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Odd Vertex-In Magic Total Labeling of Some 2-Regular Digraphs

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Abstract: Let D be a directed graph with p vertices and q arcs. A vertex in-magic total labeling (VIMTL) of a graph D is a bijection $f: V(D) \cup A(D) \rightarrow \{1, 2, \ldots p+q\}$ with the property that for every $v \in V(D)$, $f(v) + \sum_{u \in I(v)} f((v,u)) = M$, for some constant M. Such labeling is 'Odd' if $f(V(D)) = \{1, 3, \ldots, 2p-1\}$. In this paper, we explore the Odd Vertex In-magic total labeling (OVIMTL) of some 2-regular directed graphs.

MSC: 05C78.

Keywords: Digraphs, vertex in-magic labeling, Odd Vertex in-magic total labeling.

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1. Introduction

Graph Labeling is one of the most growing areas in graph theory. In graph theory, the labeling of graphs noticed to be a theoretical topic. It is used in countless applications like coding theory, X-Ray crystallography and astronomy etc. Design of graph labeling is helpful to network security, network addressing and social network in communication network. A magic total labeling of a graph is a motivating research area. Let $D = (V, A)$ be a digraph of order p and size q. For a vertex $v \in V(D)$, the set $I(v) = \{u | (v, u) \in A(D)\}$ is called the in-neighbourhood of v. The in-degree of v is defined by $deg^-(v) = |I(v)|$. A general reference for graph theoretic notions follow [1]. A labeling of a graph G is a mapping from a set of vertices(edges) into a set of numbers, usually integers. Many kinds of labelings have been studied and an excellent survey of graph labelings can be found in [2]. In 1963, Sedlacek [5] introduced the concept of magic labeling in graphs. A graph G is *magic* if the edges of G can be labelled by a set of numbers $\{1, 2, \ldots q\}$ so that the sum of labels of all the edges incident with any vertex is the same. In 2002, Macdougall [3] introduced the notion of vertex magic total labeling (VMTL) in graphs. Let $G(V, E)$ be a graph with $|V(G)| = p$ and $|E(G)| = q$. A one-to-one map f from $V(G) \cup E(G)$ onto the integers $\{1, 2, \ldots, p+q\}$ is a VTML if there is a constant M so that for every vertex $x \in V(G)$, $f(x) + \sum f(xy) = M$, where the sum is taken over all vertices y adjacent to x. In 2004, Macdougall et [4] defined the super vertex-magic total labeling (SVMTL) in graphs. They call a VTML is super if $f(V(G)) = \{1, 2 \ldots, p\}$. In this labeling the smallest labels are assigned to the vertices. In 2008, Bloom [6] extended the idea of magic labeling to digraphs. The V-super vertex out-magic total labeling (V-SVOMTL) in digraph was introduced by Durga Devi [7]. A V-SVOMTL is a bijection $f: V(D) \cup A(D) \rightarrow \{1, 2, \ldots, p+q\}$ such that

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$f(V(D)) = \{1, 2 \ldots, p\}$ and for every $v \in V(D)$, $f(v) + \sum_{u \in o(v)} f((u, v)) = M$, for some positive integer M. C. T. Nagaraj [8] in introduced the concept of an Odd vertex magic total labeling. A vertex magic total labeling (VMTL) is a bijection $f : V(D) \cup A(D) \to \{1, 2, \ldots, p + q\}$ with the property that for every $v \in V(D)$, $f(v) + \sum_{u \in N(v)} f(uv) = M$, for some constant M. Such labeling is 'Odd' if $f(V(D)) = \{1, 3, \ldots, 2p - 1\}$. A graph is called an odd vertex magic if the graph admits an Odd vertex magic total labeling. C. T. Nagaraj [9] also studied Odd vertex magic total labeling of some 2-regular graphs. In this paper, we define a new labeling called Odd Vertex-In Magic Total Labeling (OVIMTL). An Odd Vertex-In Magic Total Labeling (OVIMTL) of a directed graph D is a bijection $f : V(D) \cup A(D) \to \{1, 2, \ldots, p + q\}$ with the property $f(V(D)) = \{1, 3, \ldots, 2p - 1\}$ and for every $v \in V(D)$, $f(v) + \sum_{u \in I(v)} f((v, u)) = M$, for some constant M. A digraph that admits an OVITML is called an Odd Vertex-In Magic Total(OVIMT). From the definition of OVITML, it is easy to observe that $p \leq q$.

2. OVIMTL in Digraphs

Lemma 2.1. *If a digraph $D(p, q)$ is an Odd vertex-in magic total (OVIMT), then the magic constant M is given by $M = \frac{(p+q)(p+q+1)}{2p}$.*

Proof. Let f be an OVIMTL of D. Note that $M = f(v) + \sum_{u \in I(v)} f((v, u))$ for all $v \in V(D)$. Summing over all $v \in V(D)$, we get

$$pM = \sum_{v \in V(D)} f(v) + \sum_{v \in V(D)} \sum_{u \in I(D)} f(v, u)$$

Since $f(V(D)) = \{1, 3, \ldots, 2p - 1\}$ and $f(A(D)) = \{2, 4, \ldots, 2p, 2p + 1, 2p + 2, \ldots, p + q\}$,

$$\begin{aligned} pM &= [1 + 3 + \cdots + 2p - 1] + [2 + 4 + \cdots + 2p] + [1 + 2 + \cdots + (p + q)] - [1 + 2 + \cdots + 2p] \\ &= [1 + 2 + \cdots + (p + q)] \\ &= \frac{(p + q)(p + q + 1)}{2} \\ M &= \frac{(p + q)(p + q + 1)}{2p}. \end{aligned}$$

□

Corollary 2.2. *Let D be a connected digraph which is OVIMT, then*

(a). $M \geq 2p - 1$.

(b). $M = 2p + 1$ if $q = p$.

Proof.

(a). Since D be a connected digraph, $q \geq p - 1$. Thus by Lemma 2.1, we have $M = \frac{(p+q)(p+q+1)}{2p} \geq \frac{(p+p-1)(p+p-1+1)}{2p} = \frac{(2p-1)(2p)}{2p} = 2p - 1$.

(b). When $q = p$, $M = \frac{(p+q)(p+q+1)}{2p} = \frac{(p+p)(p+p+1)}{2p} = \frac{(2p)(2p+1)}{2p} = 2p + 1$.

□

Theorem 2.3. *The digraph $D = \overrightarrow{C_3} \cup \overrightarrow{C_{4t}}$, $t > 1$ admits OVIMTL with the magic constant $8t + 7$.*

Proof. Let the $V(D) = \{a_i : 1 \le i \le 3\} \cup \{b_i : 1 \le i \le 4t\}$ and $A(D) = \{(a_i, a_{i \oplus_3 1}) : 1 \le i \le 3\} \cup \{(b_i, b_{i \oplus_{4t} 1}) : 1 \le i \le 4t\}$ be the vertex set and arc set of D respectively. From Corollary 2.2, we get $M = 8t + 7$ (Since $|V(D)| = |A(D)| = 4t + 3$).

Define $f : V(D) \cup A(D) \to \{1, 2, \ldots, 8t + 6\}$ as follows:

$$f(u) = \begin{cases} 8t + 2i - 1 & \text{if } u = a_i \text{ for } 1 \le i \le 3 \\ 2i - 1 & \text{if } u = b_i \text{ for } 1 \le i \le 4t \end{cases}$$

$$f(e) = \begin{cases} 8 - 2i & \text{if } e = (a_i, a_{i \oplus_3 1}) : 1 \le i \le 3 \\ 8t + 8 - 2i & \text{if } e = (b_i, b_{i \oplus_{4t} 1}) : 1 \le i \le 4t \end{cases}$$

Now, we prove f is an OVIMTL with the magic constant $M = 8t + 7$.

Case 1: Suppose $v = a_i$ for $1 \le i \le 3$. Then $f(v) + \sum_{u \in I(v)} f((v, u)) = f(a_i) + f((a_i, a_{i \oplus_3 1})) = [8t + 2i - 1] + [8 - 2i] = 8t + 7$.

Case 2: Suppose $v = b_i$ for $1 \le i \le 4t$. Then $f(v) + \sum_{u \in I(v)} f((v, u)) = f(b_i) + f((b_i, b_{i \oplus_{4t} 1})) = [2i - 1] + [8t + 8 - 2i] = 8t + 7$.

Thus the graph D is admits OVIMTL with the magic constant $M = 8t + 7$. □

Example 2.4. *Consider the digraph $D = \overrightarrow{C_3} \cup \overrightarrow{C_{4t}}$, taking $t = 4$ admits OVIMTL with magic constant $M = 39$.*

Here $V(D) = \{a_i : 1 \le i \le 3\} \cup \{b_i : 1 \le i \le 16\}$ and $A(D) = \{(a_i, a_{i \oplus_3 1}) : 1 \le i \le 3\} \cup \{(b_i, b_{i \oplus_{16} 1}) : 1 \le i \le 16\}$ be the vertex set and arc set of D respectively. From Corollary 2.2, we get $M = 39$ (Since $|V(D)| = |A(D)| = 19$).

Define $f : V(D) \cup A(D) \to \{1, 2, \ldots, 38\}$ as follows:

$$f(u) = \begin{cases} 31 + 2i & \text{if } u = a_i \text{ for } 1 \le i \le 3 \\ 2i - 1 & \text{if } u = b_i \text{ for } 1 \le i \le 16 \end{cases}$$

$$f(e) = \begin{cases} 8 - 2i & \text{if } e = (a_i, a_{i \oplus_3 1}) : 1 \le i \le 3 \\ 40 - 2i & \text{if } e = (b_i, b_{i \oplus_{16} 1}) : 1 \le i \le 16 \end{cases}$$

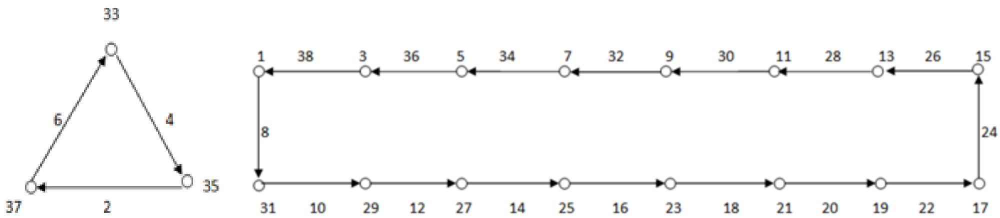

Figure 1. $C_3 \cup C_{16}, k = 39$

Now we prove f is an OVIMTL with magic constant $M = 39$

Case 1: Suppose $v = a_i$ for $1 \le i \le 3$. Then $f(v) + \sum_{u \in I(v)} f((v, u)) = f(a_i) + f((a_i, a_{i \oplus_3 1})) = [31 + 2i] + [8 - 2i] = 39$.

Case 2: Suppose $v = b_i$ for $1 \le i \le 16$. Then $f(v) + \sum_{u \in I(v)} f((v, u)) = f(b_i) + f((b_i, b_{i \oplus_{16} 1})) = [2i - 1] + [40 - 2i] = 39$.

Thus the graph D is an OVIMT with the magic constant $M = 39$.

Theorem 2.5. *The digraph $D = \overrightarrow{C_3} \cup \overrightarrow{C_{4t+2}}$, $t > 1$ admits OVIMTL with magic constant $M = 8t + 11$.*

Proof. Let the $V(D) = \{a_i : 1 \le i \le 3\} \cup \{b_i : 1 \le i \le 4t + 2\}$ and $A(D) = \{(a_i, a_{i \oplus_3 1}) : 1 \le i \le 3\} \cup \left\{(b_i, b_{i \oplus_{4t+2} 1}) : 1 \le i \le 4t + 2\right\}$ be the vertex set and arc set of D respectively. From Corollary 2.2, we get $M = 8t + 11$ (Since $|V(D)| = |A(D)| = 4t + 5$).

Define $f : V(D) \cup A(D) \to \{1, 2, \ldots, 8t+10\}$ as follows:

$$f(u) = \begin{cases} 8t + 2(i-1) + 5 & \text{if } u = a_i \text{ for } 1 \le i \le 3 \\ 2i - 1 & \text{if } u = b_i \text{ for } 1 \le i \le 4t+2 \end{cases}$$

$$f(e) = \begin{cases} 8 - 2i & \text{if } e = (a_i, a_{i \oplus_3 1}) : 1 \le i \le 3 \\ 8t + 12 - 2i & \text{if } e = (b_i, b_{i \oplus_{4t+2} 1}) : 1 \le i \le 4t+2 \end{cases}$$

Now, we prove f is an OVIMTL with the magic constant $M = 8t + 11$.

Case 1: Suppose $v = a_i$ for $1 \le i \le 3$. Then $f(v) + \sum_{u \in I(v)} f((v,u)) = f(a_i) + f((a_i, a_{i \oplus_3 1})) = [8t + 2(i-1) + 5] + [8 - 2i] = 8t + 11$.

Case 2: Suppose $v = b_i$ for $1 \le i \le 4t+2$. Then $f(v) + \sum_{u \in I(v)} f((v,u)) = f(b_i) + f((b_i, b_{i \oplus_{4t+2} 1})) = [2i - 1] + [8t + 12 - 2i] = 8t + 11$.

Thus the digraph D admits OVIMTL with the magic constant $M = 8t + 11$. □

Example 2.6. *Consider the digraph $D = \overrightarrow{C_3} \cup \overrightarrow{C_{4t+2}}$,taking $t = 4$ admits OVIMTL with magic constant $M = 43$.*

Here $V(D) = \{a_i : 1 \le i \le 3\} \cup \{b_i : 1 \le i \le 18\}$ and $A(D) = \left\{(a_i, a_{i \oplus_3 1}) : 1 \le i \le 3\right\} \cup \left\{(b_i, b_{i \oplus_{18} 1}) : 1 \le i \le 18\right\}$ be the vertex set and arc set of D respectively. From Corollary 2.2, we get $M = 43$ (Since $|V(D)| = |A(D)| = 21$).

Define $f : V(D) \cup A(D) \to \{1, 2, \ldots, 42\}$ as follows

$$f(u) = \begin{cases} 37 + 2(i-1) & \text{if } u = a_i \text{ for } 1 \le i \le 3 \\ 2i - 1 & \text{if } u = b_i \text{ for } 1 \le i \le 18 \end{cases}$$

$$f(e) = \begin{cases} 8 - 2i & \text{if } e = (a_i, a_{i \oplus_3 1}) \text{ for } 1 \le i \le 3 \\ 44 - 2i & \text{if } e = (b_i, b_{i \oplus_{18} 1}) \text{ for } 1 \le i \le 18 \end{cases}$$

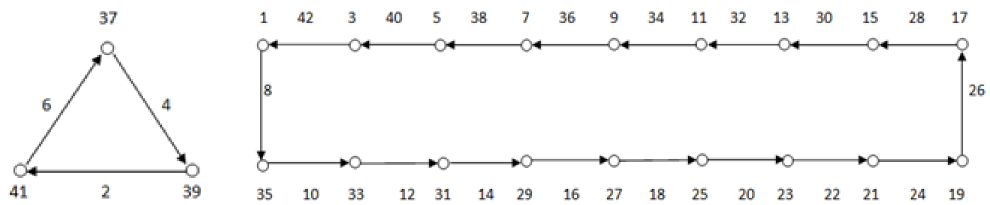

Figure 2. $C_3 \cup C_{18}, k = 43$

Now, we prove f is an OVIMTL.

Case 1: Suppose $v = a_i$ for $1 \le i \le 3$. Then $f(v) + \sum_{u \in I(v)} f((v,u)) = f(a_i) + f(a_i, a_{i \oplus_3 1}) = [37 + 2(i-1)] + [8 - 2i] = 43$.

Case 2: Suppose $v = b_i$ for $1 \le i \le 18$. Then $f(v) + \sum_{u \in I(v)} f((v,u)) = f(b_i) + f((b_i, b_{i \oplus_{18} 1})) = [2i - 1] + [44 - 2i] = 43$.

Thus the graph D is an OVIMT with the magic constant $M = 43$.

Theorem 2.7. *The digraph $D = \overrightarrow{C_4} \cup \overrightarrow{C_{4t+3}}$, $t \ge 1$ admits OVIMTL with magic constant $M = 8t + 15$.*

Proof. Let the $V(D) = \{a_i : 1 \le i \le 4\} \cup \{b_i : 1 \le i \le 4t+3\}$ and $A(D) = \left\{(a_i, a_{i \oplus_4 1}) : 1 \le i \le 4\right\} \cup \left\{(b_i, b_{i \oplus_{4t+3} 1}) : 1 \le i \le 4t+3\right\}$ be the vertex set and arc set of D respectively. From Corollary 2.2, we get $M = 8t + 15$ (Since $|V(D)| = |A(D)| = 4t + 7$).

Define $f : V(D) \cup A(D) \to \{1, 2, \ldots, 8t + 14\}$ as follows:

$$f(u) = \begin{cases} 8t + 2i + 5 & \text{if } u = a_i \text{ for } 1 \le i \le 4 \\ 2i - 1 & \text{if } u = b_i \text{ for } 1 \le i \le 4t + 3 \end{cases}$$

$$f(e) = \begin{cases} 10 - 2i & \text{if } e = (a_i, a_{i \oplus_4 1}) : 1 \le i \le 4 \\ 8t + 16 - 2i & \text{if } e = (b_i, b_{i \oplus_{4t+3} 1}) : 1 \le i \le 4t + 3 \end{cases}$$

Now, we prove f is an OVIMTL with the magic constant $M = 8t + 15$.

Case 1: Suppose $v = a_i$ for $1 \le i \le 4$. Then $f(v) + \sum\limits_{u \in I(v)} f((v, u)) = f(a_i) + f((a_i, a_{i \oplus_4 1})) = [8t + 2i + 5] + [10 - 2i] = 8t + 15$.

Case 2: Suppose $v = b_i$ for $1 \le i \le 4t+3$. Then$f(v) + \sum\limits_{u \in I(v)} f((v, u)) = f(b_i) + f((b_i, b_{i \oplus_{4t+2} 1})) = [2i - 1] + [8t + 16 - 2i] = 8t + 15$.

Thus the digraph D is admits OVIMTL with the magic constant $M = 8t + 15$. $\square$

Example 2.8. *Consider the digraph $D = \overrightarrow{C_4} \cup \overrightarrow{C_{4t+3}}$ taking $t = 3$ admits OVIMTL with magic constant $M = 39$.*

Here $V(D) = \{a_i : 1 \le i \le 4\} \cup \{b_i : 1 \le i \le 15\}$ and $A(D) = \left\{(a_i, a_{i \oplus_4 1}) : 1 \le i \le 4\right\} \cup \left\{(b_i, b_{i \oplus_{15} 1}) : 1 \le i \le 15\right\}$ be the vertex set and arc set of D respectively. From Corollary 2.2, we get $M = 39$ (Since $|V(D)| = |A(D)| = 19$).

Define $f : V(D) \cup A(D) \to \{1, 2, \ldots, 38\}$ as follows:

$$f(u) = \begin{cases} 29 + 2i & \text{if } u = a_i \text{ for } 1 \le i \le 4 \\ 2i - 1 & \text{if } u = b_i \text{ for } 1 \le i \le 15 \end{cases}$$

$$f(e) = \begin{cases} 10 - 2i & \text{if } e = (a_i, a_{i \oplus_4 1}) : 1 \le i \le 4 \\ 40 - 2i & \text{if } e = (b_i, b_{i \oplus_{15} 1}) : 1 \le i \le 15. \end{cases}$$

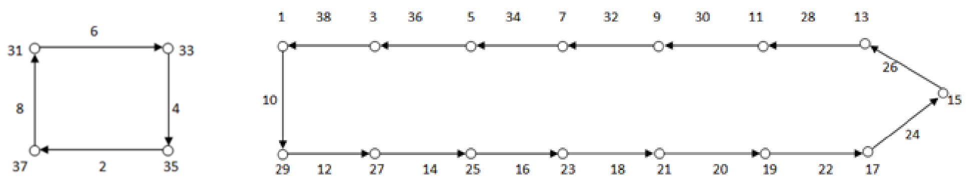

Figure 3. $C_4 \cup C_{15}, k = 39$

Now, we prove f is an OVIMTL.

Case 1: Suppose $v = a_i$ for $1 \le i \le 4$. Then $f(v) + \sum\limits_{u \in I(v)} f((v, u)) = f(a_i) + f((a_i, a_{i \oplus_4 1})) = [29 + 2i] + [10 - 2i] = 39$.

Case 2: Suppose $v = b_i$ for $1 \le i \le 15$. Then $f(v) + \sum\limits_{u \in I(v)} f((v, u)) = f(b_i) + f((b_i, b_{i \oplus_{15} 1})) = [2i - 1] + [40 - 2i] = 39$.

Thus the graph D is an OVIMT with the magic constant $M = 39$.

Theorem 2.9. *The digraph $D = \overrightarrow{C_4} \cup \overrightarrow{C_{4t+1}}$, $t \ge 1$ admits OVIMTL with magic constant $M = 8t + 11$.*

Proof. Let the $V(D) = \{a_i : 1 \le i \le 4\} \cup \{b_i : 1 \le i \le 4t + 1\}$ and $A(D) = \left\{(a_i, a_{i \oplus_4 1}) : 1 \le i \le 4\right\} \cup \left\{(b_i, b_{i \oplus_{4t+1} 1}) : 1 \le i \le 4t + 1\right\}$ be the vertex set and arc set of D respectively. From Corollary 2.2, we get $M = 8t + 11$ (Since $|V(D)| = |A(D)| = 4t + 5$).

Define $f : V(D) \cup A(D) \to \{1, 2, \ldots, 8t + 10\}$ as follows:

$$f(u) = \begin{cases} 8t + 2i + 1 & \text{if } u = a_i \text{ for } 1 \le i \le 4 \\ 2i - 1 & \text{if } u = b_i \text{ for } 1 \le i \le 4t + 1 \end{cases}$$

$$f(e) = \begin{cases} 10 - 2i & \text{if } e = (a_i, a_{i \oplus_4 1}) : 1 \le i \le 4 \\ 8t + 12 - 2i & \text{if } e = (b_i, b_{i \oplus_{4t+1} 1}) : 1 \le i \le 4t + 1 \end{cases}$$

Now, we prove f is an OVIMTL with the magic constant $M = 8t + 11$.

Case 1: Suppose $v = a_i$ for $1 \le i \le 4$. Then $f(v) + \sum_{u \in I(v)} f((v,u)) = f(a_i) + f((a_i, a_{i \oplus_4 1})) = [8t + 2i + 1] + [10 - 2i] = 8t + 11$.

Case 2: Suppose $v = b_i$ for $1 \le i \le 4t + 1$. Then $f(v) + \sum_{u \in I(v)} f((v,u)) = f(b_i) + f((b_i, b_{i \oplus_{4t+1} 1})) = [2i - 1] + [8t + 12 - 2i] = 8t + 11$. Thus the digraph D is admits OVIMTL with the magic constant $M = 8t + 11$. □

Example 2.10. *Consider the digraph $D = \overrightarrow{C_4} \cup \overrightarrow{C_{4t+1}}$, taking $t = 3$ admits OVIMTL with magic constant $M = 35$.*

Here $V(D) = \{a_i : 1 \le i \le 4\} \cup \{b_i : 1 \le i \le 13\}$ and $A(D) = \{(a_i, a_{i \oplus_4 1}) : 1 \le i \le 4\} \cup \{(b_i, b_{i \oplus_{13} 1}) : 1 \le i \le 13\}$ be the vertex set and arc set of D respectively. From Corollary 2.2, we get $M = 35$ (Since $|V(D)| = |A(D)| = 17$).

Define $f : V(D) \cup A(D) \to \{1, 2, \ldots, 34\}$ as follows:

$$f(u) = \begin{cases} 25 + 2i & \text{if } u = a_i \text{ for } 1 \le i \le 4 \\ 2i - 1 & \text{if } u = b_i \text{ for } 1 \le i \le 13 \end{cases}$$

$$f(e) = \begin{cases} 10 - 2i & \text{if } e = (a_i, a_{i \oplus_4 1}) : 1 \le i \le 4 \\ 36 - 2i & \text{if } e = (b_i, b_{i \oplus_{13} 1}) : 1 \le i \le 13 \end{cases}$$

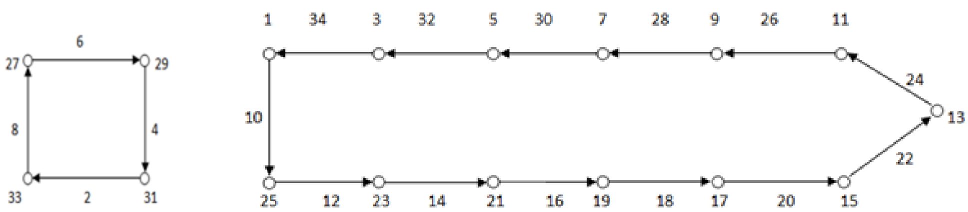

Figure 4. $C_4 \cup C_{13}, k = 35$

Now, we prove f is an OVIMTL.

Case 1: Suppose $v = a_i$ for $1 \le i \le 4$. Then $f(v) + \sum_{u \in I(v)} f((v,u)) = f(a_i) + f((a_i, a_{i \oplus_4 1})) = [25 + 2i] + [10 - 2i] = 35$.

Case 2: Suppose $v = b_i$ for $1 \le i \le 13$. Then $f(v) + \sum_{u \in I(v)} f((v,u)) = f(b_i) + f((b_i, b_{i \oplus_{13} 1})) = [2i - 1] + [36 - 2i] = 35$.

Thus the graph D is an OVIMT with the magic constant $M = 35$.

3. Conclusion

In this paper we have discussed some cycles of graphs that admits OVIMTL. In future we can prove different families of graphs which satisfy OVIMTL.

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