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The Matching Equivalent Classes of

$$P_2 \cup I_6 \cup T(1,1,n)$$

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ABSTRACT: Completely characterize the matching equivalent classes of $P_2 \cup I_6 \cup T(1,1,n)$, by the property of graph's matching polynomial and its maximum roots.

KEYWORDS: Matching polynomial, Matching equivalence, Matching uniqueness, The maximum real roots.

I. INTRODUCTION

All graphs considered in this paper are undirected and simple (i.e., loops and multiple edges are not allowed). Let $G = (V(G), E(G))$ be a graph with vertex set $V(G) = \{v_1, v_2, \dots, v_n\}$ and edge set $E(G) = \{e_1, e_2, \dots, e_m\}$, where $|V(G)| = n$ is the order and $|E(G)| = m$ is the size of G . A spanning subgraph H is called a matching of G , if every connected component of H is isolated edge or isolated vertex. k -matching of G is a matching with k edges. In [1] E. J. Farrell denote the matching polynomial as

$$\mu(G, x) = \sum_{k \geq 0} (-1)^k p(G, k) x^{n-2k},$$

where $p(G, k)$ is the number of k -matchings of G .

Two graphs G and H are called matching-equivalent if $\mu(G, x) = \mu(H, x)$, and denoted by $G \sim H$. The disjoint union of two graphs G and H , denoted by $G \cup H$, is the graph with vertex set $V(G) \cup V(H)$ and edge set $E(G) \cup E(H)$. kG denotes the disjoint union of k copies of G . Let $M(G)$ be the largest matching root of $\mu(G, x)$. We denote by P_n ($n \geq 1$), C_n ($n \geq 3$) a path and a cycle of order n , respectively. A graph $D_{m,n}$ ($m \geq 3, n \geq 1$) is defined as the graph obtained by identifying one end of the path P_{n+1} with a vertex of the cycle C_m . By $T(a, b, c)$ denote the tree which has one 3-degree vertex u and three 1-degree vertices v_1, v_2, v_3 and the distance between u and v_1, v_2, v_3 are a, b, c , respectively. Let P_{n-2} be a path with vertices sequence $1, 2, \dots, n-2$, I_n ($n \geq 6$) denotes the tree obtained by adding pendant edges at vertices 2 and $n-3$ of P_{n-2} , respectively. For a graph G , let G^c be the complement of G . The classes of matching equivalent graphs determined by G under \sim is denoted by $[G]$. In this paper, we Completely characterize the matching equivalent classes of $P_2 \cup I_6 \cup T(1,1,n)$.

II. PRELIMINARIES

Lemma 2.1[1] Let G be a graph with k components G_1, G_2, \dots, G_k . Then $\mu(G, x) = \prod_{i=1}^k \mu(G_i, x)$.

Lemma 2.2 [1] Let $e = uv \in E(G)$. Then $\mu(G, x) = \mu(G - e, x) - \mu(G - \{u, v\}, x)$.

Lemma 2.3 [1] Let G be a connected graph and $u \in V(G)$, $e \in E(G)$. Then $M(G)$ is a single root of $\mu(G, x)$ and $M(G) > M(G - u)$, $M(G) > M(G - e)$.

Lemma 2.4 [3] Let G be a connected graph. Then

(1) $M(G) < 2$ if and only if $G \in \Omega_1 = \{K_1, P_n, C_n, T(1, 1, n), T(1, 2, i) (2 \leq i \leq 4), D_{3,1}\}$;

(2) $M(G) = 2$ if and only if $G \in \Omega_2 = \{K_{1,4}, T(2, 2, 2), T(1, 3, 3), T(1, 2, 5), I_n, D_{3,2}, D_{4,1}\}$.

Lemma 2.5 [4] Let $M(G) < 2$. Then graph G is matching uniquely if and only if $G = kK_1 \cup m_2P_2 \cup m_3P_3 \cup [\bigcup_{i \geq 2} m_{2i}P_{2i}] \cup [\bigcup_{j \geq 3} n_jC_j] \cup dD_{3,1} \cup eT(1, 2, 3) \cup fT(1, 2, 4)$, where $kn_j = m_i n_{i+1} = m_2d = m_3d = n_3e = n_{15}e = n_3n_5f = n_5n_9f = 0$ and k, m_i, n_j, d, e, f are non-negative integer.

Lemma 2.6 [5] (1) $P_{2m+1} \sqsubset P_m \cup C_{m+1}$ ($m \geq 2$) (2) $T(1, 1, n) \sqsubset K_1 \cup C_{n+2}$

(3) $T(1, 2, 2) \sqsubset P_2 \cup D_{3,1}$ (4) $K_1 \cup C_6 \sqsubset P_3 \cup D_{3,1}$

(5) $K_1 \cup C_9 \sqsubset C_3 \cup T(1, 2, 3)$ (6) $K_1 \cup C_{15} \sqsubset C_3 \cup C_5 \cup T(1, 2, 4)$

Lemma 2.7 [6] (1) $D_{3,2} \sqsubset D_{4,1}$ (2) $K_1 \cup D_{3,2} \sqsubset I_6$

(3) $T(2, 2, 2) \sqsubset P_2 \cup D_{3,2}$ (4) $T(1, 3, 3) \sqsubset P_3 \cup D_{3,2}$

(5) $T(1, 2, 5) \sqsubset P_4 \cup D_{3,2}$ (6) $K_1 \cup I_6 \sqsubset P_2 \cup K_{1,4}$

(7) $P_{m-4} \cup I_n \sqsubset P_{n-4} \cup I_m$ ($m, n \geq 6$) (8) $I_{2m-3} \sqsubset I_m \cup C_{m-3}$ ($m \geq 6$)

Lemma 2.8 [5] $G \sim H$ if and only if $G^c \sim H^c$.

III. MAIN RESULTS

Theorem 3.1 Let $[P_2 \cup I_6 \cup T(1, 1, n)]$ be the classes of matching equivalent graphs of $P_2 \cup I_6 \cup T(1, 1, n)$.

Then

(1) If $n \neq 1, 4, 7, 13$, $[P_2 \cup I_6 \cup T(1, 1, n)] = \{2P_2 \cup K_{1,4} \cup C_{n+2}, K_1 \cup T(2, 2, 2) \cup T(1, 1, n), 2K_1 \cup T(2, 2, 2) \cup C_{n+2}, K_1 \cup P_2 \cup I_6 \cup C_{n+2}, K_1 \cup P_2 \cup D_{3,2} \cup T(1, 1, n), 2K_1 \cup P_2 \cup D_{3,2} \cup C_{n+2}, K_1 \cup P_2 \cup D_{4,1} \cup T(1, 1, n), 2K_1 \cup P_2 \cup D_{4,1} \cup C_{n+2}\}$;

(2) If $n = 1$, $[P_2 \cup I_6 \cup T(1, 1, 1)] = \{2P_2 \cup K_{1,4} \cup C_3, P_2 \cup K_{1,4} \cup P_5, K_1 \cup P_2 \cup I_6 \cup C_3, K_1 \cup I_6 \cup P_5, K_1 \cup P_2 \cup I_9, K_1 \cup P_2 \cup D_{3,2} \cup T(1, 1, 1), 2K_1 \cup P_2 \cup D_{3,2} \cup C_3, 2K_1 \cup P_5 \cup D_{3,2}, K_1 \cup P_2 \cup D_{4,1} \cup T(1, 1, 1), 2K_1 \cup P_2 \cup D_{4,1} \cup C_3, 2K_1 \cup P_5 \cup D_{4,1}\}$;

(3) If $n = 4$, $[P_2 \cup I_6 \cup T(1, 1, 4)] = \{K_1 \cup T(2, 2, 2) \cup T(1, 1, 4), 2K_1 \cup T(2, 2, 2) \cup C_6, K_1 \cup P_3 \cup D_{3,1} \cup T(2, 2, 2), K_1 \cup P_2 \cup C_6 \cup I_6, P_2 \cup P_3 \cup D_{3,1} \cup I_6, P_3 \cup T(1, 2, 2) \cup I_6, K_1 \cup P_2 \cup D_{3,2} \cup T(1, 1, 4), 2K_1 \cup P_2 \cup C_6 \cup D_{3,2}, K_1 \cup P_2 \cup P_3 \cup D_{3,1} \cup D_{3,2}, K_1 \cup P_3 \cup T(1, 2, 2) \cup D_{3,2}, K_1 \cup P_2 \cup D_{4,1} \cup T(1, 1, 4), 2K_1 \cup P_2 \cup C_6 \cup D_{4,1}, K_1 \cup P_2 \cup P_3 \cup D_{3,1} \cup D_{4,1}, K_1 \cup P_3 \cup T(1, 2, 2) \cup D_{4,1}\}$;

(4) If $n = 7$, $[P_2 \cup I_6 \cup T(1, 1, 7)] = \{K_1 \cup T(2, 2, 2) \cup T(1, 1, 7), 2K_1 \cup T(2, 2, 2) \cup C_9, K_1 \cup C_3 \cup T(1, 2, 3) \cup T(2, 2, 2), K_1 \cup P_2 \cup C_9 \cup I_6, P_2 \cup C_3 \cup T(1, 2, 3) \cup I_6, P_5 \cup T(1, 2, 3) \cup I_6, K_1 \cup P_2 \cup D_{3,2} \cup T(1, 1, 7), 2K_1 \cup P_2 \cup C_9 \cup D_{3,2}, K_1 \cup P_2 \cup C_3 \cup T(1, 2, 3) \cup D_{3,2}, K_1 \cup P_5 \cup$

$T(1,2,3) \cup D_{3,2}, K_1 \cup P_2 \cup D_{4,1} \cup T(1,1,7), 2K_1 \cup P_2 \cup C_9 \cup D_{4,1}, K_1 \cup P_2 \cup C_3 \cup T(1,2,3) \cup D_{4,1}, K_1 \cup P_5 \cup T(1,2,3) \cup D_{4,1}$ };

(5) If $n=13$, $[P_2 \cup I_6 \cup T(1,1,13)] = \{K_1 \cup T(2,2,2) \cup T(1,1,13), 2K_1 \cup T(2,2,2) \cup C_{15}, K_1 \cup C_3 \cup C_5 \cup T(1,2,4) \cup T(2,2,2), K_1 \cup P_2 \cup C_{15} \cup I_6, P_2 \cup C_3 \cup C_5 \cup T(1,2,4) \cup I_6, P_5 \cup C_5 \cup T(1,2,4) \cup I_6, K_1 \cup P_2 \cup D_{3,2} \cup T(1,1,13), 2K_1 \cup P_2 \cup C_{15} \cup D_{3,2}, K_1 \cup P_2 \cup C_3 \cup C_5 \cup T(1,2,4) \cup D_{3,2}, K_1 \cup P_5 \cup C_5 \cup T(1,2,4) \cup D_{3,2}, K_1 \cup P_2 \cup D_{4,1} \cup T(1,1,13), 2K_1 \cup P_2 \cup C_{15} \cup D_{4,1}, K_1 \cup P_2 \cup C_3 \cup C_5 \cup T(1,2,4) \cup D_{4,1}, K_1 \cup P_5 \cup C_5 \cup T(1,2,4) \cup D_{4,1}\}$.

Proof. Let $H \sim P_2 \cup I_6 \cup T(1,1,n)$, then $M(H) = M(P_2 \cup I_6 \cup T(1,1,n))$, By Lemma 2.4, we obtain $M(H) = M(I_6) = 2$. There must be a connected component H_1 in H belonging to the set Ω_2 . Let $H = H_1 \cup H_2$. Thus, we distinguish with the following cases according to $M(I_6)$.

Case 1: If $H_1 = K_{1,4}$, then $P_2 \cup I_6 \cup T(1,1,n) \sqsubseteq K_{1,4} \cup H_2$. By $K_{1,4} \cup H_2 \sqsubseteq P_2 \cup I_6 \cup T(1,1,n) \sqsubseteq P_2 \cup I_6 \cup K_1 \cup C_{n+2} \sqsubseteq 2P_2 \cup K_{1,4} \cup C_{n+2}$, we have $H_2 \sqsubseteq 2P_2 \cup C_{n+2}$.

Subcase 1.1: If $n \neq 1$, then $H_2 \sqsubseteq 2P_2 \cup C_{n+2}$;

Subcase 1.2: If $n=1$, by Lemma 2.6, we have $H_2 \sqsubseteq 2P_2 \cup C_3 \sqsubseteq P_2 \cup P_5$.

Case 2: If $H_1 = T(2,2,2)$, then $P_2 \cup I_6 \cup T(1,1,n) \sqsubseteq T(2,2,2) \cup H_2$. By $T(2,2,2) \cup H_2 \sqsubseteq P_2 \cup I_6 \cup T(1,1,n) \sqsubseteq P_2 \cup K_1 \cup D_{3,2} \cup T(1,1,n) \sqsubseteq K_1 \cup T(2,2,2) \cup T(1,1,n)$, we have $H_2 \sqsubseteq K_1 \cup T(1,1,n)$.

Subcase 2.1: If $n \neq 4, 7, 13$, By Lemma 2.6, we have $H_2 \sqsubseteq K_1 \cup T(1,1,n) \sqsubseteq 2K_1 \cup C_{n+2}$.

Subcase 2.2: If $n=4$, by Lemma 2.6, we have $H_2 \sqsubseteq K_1 \cup T(1,1,4) \sqsubseteq 2K_1 \cup C_6 \sqsubseteq K_1 \cup P_3 \cup D_{3,1}$;

Subcase 2.3: If $n=7$, by Lemma 2.6, we have $H_2 \sqsubseteq K_1 \cup T(1,1,7) \sqsubseteq 2K_1 \cup C_9 \sqsubseteq K_1 \cup C_3 \cup T(1,2,3)$;

Subcase 2.4: If $n=13$, by Lemma 2.6, we have $H_2 \sqsubseteq K_1 \cup T(1,1,13) \sqsubseteq 2K_1 \cup C_{15} \sqsubseteq$

$K_1 \cup C_3 \cup C_5 \cup T(1,2,4)$;

Case 3: If $H_1 = T(1,3,3)$, then $P_2 \cup I_6 \cup T(1,1,n) \sqsubseteq T(1,3,3) \cup H_2$. By $K_1 \cup P_2 \cup I_6 \cup T(1,1,n) \sqsubseteq K_1 \cup T(1,3,3) \cup H_2 \sqsubseteq K_1 \cup P_3 \cup D_{3,2} \cup H_2 \sqsubseteq P_3 \cup I_6 \cup H_2$, we have $P_3 \cup H_2 \sqsubseteq K_1 \cup P_2 \cup T(1,1,n) \sqsubseteq 2K_1 \cup P_2 \cup C_{n+2}$. By Lemma 2.5 and Lemma 2.6, this case does not exist.

Case 4: If $H_1 = T(1,2,5)$, then $P_2 \cup I_6 \cup T(1,1,n) \sqsubseteq T(1,2,5) \cup H_2$. By $K_1 \cup P_2 \cup I_6 \cup T(1,1,n) \sqsubseteq K_1 \cup T(1,2,5) \cup H_2 \sqsubseteq K_1 \cup P_4 \cup D_{3,2} \cup H_2 \sqsubseteq P_4 \cup I_6 \cup H_2$, we have $P_4 \cup H_2 \sqsubseteq K_1 \cup P_2 \cup T(1,1,n) \sqsubseteq 2K_1 \cup P_2 \cup C_{n+2}$. By Lemma 2.5 and Lemma 2.6, this case does not exist.

Case 5: If $H_1 = I_m$, then $P_2 \cup I_6 \cup T(1,1,n) \sqsubseteq I_m \cup H_2$.

Subcase 5.1: If $n \neq 1, 4, 7, 13$, By Lemma 2.6, we have $I_m \cup H_2 \sqsubseteq P_2 \cup I_6 \cup T(1,1,n) \sqsubseteq P_2 \cup I_6 \cup K_1 \cup C_{n+2}$. So, if $m=6$, we have $H_2 \sqsubseteq P_2 \cup T(1,1,n) \sqsubseteq P_2 \cup K_1 \cup C_{n+2}$;

Subcase 5.2: If $n=1$, By Lemma 2.6 and Lemma 2.7, we have $I_m \cup H_2 \sqsubseteq P_2 \cup I_6 \cup T(1,1,1) \sqsubseteq P_2 \cup I_6 \cup K_1 \cup C_3 \sqsubseteq I_6 \cup K_1 \cup P_5 \sqsubseteq P_2 \cup K_1 \cup I_9$. So, if $m=6$, we have $H_2 \sqsubseteq P_2 \cup T(1,1,1) \sqsubseteq P_2 \cup K_1 \cup C_3 \sqsubseteq K_1 \cup P_5$; if $m=9$, $H_2 \sqsubseteq P_2 \cup K_1$;

Subcase 5.3: If $n=4$, By Lemma 2.6, we have $I_m \cup H_2 \sqsubseteq P_2 \cup I_6 \cup T(1,1,4) \sqsubseteq P_2 \cup I_6 \cup K_1 \cup C_6 \sqsubseteq P_2 \cup I_6 \cup P_3 \cup D_{3,1} \sqsubseteq I_6 \cup P_3 \cup T(1,2,2)$. So, if $m=6$, we have $H_2 \sqsubseteq P_2 \cup T(1,1,4) \sqsubseteq P_2 \cup K_1 \cup C_6 \sqsubseteq P_2 \cup P_3 \cup D_{3,1} \sqsubseteq P_3 \cup T(1,2,2)$;

Subcase 5.4: If $n=7$, By Lemma 2.6, we have $I_m \cup H_2 \sqsubseteq P_2 \cup I_6 \cup T(1,1,7) \sqsubseteq P_2 \cup I_6 \cup K_1 \cup C_9 \sqsubseteq P_2 \cup I_6 \cup C_3 \cup T(1,2,3) \sqsubseteq I_6 \cup P_5 \cup T(1,2,3)$. So, if $m=6$, we have $H_2 \sqsubseteq P_2 \cup T(1,1,7) \sqsubseteq P_2 \cup K_1 \cup C_9 \sqsubseteq P_2 \cup C_3 \cup T(1,2,3) \sqsubseteq P_5 \cup T(1,2,3)$;

Subcase 5.5: If $n=13$, By Lemma 2.6, we have $I_m \cup H_2 \sqsubseteq P_2 \cup I_6 \cup T(1,1,13) \sqsubseteq P_2 \cup I_6 \cup K_1 \cup C_{15} \sqsubseteq P_2 \cup I_6 \cup C_3 \cup C_5 \cup T(1,2,4) \sqsubseteq I_6 \cup P_5 \cup C_5 \cup T(1,2,4)$. So, if $m=6$, we have $H_2 \sqsubseteq P_2 \cup T(1,1,13) \sqsubseteq P_2 \cup K_1 \cup C_{15} \sqsubseteq P_2 \cup C_3 \cup C_5 \cup T(1,2,4) \sqsubseteq P_5 \cup C_5 \cup T(1,2,4)$.

Case 6: If $H_1 = D_{3,2}$, then $P_2 \cup I_6 \cup T(1,1,n) \sqsubseteq D_{3,2} \cup H_2$. By Lemma 2.7, we have $K_1 \cup P_2 \cup I_6 \cup T(1,1,n) \sqsubseteq K_1 \cup D_{3,2} \cup H_2 \sqsubseteq I_6 \cup H_2$.

Subcase 6.1: If $n \neq 1, 4, 7, 13$, By Lemma 2.6, we have $H_2 \sqsubseteq K_1 \cup P_2 \cup T(1,1,n) \sqsubseteq 2K_1 \cup P_2 \cup C_{n+2}$;

Subcase 6.2: If $n=1$, By Lemma 2.6, we have $H_2 \sqsubseteq K_1 \cup P_2 \cup T(1,1,1) \sqsubseteq 2K_1 \cup P_2 \cup C_3 \sqsubseteq 2K_1 \cup P_5$;

Subcase 6.3: If $n=4$, By Lemma 2.6, we have $H_2 \sqsubseteq K_1 \cup P_2 \cup T(1,1,4) \sqsubseteq 2K_1 \cup P_2 \cup C_6 \sqsubseteq K_1 \cup P_2 \cup P_3 \cup D_{3,1}$;

Subcase 6.4: If $n=7$, By Lemma 2.6, we have $H_2 \sqsubseteq K_1 \cup P_2 \cup T(1,1,7) \sqsubseteq 2K_1 \cup P_2 \cup C_9 \sqsubseteq K_1 \cup P_2 \cup C_3 \cup T(1,2,3) \sqsubseteq K_1 \cup P_5 \cup T(1,2,3)$;

Subcase 6.5: If $n=13$, By Lemma 2.6, we have $H_2 \sqsubseteq K_1 \cup P_2 \cup T(1,1,13) \sqsubseteq 2K_1 \cup P_2 \cup C_{15} \sqsubseteq K_1 \cup P_2 \cup C_3 \cup C_5 \cup T(1,2,4) \sqsubseteq K_1 \cup P_5 \cup C_5 \cup T(1,2,4)$;

Case 7: If $H_1 = D_{4,1}$. By $D_{3,2} \sqsubseteq D_{4,1}$, it is similar to Case 6. The proof is omitted.

The proof of Theorem 3.1 is complete.

By Theorem 3.1 and Lemma 2.8, we have Theorem 3.2:

Theorem 3.2 Let $[(P_2 \cup I_6 \cup T(1,1,n))^c]$ be The classes of matching equivalent graphs of $(P_2 \cup I_6 \cup T(1,1,n))^c$. Then

(1) If $n \neq 1, 4, 7, 13$, $[(P_2 \cup I_6 \cup T(1,1,n))^c] = \{(2P_2 \cup K_{1,4} \cup C_{n+2})^c, (K_1 \cup T(2,2,2) \cup T(1,1,n))^c, (2K_1 \cup T(2,2,2) \cup C_{n+2})^c, (K_1 \cup P_2 \cup I_6 \cup C_{n+2})^c, (K_1 \cup P_2 \cup D_{3,2} \cup T(1,1,n))^c, (2K_1 \cup P_2 \cup D_{3,2} \cup C_{n+2})^c, (K_1 \cup P_2 \cup D_{4,1} \cup T(1,1,n))^c, (2K_1 \cup P_2 \cup D_{4,1} \cup C_{n+2})^c\}$;

(2) If $n=1$, $[(P_2 \cup I_6 \cup T(1,1,1))^c] = \{(2P_2 \cup K_{1,4} \cup C_3)^c, (P_2 \cup K_{1,4} \cup P_5)^c, (K_1 \cup P_2 \cup I_6 \cup C_3)^c, (K_1 \cup I_6 \cup P_5)^c, (K_1 \cup P_2 \cup I_9)^c, (K_1 \cup P_2 \cup D_{3,2} \cup T(1,1,1))^c, (2K_1 \cup P_2 \cup D_{3,2} \cup C_3)^c, (2K_1 \cup P_5 \cup D_{3,2})^c, (K_1 \cup P_2 \cup D_{4,1} \cup T(1,1,1))^c, (2K_1 \cup P_2 \cup D_{4,1} \cup C_3)^c, (2K_1 \cup P_5 \cup D_{4,1})^c\}$;

(3) If $n = 4$, $[(P_2 \cup I_6 \cup T(1,1,4))^c] = \{(K_1 \cup T(2,2,2) \cup T(1,1,4))^c, (2K_1 \cup T(2,2,2) \cup C_6)^c, (K_1 \cup P_3 \cup D_{3,1} \cup T(2,2,2))^c, (K_1 \cup P_2 \cup C_6 \cup I_6)^c, (P_2 \cup P_3 \cup D_{3,1} \cup I_6)^c, (P_3 \cup T(1,2,2) \cup I_6)^c, (K_1 \cup P_2 \cup D_{3,2} \cup T(1,1,4))^c, (2K_1 \cup P_2 \cup C_6 \cup D_{3,2})^c, (K_1 \cup P_2 \cup P_3 \cup D_{3,1} \cup D_{3,2})^c, (K_1 \cup P_3 \cup T(1,2,2) \cup D_{3,2})^c, (K_1 \cup P_2 \cup D_{4,1} \cup T(1,1,4))^c, (2K_1 \cup P_2 \cup C_6 \cup D_{4,1})^c, (K_1 \cup P_2 \cup P_3 \cup D_{3,1} \cup D_{4,1})^c, (K_1 \cup P_3 \cup T(1,2,2) \cup D_{4,1})^c\}$;

(4) If $n = 7$, $[(P_2 \cup I_6 \cup T(1,1,7))^c] = \{(K_1 \cup T(2,2,2) \cup T(1,1,7))^c, (2K_1 \cup T(2,2,2) \cup C_9)^c, (K_1 \cup C_3 \cup T(1,2,3) \cup T(2,2,2))^c, (K_1 \cup P_2 \cup C_9 \cup I_6)^c, (P_2 \cup C_3 \cup T(1,2,3) \cup I_6)^c, (P_5 \cup T(1,2,3) \cup I_6)^c, (K_1 \cup P_2 \cup D_{3,2} \cup T(1,1,7))^c, (2K_1 \cup P_2 \cup C_9 \cup D_{3,2})^c, (K_1 \cup P_2 \cup C_3 \cup T(1,2,3) \cup D_{3,2})^c, (K_1 \cup P_5 \cup T(1,2,3) \cup D_{3,2})^c, (K_1 \cup P_2 \cup D_{4,1} \cup T(1,1,7))^c, (2K_1 \cup P_2 \cup C_9 \cup D_{4,1})^c, (K_1 \cup P_2 \cup C_3 \cup T(1,2,3) \cup D_{4,1})^c, (K_1 \cup P_5 \cup T(1,2,3) \cup D_{4,1})^c\}$;

(5) If $n = 13$, $[(P_2 \cup I_6 \cup T(1,1,13))^c] = \{(K_1 \cup T(2,2,2) \cup T(1,1,13))^c, (2K_1 \cup T(2,2,2) \cup C_{15})^c, (K_1 \cup C_3 \cup C_5 \cup T(1,2,4) \cup T(2,2,2))^c, (K_1 \cup P_2 \cup C_{15} \cup I_6)^c, (P_2 \cup C_3 \cup C_5 \cup T(1,2,4) \cup I_6)^c, (P_5 \cup C_5 \cup T(1,2,4) \cup I_6)^c, (K_1 \cup P_2 \cup D_{3,2} \cup T(1,1,13))^c, (2K_1 \cup P_2 \cup C_{15} \cup D_{3,2})^c, (K_1 \cup P_2 \cup C_3 \cup C_5 \cup T(1,2,4) \cup D_{3,2})^c, (K_1 \cup P_5 \cup C_5 \cup T(1,2,4) \cup D_{3,2})^c, (K_1 \cup P_2 \cup D_{4,1} \cup T(1,1,13))^c, (2K_1 \cup P_2 \cup C_{15} \cup D_{4,1})^c, (K_1 \cup P_2 \cup C_3 \cup C_5 \cup T(1,2,4) \cup D_{4,1})^c, (K_1 \cup P_5 \cup C_5 \cup T(1,2,4) \cup D_{4,1})^c\}$.

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