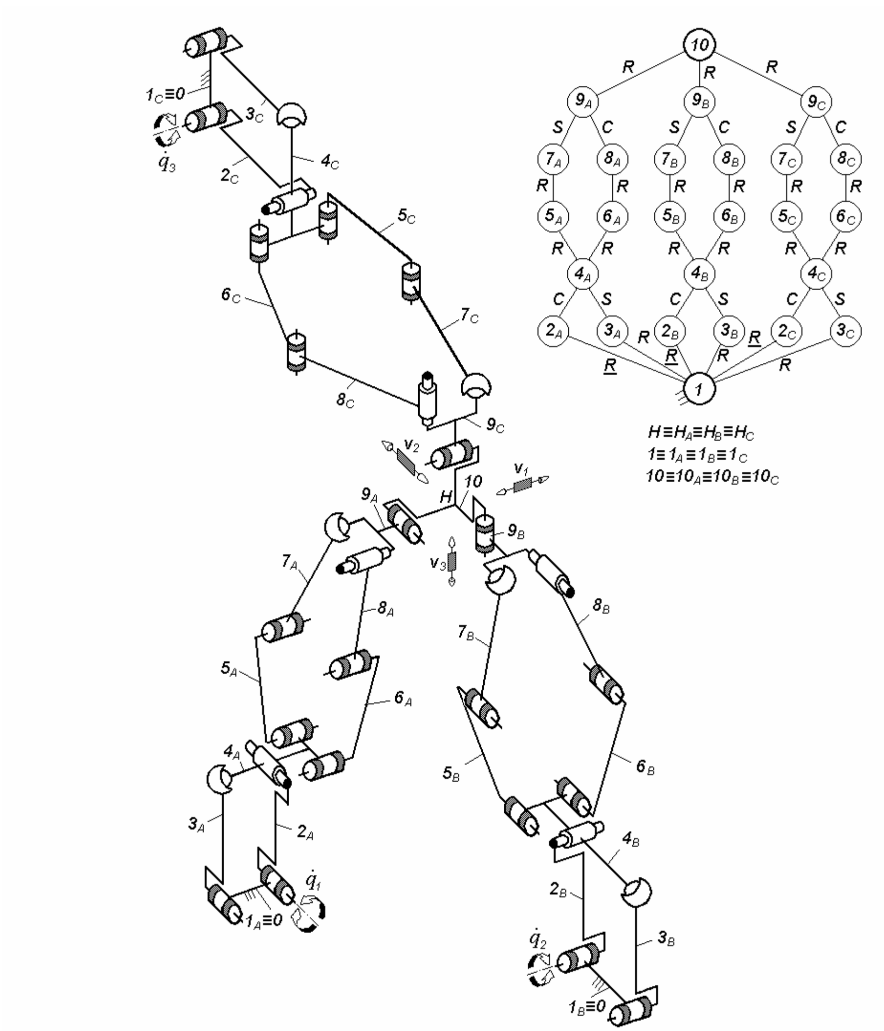


Fig. 6.37. $3\text{-}\underline{Pa}^{cs}Pn3^{cs}R^*$-type non overconstrained TPM with uncoupled motions, limb topology $\underline{Pa}^{cs} \perp Pn3^{cs} \perp R^*$

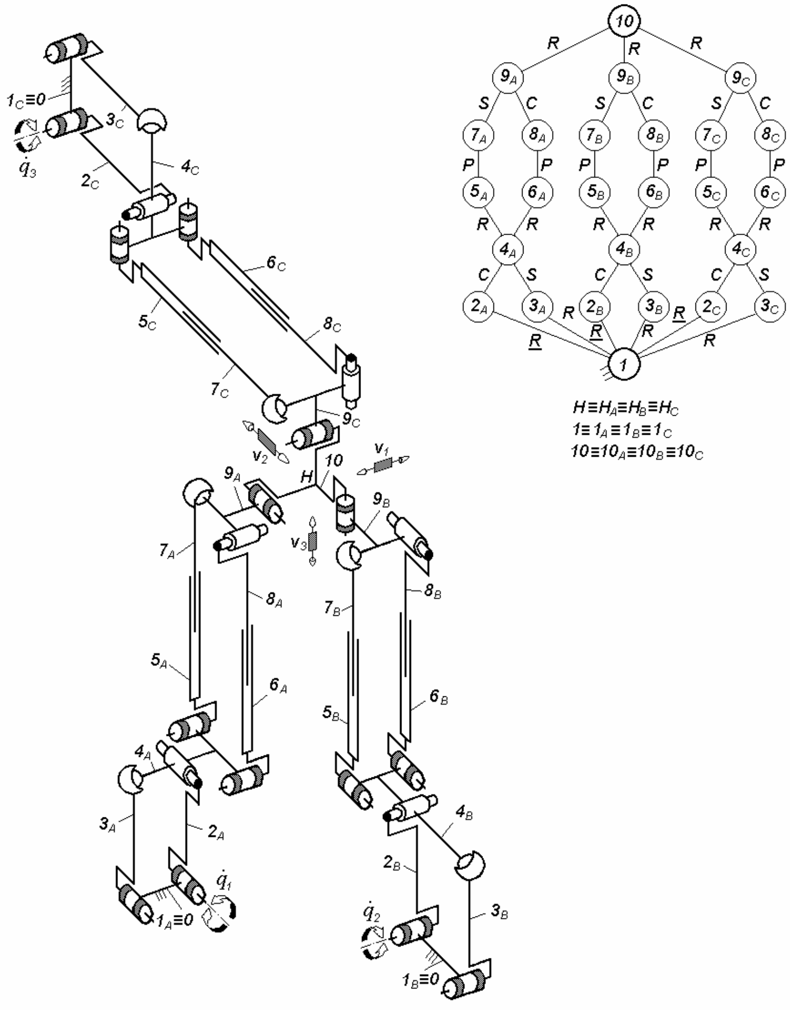


Fig. 6.38. *3-$\underline{Pa}^{cs}Pn3^{cs}R$**-type non overconstrained TPM with uncoupled motions, limb topology $\underline{Pa}^{cs} \perp Pn3^{cs} \perp R^*$

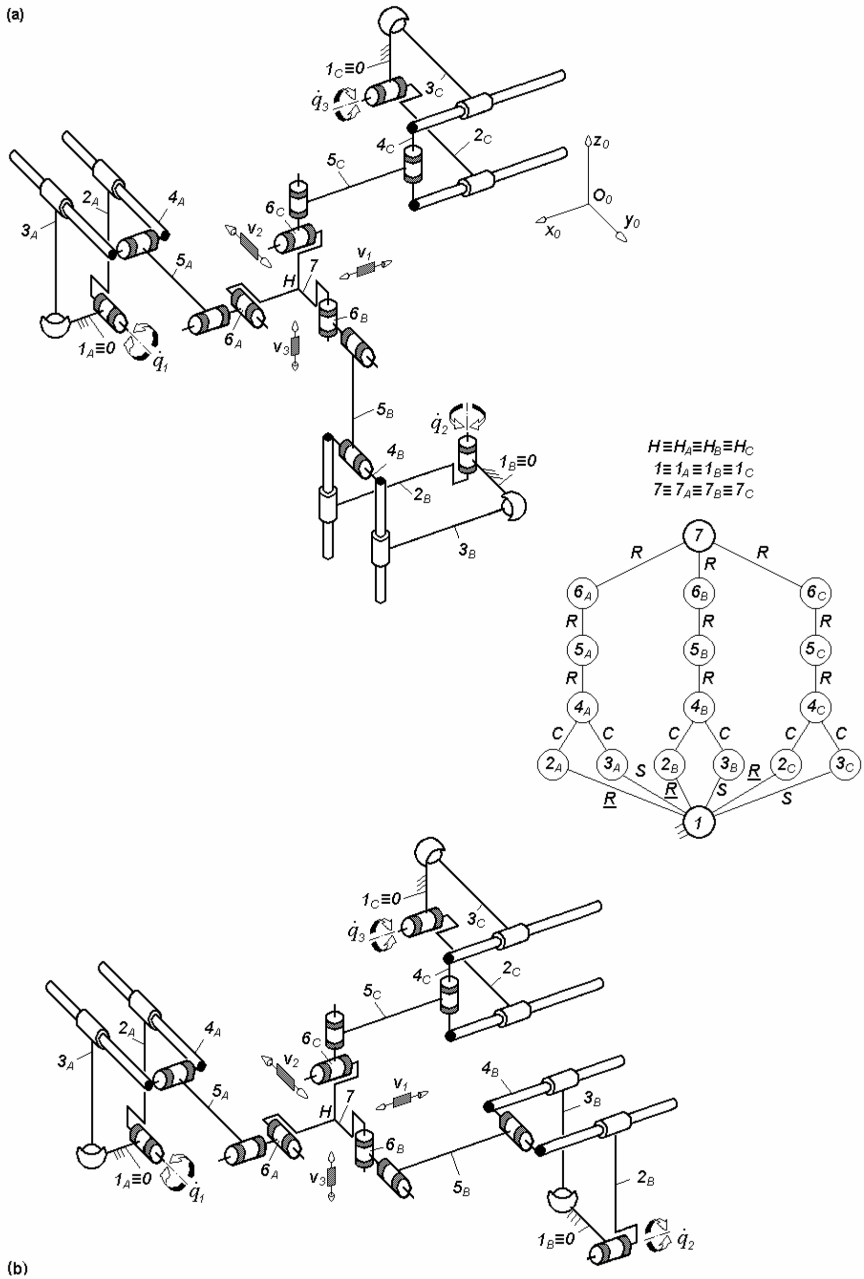


Fig. 6.39. *3-Pa^scc RRR**-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{Pa}^{cs}\perp Pn3^{cs}\perp R^*$

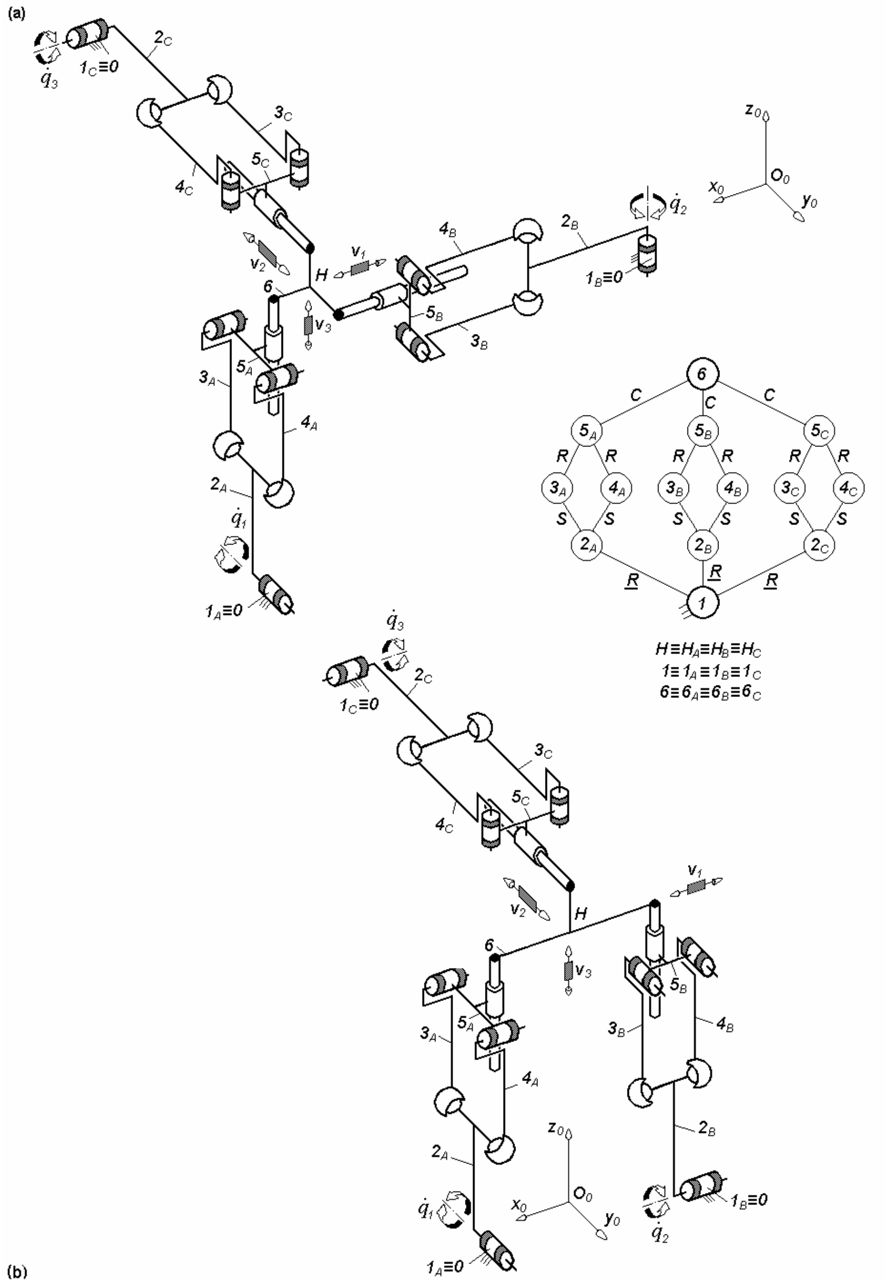


Fig. 6.40. *3-$\underline{R}Pa^{ss}C$**-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{R} \perp Pa^{ss} \perp^{\perp} C^*$

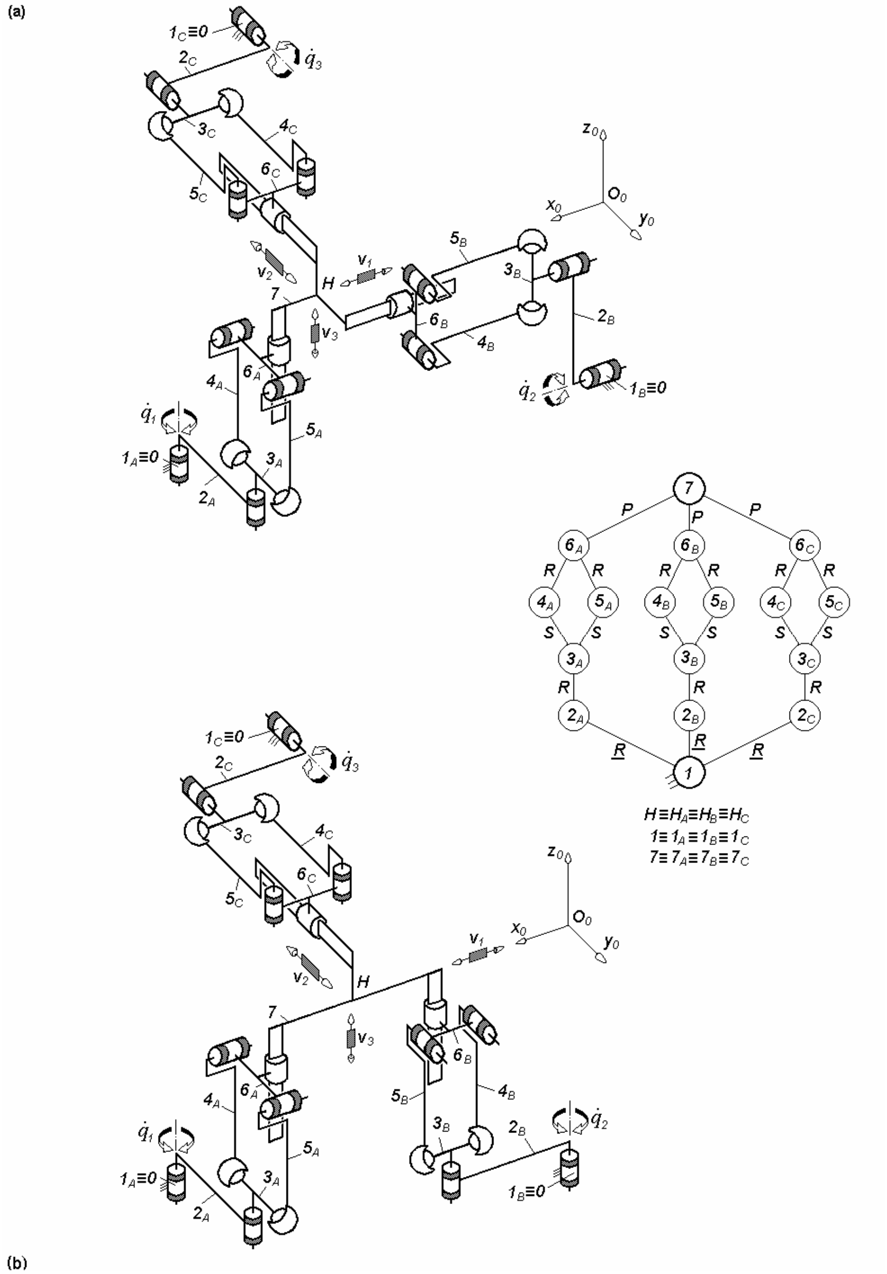


Fig. 6.41. $3\text{-}\underline{R}RPa^{ss}P$-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{R}||R \perp Pa^{ss} \perp^{||} P$

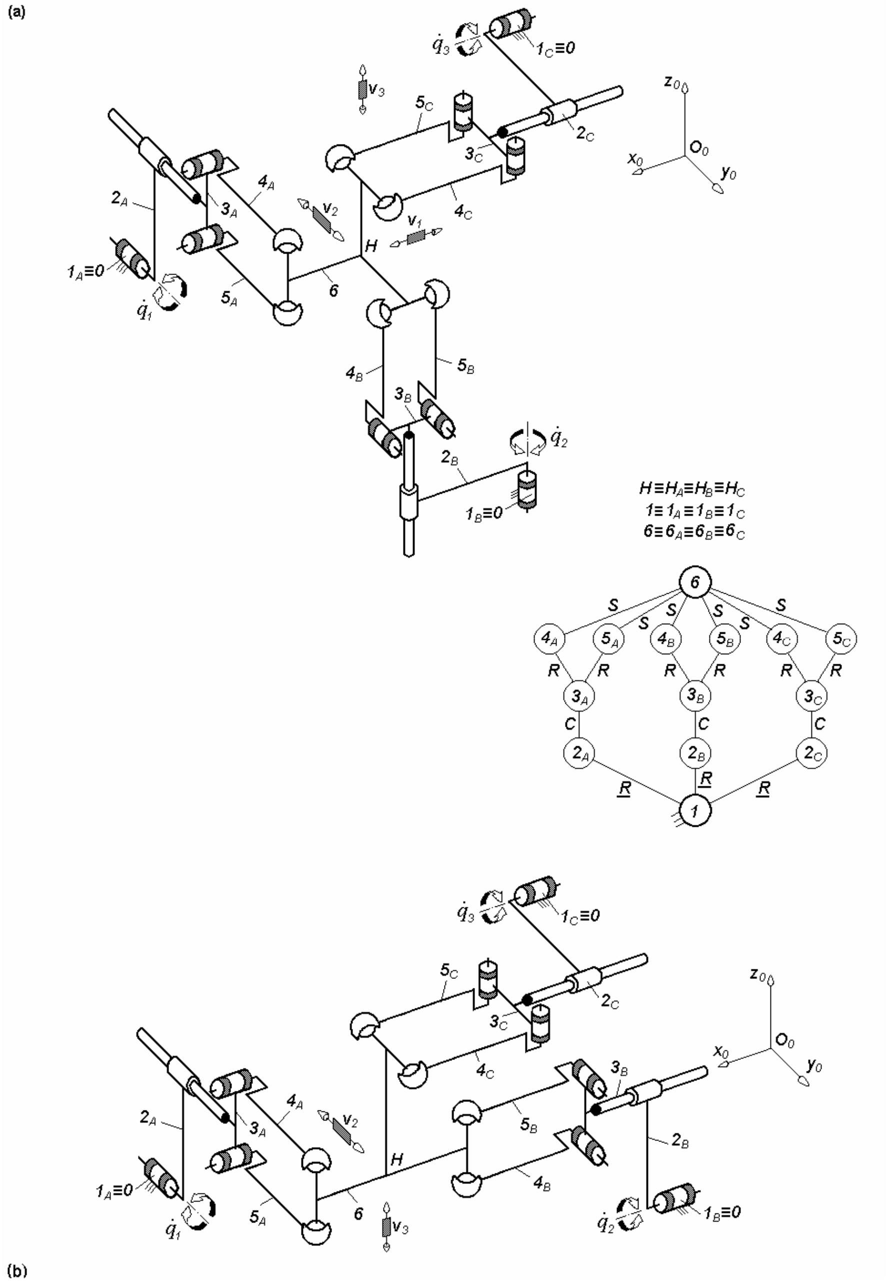


Fig. 6.42. *3-RCPa^{ss}*-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{R}||C \perp Pa^{ss}$

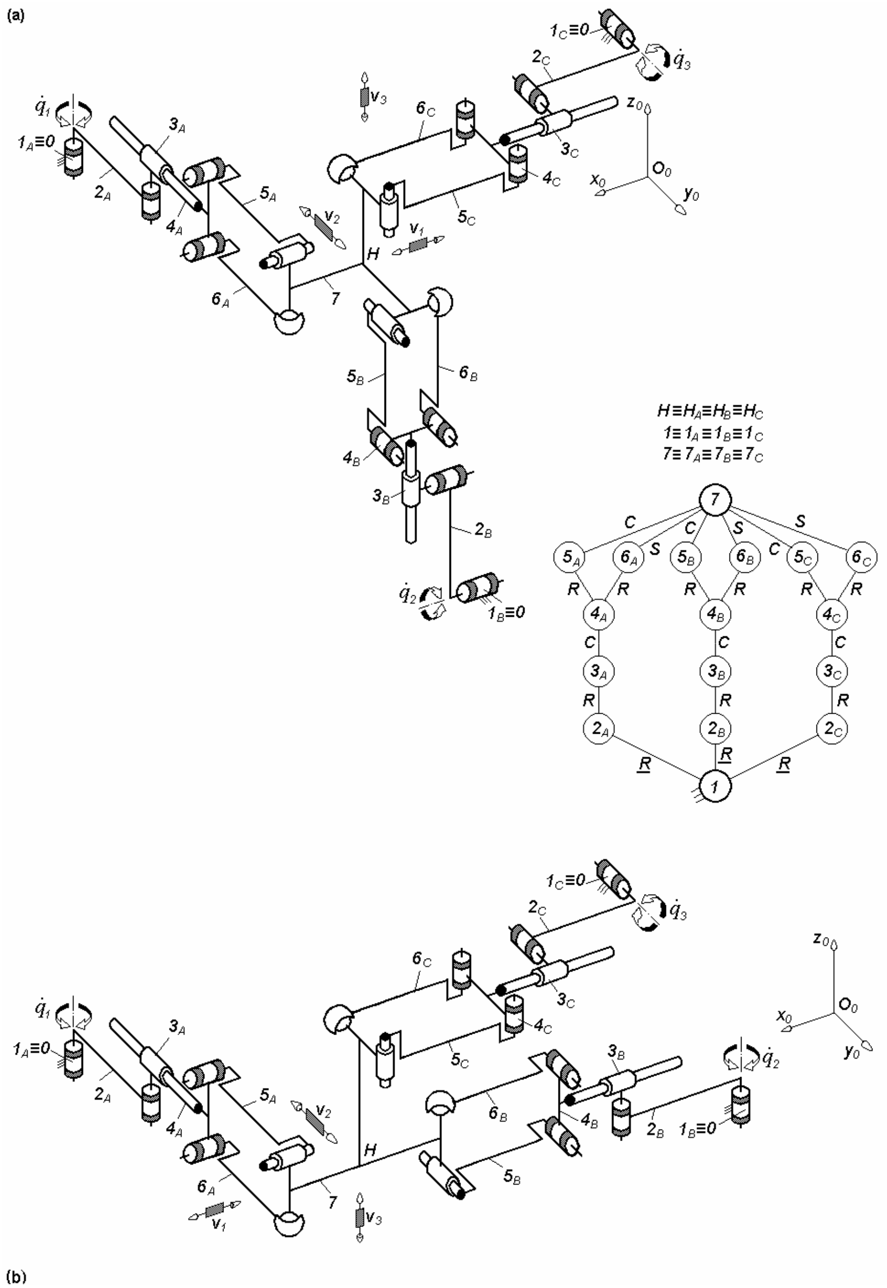


Fig. 6.43. *3-RRC*Pa^cs*-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{R}||R\perp C^{*}\perp^{\perp}Pa^{cs}$

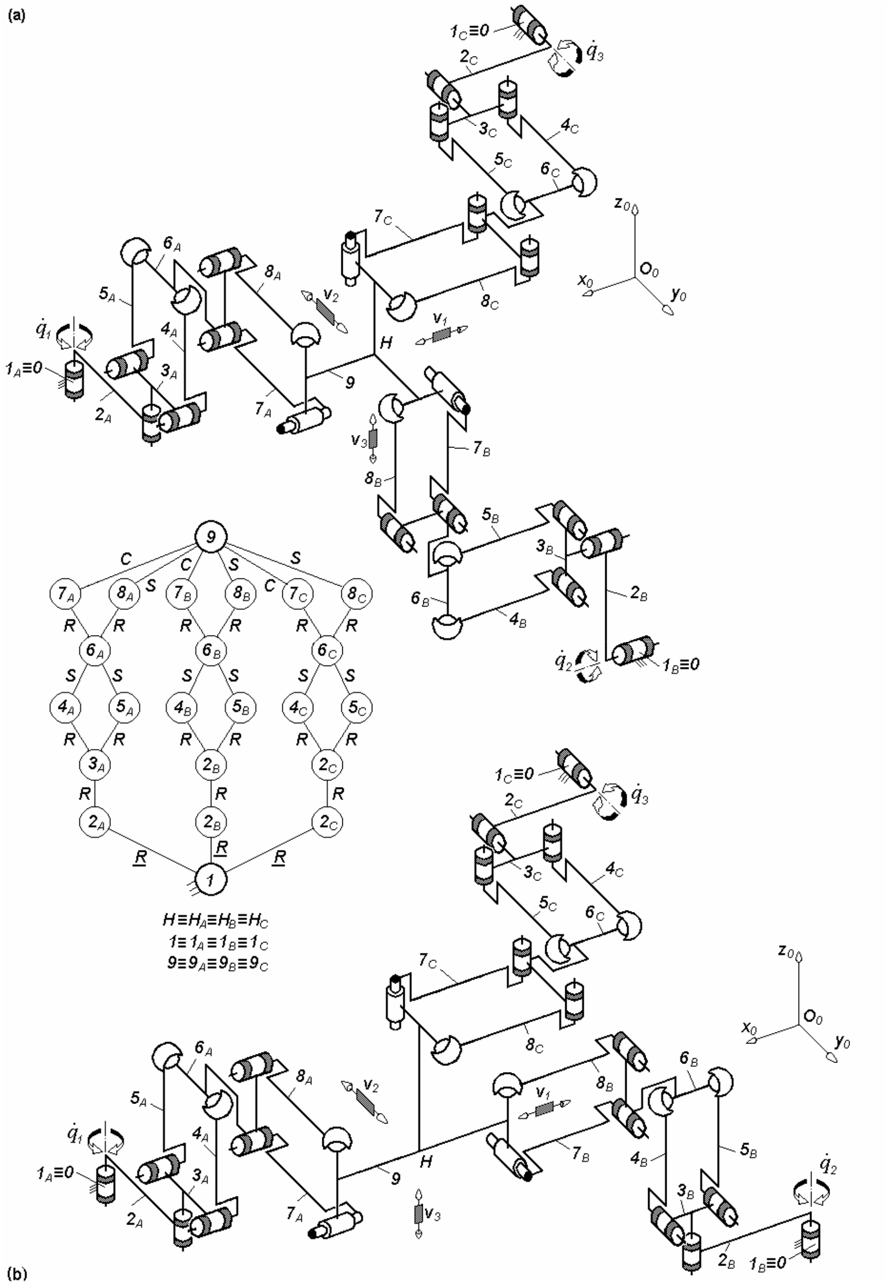


Fig. 6.44. *3-$\underline{R}$RPa^{ss}Pa^{cs}*-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{R}||R \perp Pa^{ss}||Pa^{cs}$

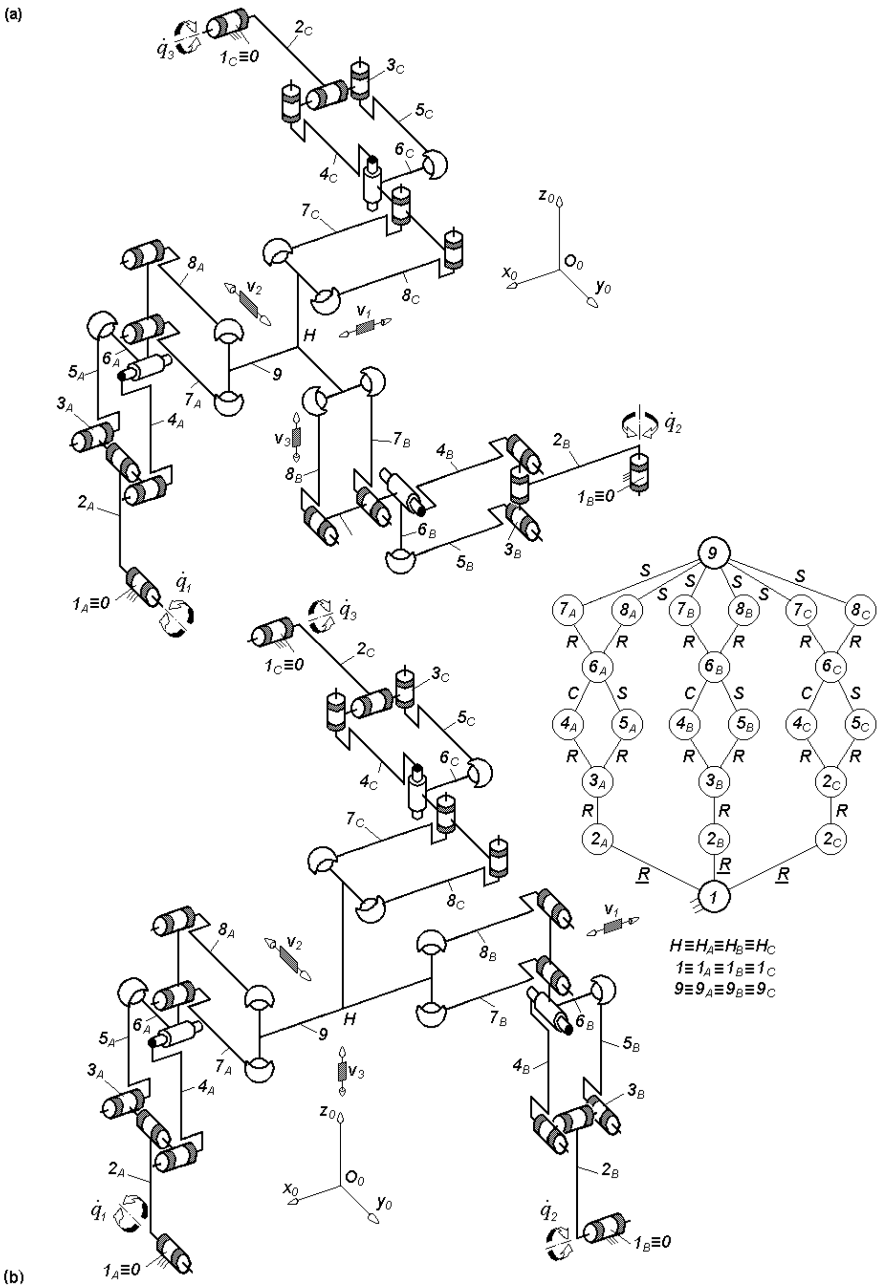


Fig. 6.45 *3-$\underline{R}RPa^{cs}Pa^{ss}$*-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{R}||R\perp Pa^{cs}||Pa^{ss}$

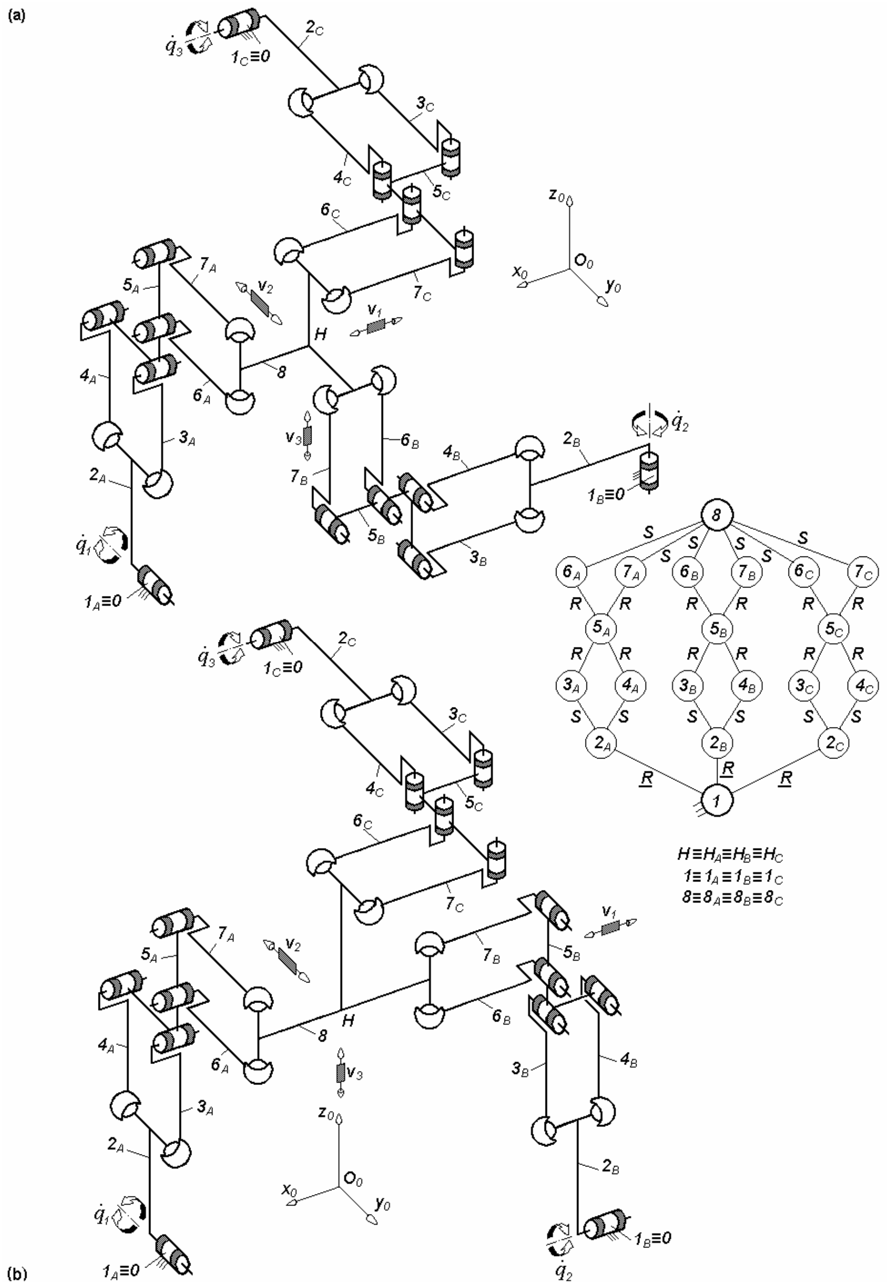


Fig. 6.46 *3-<u>R</u>Pa^ss^Pa^ss*-type non overconstrained TPMs with uncoupled motions, limb topology $\underline{R} \perp Pa^{ss} || Pa^{ss}$

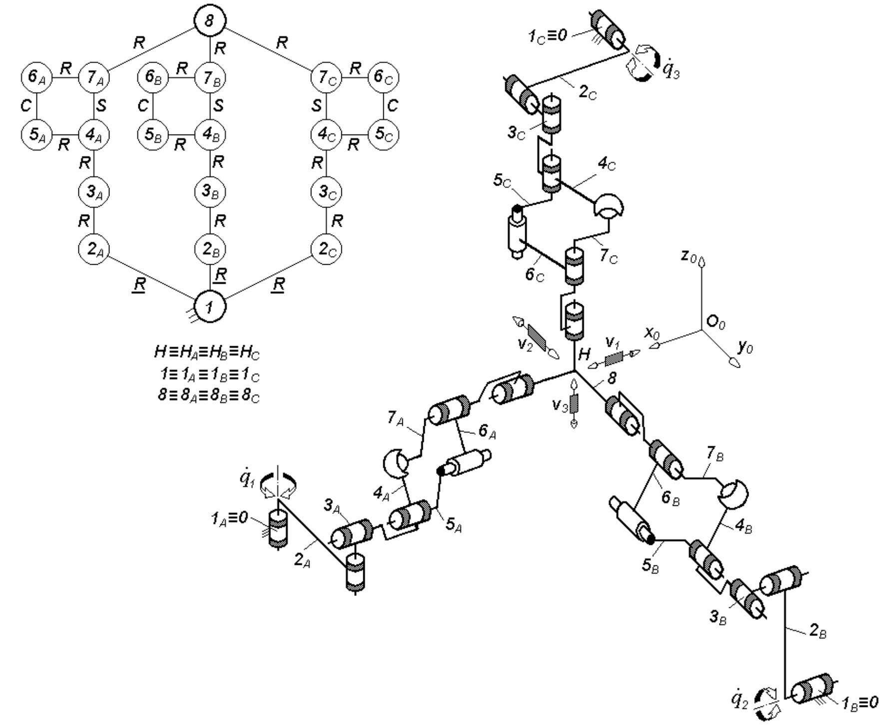


Fig. 6.47. *3-$\underline{R}$RRRb^{cs}R*-type non overconstrained TPM with uncoupled motions, limb topology $\underline{R}||R\perp R||Rb^{cs}||R$

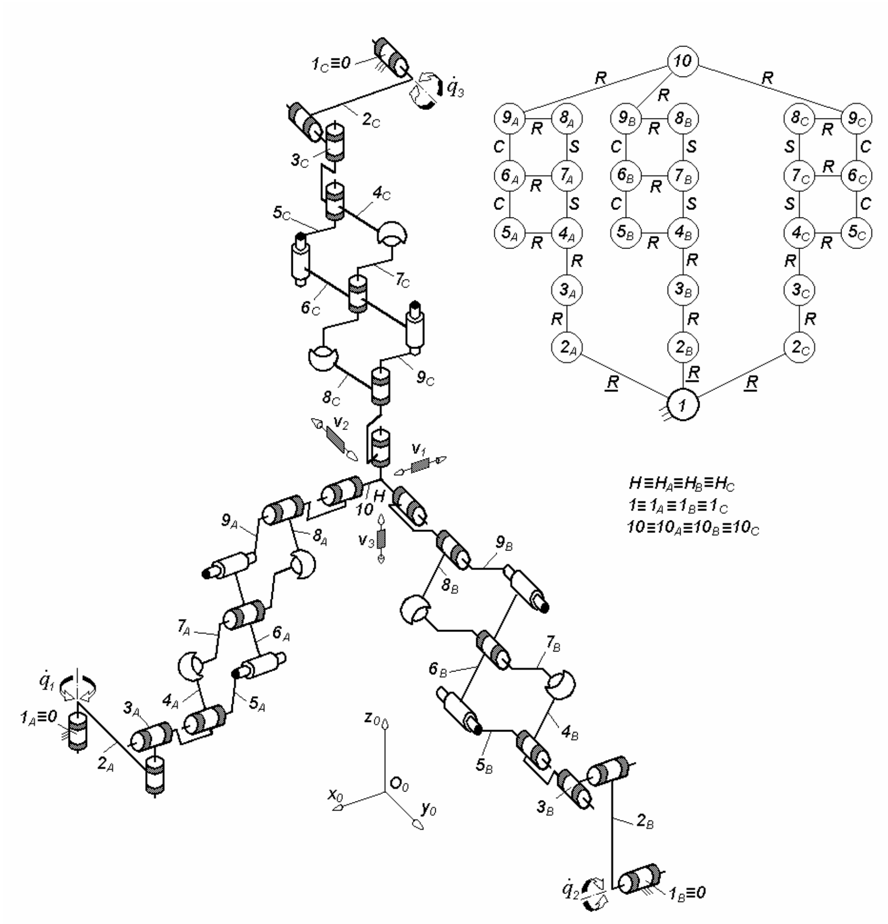


Fig. 6.48. *3-<u>R</u>RRRb^{cs}Rb^{cs}R*-type non overconstrained TPM with uncoupled motions, limb topology $\underline{R}||R \perp R||Rb^{cs}||Rb^{cs}||R$

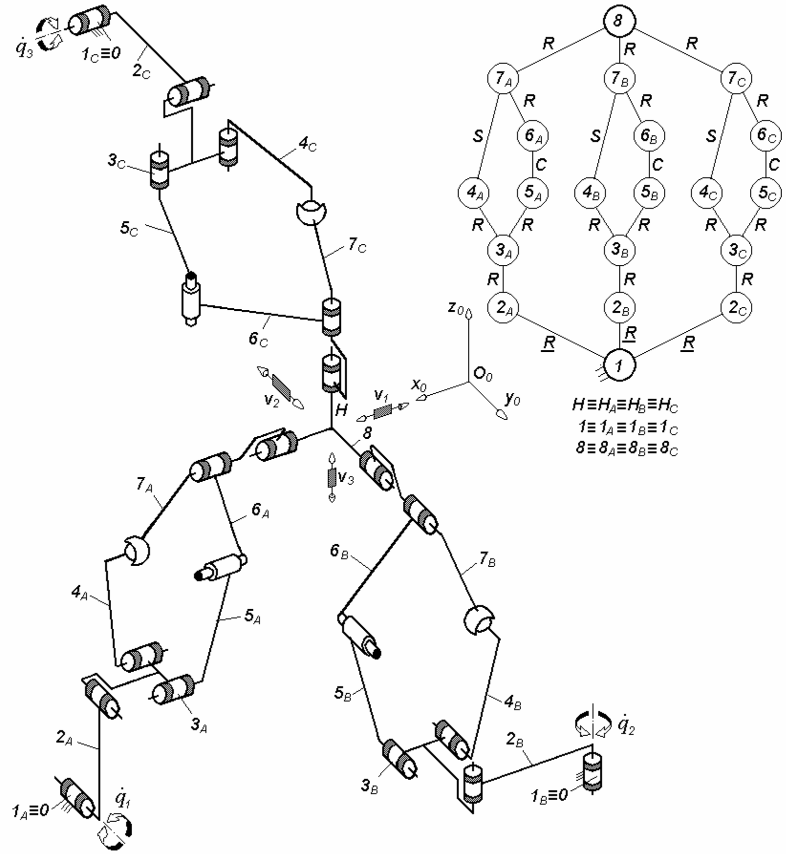


Fig. 6.49. *3-RRPn2^cs R*-type non overconstrained TPM with uncoupled motions, limb topology $\underline{R}||R \perp Pn2^{cs}||R$

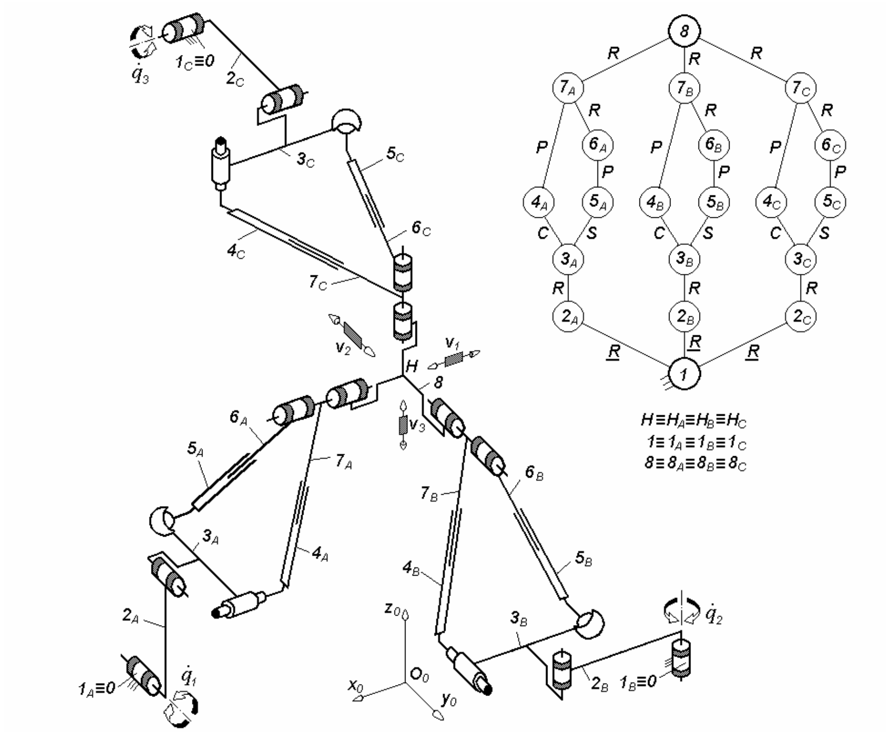


Fig. 6.50. *3-RRPn2^cs R*-type non overconstrained TPM with uncoupled motions, limb topology $\underline{R}||R\perp Pn3^{cs}||R$

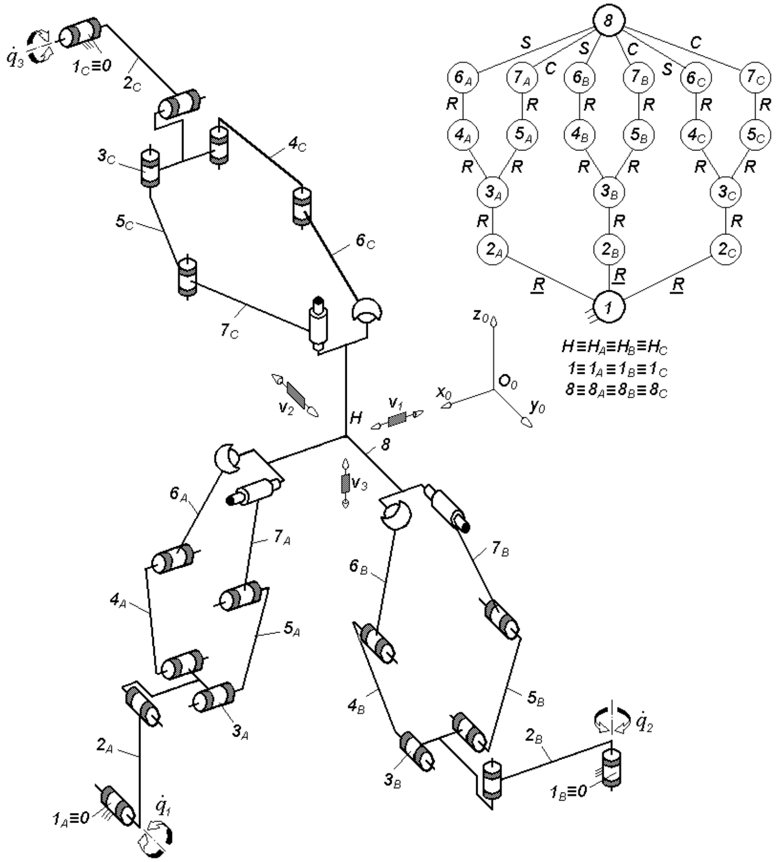


Fig. 6.51. *3-$\underline{R}$RPn3^{cs}*-type non overconstrained TPM with uncoupled motions, limb topology $\underline{R}||R \perp Pn3^{cs}$

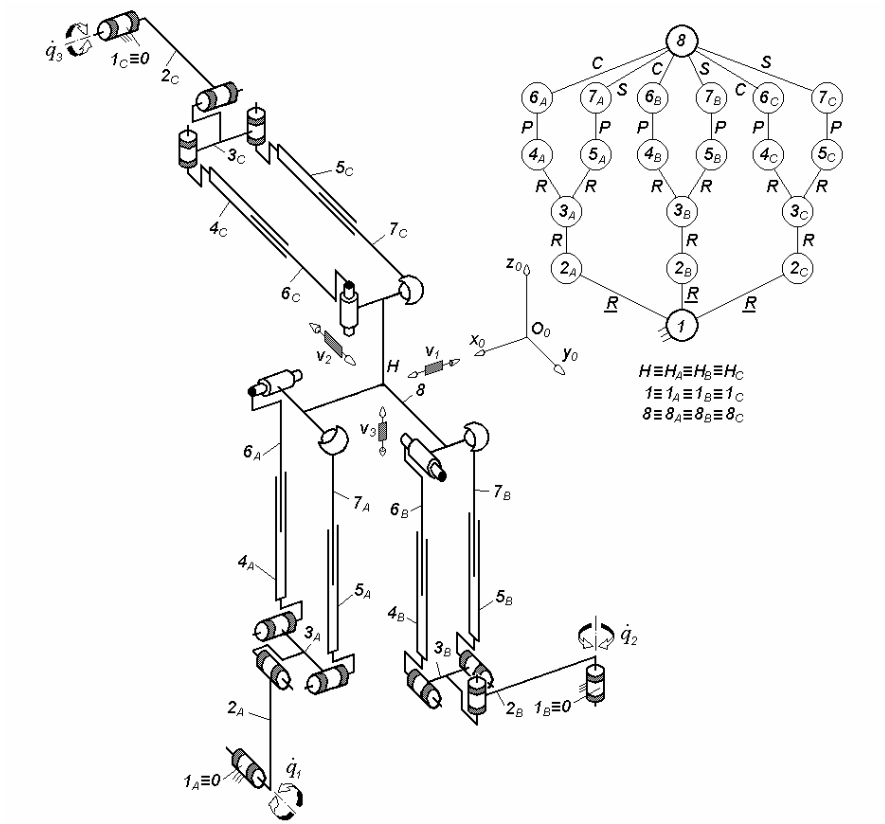


Fig. 6.52. *3-RRPn3*^{cs}-type non overconstrained TPM with uncoupled motions, limb topology $\underline{R}||R \perp Pn3^{cs}$

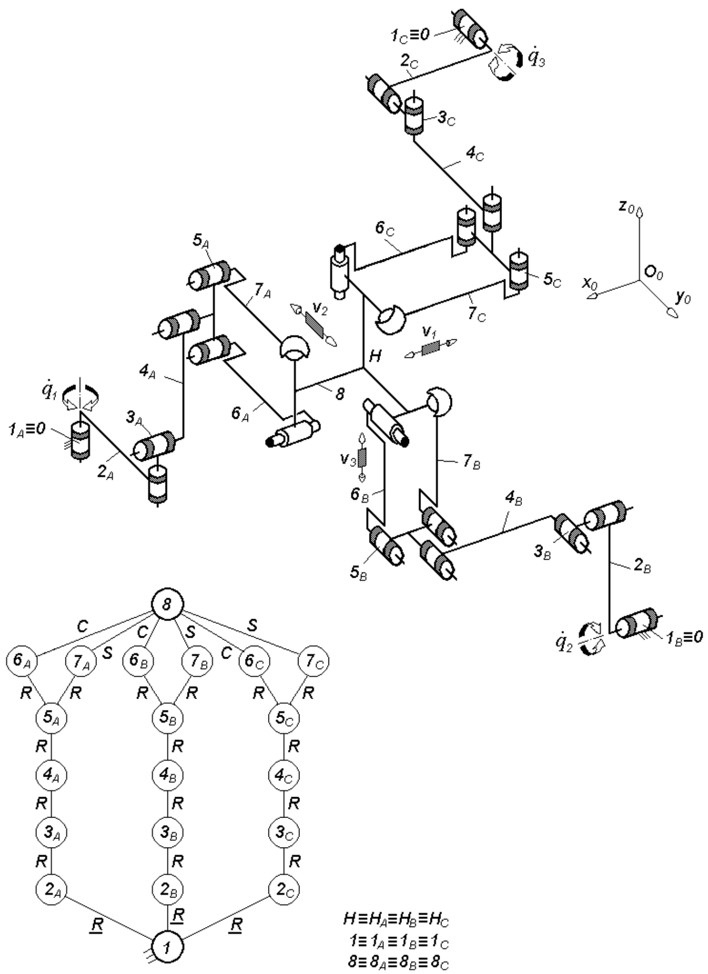


Fig. 6.53. *3-*$\underline{R}RRRPa^{cs}$-type non overconstrained TPM with uncoupled motions, limb topology $\underline{R}||R \perp R||R\ ||Pa^{cs}$

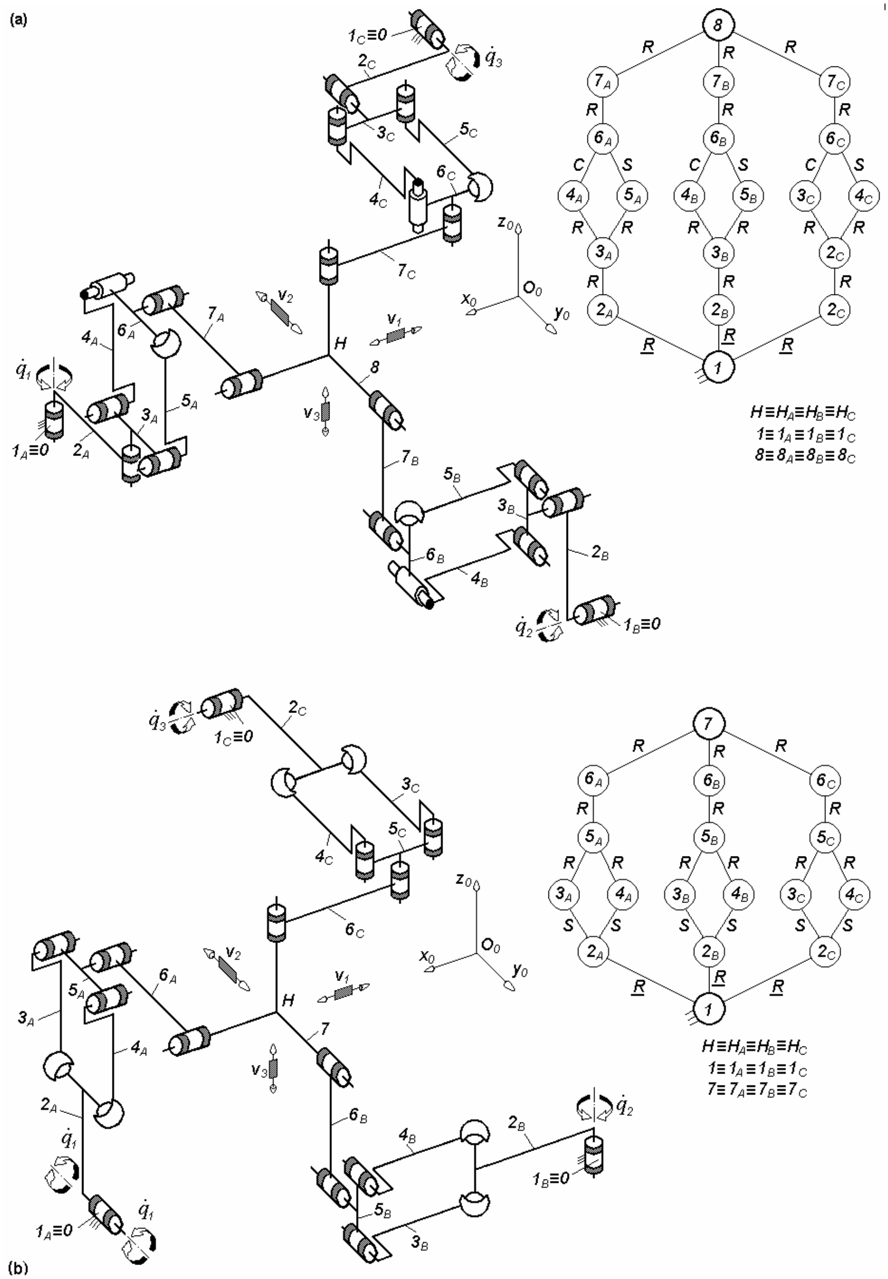


Fig. 6.54. Non overconstrained TPM with uncoupled motions of types *3-*$\underline{R}RPa^{cs}RR$ (**a**) and *3-*$\underline{R}Pa^{ss}RR$ (**b**), limb topology $\underline{R}||R \perp Pa^{cs}||R||R$ (**a**) and $\underline{R} \perp Pa^{ss}||R||R$ (**b**)