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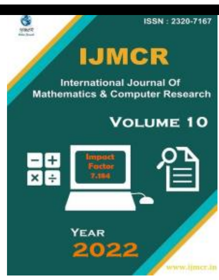

Temperature-Sombor and Temperature-Nirmala Indices

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ARTICLE INFO	ABSTRACT
Published online: 24 September 2022 Corresponding Author: **V. R. Kulli**	In this paper, we introduce the temperature-Sombor index, modified temperature-Sombor index and temperature-Nirmala index of a graph. Also we compute these temperature indices for some standard graphs and tetrameric 1,3-adamantane. Furthermore, we establish some properties of newly defined temperature-Sombor index and temperature-Nirmala index.

KEYWORDS: temperature Somber index, modified temperature Sombor index, temperature Nirmala index, graph, tetrameric 1,3-adamantane.

I. INTRODUCTION

In this paper, we consider only finite, simple, connected graphs. Let G be such a graph with vertex set $V(G)$ and edge set $E(G)$. The degree $d_G(u)$ of a vertex u is the number of vertices adjacent to u. For basic notations and terminologies, we refer [1].

In [2], the temperature of a vertex u of a graph G is defined as

$$T(u)=\frac{d_G(u)}{n-d_G(u)}$$

where n is the number of vertices of G.

In [3], the first temperature index of a graph G is defined as

$$T_1(G)=\sum_{uv\in E(G)}\left[T(u)+T(v)\right].$$

The second temperature index [4] of a graph G is defined as

$$T_2(G)=\sum_{uv\in E(G)}T(u)T(v).$$

Recently, some temperature indices were studied, for example, in [5, 6, 7, 8].

We propose the temperature Sombor index of a graph G and it is defined as

$$TSO(G)=\sum_{uv\in E(G)}\sqrt{T(u)^2+T(v)^2}.$$

Considering the temperature Sombor index, we define the temperature Sombor exponential of a graph G as

$$TSO(G,x)=\sum_{uv\in E(G)}x^{\sqrt{T(u)^2+T(v)^2}}.$$

We propose the modified temperature Sombor index of a graph G and it is defined as

$${}^{m}TSO(G)=\sum_{uv\in E(G)}\frac{1}{\sqrt{T(u)^2+T(v)^2}}.$$

Considering the modified temperature Sombor index, we define the modified temperature Sombor exponential of a graph G as

$${}^{m}TSO(G,x)=\sum_{uv\in E(G)}x^{\frac{1}{\sqrt{T(u)^2+T(v)^2}}}.$$

Recently, some Sombor indices were studied, for example, in [9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32].

We define the temperature Nirmala index of a graph G as

$$TN(G)=\sum_{uv\in E(G)}\sqrt{T(u)+T(v)}.$$

Considering the temperature Nirmala index, we define the temperature Nirmala exponential of a graph G as

$$TN(G,x)=\sum_{uv\in E(G)}x^{\sqrt{T(u)+T(v)}}.$$

Recently, some Nirmala indices were studied, for example, in [33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45].

In [46], the F- temperature index of a graph G is defined as

$$FT(G)=\sum_{uv\in E(G)}\left[T(u)^2+T(v)^2\right].$$

We define the temperature misbalance prodeg index of a graph G as

$$TMPI(G)=\sum_{uv\in E(G)}\left[\sqrt{T(u)}+\sqrt{T(v)}\right].$$

We put forward the temperature inverse sum indeg index of a graph G and defined it as

$$ISI_T(G)=\sum_{uv\in E(G)}\frac{T(u)T(v)}{T(u)+T(v)}.$$

In this paper, we compute the temperature-Sombor index, modified temperature-Sombor index and temperature-Nirmala index for some standard graphs and tetrameric 1,3-adamantane. Also we establish some properties of newly defined temperature-Sombor index and temperature-Nirmala index.

II. RESULTS FOR SOME STANDARD GRAPHS

Proposition 1. If G is r-regular with n vertices and $r \geq 2$, then $TSO(G)=\dfrac{nr^2}{\sqrt{2}(n-r)}$.

Proof: Let G be an r-regular graph with n vertices and $r \geq 2$ and $\frac{nr}{2}$ edges. Then $T(u)=\dfrac{r}{n-r}$

$$TSO(G)=\frac{nr}{2}\sqrt{\left(\frac{r}{n-r}\right)^2+\left(\frac{r}{n-r}\right)^2}=\frac{nr}{2}\frac{\sqrt{2}r}{n-r}$$

$$=\frac{nr^2}{\sqrt{2}(n-r)}.$$

Corollary 1.1. Let C_n be a cycle with $n\geq 3$ vertices. Then

$$TSO(C_n)=\frac{2\sqrt{2}n}{n-2}.$$

Corollary 1.2. Let K_n be a complete graph with $n\geq 3$ vertices. Then

$$TSO(K_n)=\frac{n(n-1)^2}{\sqrt{2}}.$$

Proposition 2. If G is r-regular with n vertices and $r \geq 2$, then $^{m}TSO(G)=\dfrac{n(n-r)}{2\sqrt{2}}$.

Proof: Let G be an r-regular graph with n vertices and $r \geq 2$ and $\frac{nr}{2}$ edges. Then $T(u)=\dfrac{r}{n-r}$

$$^{m}TSO(G)=\frac{nr}{2}\frac{1}{\sqrt{\left(\frac{r}{n-r}\right)^2+\left(\frac{r}{n-r}\right)^2}}=\frac{nr}{2}\frac{(n-r)}{\sqrt{2}r}$$

$$=\frac{n(n-r)}{2\sqrt{2}}.$$

Corollary 2.1. Let C_n be a cycle with $n\geq 3$ vertices. Then

$$^{m}TSO(C_n)=\frac{n(n-2)}{2\sqrt{2}}.$$

Corollary 2.2. Let K_n be a complete graph with $n\geq 3$ vertices. Then

$$^{m}TSO(K_n)=\frac{n}{2\sqrt{2}}.$$

Proposition 3. If G is r-regular with n vertices and $r \geq 2$, then $TN(G)=\dfrac{nr\sqrt{r}}{\sqrt{2}\sqrt{n-r}}$.

Proof: Let G be an r-regular graph with n vertices and $r \geq 2$ and $\frac{nr}{2}$ edges. Then $T(u)=\dfrac{r}{n-r}$

$$TN(G)=\frac{nr}{2}\sqrt{\left(\frac{r}{n-r}\right)+\left(\frac{r}{n-r}\right)}$$

$$=\frac{nr\sqrt{r}}{\sqrt{2}\sqrt{n-r}}.$$

Corollary 3.1. Let C_n be a cycle with $n\geq 3$ vertices. Then

$$TN(C_n)=\frac{2n}{\sqrt{n-2}}.$$

Corollary 3.2. Let K_n be a complete graph with $n\geq 3$ vertices. Then

$$TN(K_n)=\frac{n(n-1)^{3/2}}{\sqrt{2}}.$$

III. RESULTS FOR TETRAMERIC 1,3-ADAMNTANE

In Chemistry, diamondoids are variants of the carbon cage known as adamantane (C_{10}, H_{16}), the smallest unit cage structure of the diamond crystal lattice. We focus on the molecular structure of the family of tetrameric 1,3-adamantane and it is denoted by $TA[n]$. Let G be the graph of tetrameric 1,3-adamantane $TA[n]$. The graph of tetrameric 1,3-adamantane $TA[4]$ is depicted in Figure 1.

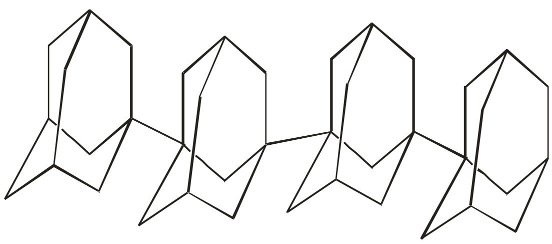

Figure 1. The graph of tetrameric 1,3-adamantane $TA[4]$

By calculation, G has $10n$ vertices and $13n$ – 1edges. Also by calculation, we obtain three edge partitions of G

based on the degrees of the end vertices of each edge as follows:

$E_1=\{uv\in E(G) \mid d_G(u)=2, d_G(v)=3\}$, $|E_1| = 6n + 6$.

$E_2=\{uv\in E(G) \mid d_G(u)=2, d_G(v)=4\}$, $|E_2| = 6n - 6$.

$E_3=\{uv\in E(G) \mid d_G(u)=d_G(v) = 4\}$, $|E_3| = n - 1$.

Therefore, in $TA[n]$, there are three types of edges based on the temperature of end vertices of each edge as follows:

$TE_1=\{uv\in E(G) \mid T(u)=\frac{2}{10n-2},\ T(v)=\frac{3}{10n-3}\}$, $|E_1| = 6n + 6$.

$TE_2=\{uv\in E(G) \mid T(u)=\frac{2}{10n-2},\ T(v)=\frac{4}{10n-4}\}$, $|E_2| = 6n - 6$.

$TE_3=\{uv\in E(G) \mid T(u)=T(v) = \frac{4}{10n-4}\}$, $|E_3| = n - 1$.

Theorem 1. The temperature Sombor index of a tetrameric 1,3-adamantane $TA[n]$ is

$$TSO(TA[n])=\left[\frac{1}{(5n-1)^2}+\frac{9}{(10n-3)^2}\right]^{\frac{1}{2}}(6n+6)$$

$$+\left[\frac{1}{(5n-1)^2}+\frac{4}{(5n-2)^2}\right]^{\frac{1}{2}}(6n-6)$$

$$+\left[\frac{8}{(5n-2)^2}\right]^{\frac{1}{2}}(n-1).$$

Proof: To compute $TSO(TA[n])$, we see that

$$TSO(TA[n])=\sum_{uv\in E(G)}\left[T(u)^2+T(v)^2\right]^{\frac{1}{2}}$$

$$=\left[\left(\frac{1}{5n-1}\right)^2+\left(\frac{3}{10n-3}\right)^2\right]^{\frac{1}{2}}(6n+6)$$

$$+\left[\left(\frac{2}{10n-2}\right)^2+\left(\frac{4}{10n-4}\right)^2\right]^{\frac{1}{2}}(6n-6)$$

$$+\left[\left(\frac{4}{10n-4}\right)^2+\left(\frac{4}{10n-4}\right)^2\right]^{\frac{1}{2}}(n-1)$$

$$=\left[\frac{1}{(5n-1)^2}+\frac{9}{(10n-3)^2}\right]^{\frac{1}{2}}(6n+6)$$

$$+\left[\frac{1}{(5n-1)^2}+\frac{4}{(5n-2)^2}\right]^{\frac{1}{2}}(6n-6)$$

$$+\left[\frac{8}{(5n-2)^2}\right]^{\frac{1}{2}}(n-1).$$

Theorem 2. The modified temperature Sombor index of a tetrameric 1,3-adamantane $TA[n]$ is

$$^{m}TSO(TA[n])=\left[\frac{1}{(5n-1)^2}+\frac{9}{(10n-3)^2}\right]^{-\frac{1}{2}}(6n+6)$$

$$+\left[\frac{1}{(5n-1)^2}+\frac{4}{(5n-2)^2}\right]^{-\frac{1}{2}}(6n-6)$$

$$+\left[\frac{8}{(5n-2)^2}\right]^{-\frac{1}{2}}(n-1).$$

Proof: To compute $^{m}TSO(TA[n])$, we see that

$$^{m}TSO(TA[n])=\sum_{uv\in E(G)}\left[T(u)^2+T(v)^2\right]^{-\frac{1}{2}}$$

$$=\left[\left(\frac{1}{5n-1}\right)^2+\left(\frac{3}{10n-3}\right)^2\right]^{-\frac{1}{2}}(6n+6)$$

$$+\left[\left(\frac{2}{10n-2}\right)^2+\left(\frac{4}{10n-4}\right)^2\right]^{-\frac{1}{2}}(6n-6)$$

$$+\left[\left(\frac{4}{10n-4}\right)^2+\left(\frac{4}{10n-4}\right)^2\right]^{-\frac{1}{2}}(n-1)$$

$$=\left[\frac{1}{(5n-1)^2}+\frac{9}{(10n-3)^2}\right]^{-\frac{1}{2}}(6n+6)$$

$$+\left[\frac{1}{(5n-1)^2}+\frac{4}{(5n-2)^2}\right]^{-\frac{1}{2}}(6n-6)$$

$$+\left[\frac{8}{(5n-2)^2}\right]^{-\frac{1}{2}}(n-1).$$

Theorem 3. The temperature Nirmala index of a tetrameric 1,3-adamantane $TA[n]$ is

$$TN(TA[n])=\left[\frac{25n-6}{(5n-1)(10n-3)}\right]^{\frac{1}{2}}(6n+6)$$

$$+\left[\frac{15n-4}{(5n-1)(5n-2)}\right]^{\frac{1}{2}}(6n-6)+\left(\frac{4}{5n-2}\right)^{\frac{1}{2}}(n-1).$$

Proof: To compute $TN(TA[n])$, we see that

$$TN(TA[n]) = \sum_{uv\in E(G)} [T(u)+T(v)]^{\frac{1}{2}}$$

$$= \left[\left(\frac{1}{5n-1}\right)+\left(\frac{3}{10n-3}\right)\right]^{\frac{1}{2}}(6n+6)$$

$$+\left[\left(\frac{2}{10n-2}\right)+\left(\frac{4}{10n-4}\right)\right]^{\frac{1}{2}}(6n-6)$$

$$+\left[\left(\frac{4}{10n-4}\right)+\left(\frac{4}{10n-4}\right)\right]^{\frac{1}{2}}(n-1)$$

$$= \left[\frac{25n-6}{(5n-1)(10n-3)}\right]^{\frac{1}{2}}(6n+6)$$

$$+\left[\frac{15n-4}{(5n-1)(5n-2)}\right]^{\frac{1}{2}}(6n-6)+\left(\frac{4}{5n-2}\right)^{\frac{1}{2}}(n-1).$$

Similarly, we can find the values of $TSO(TA[n],x)$, ${}^{m}TSO(TA[n],x)$ and $TN(TA[n],x)$.

IV. MATHEMATICAL PROPERTIES

Theorem 4. Let G be a connected graph with m edges. Then

$$TSO(G) \le \sqrt{2mFT(G)}.$$

Proof: Using the Cauchy-Schwarz inequality, we obtain

$$\left(\sum_{uv\in E(G)} \sqrt{T(u)^2+T(v)^2}\right)^2 \le \sum_{uv\in E(G)} 1 \sum_{uv\in E(G)} \left[T(u)^2+T(v)^2\right] = 2mFT(G).$$

Thus $TSO(G) \le \sqrt{2mFT(G)}$.

Theorem 5. Let G be a connected graph. Then

$$\frac{1}{\sqrt{2}} T_1(G) \le TSO(G) \le T_1(G).$$

Proof: For any two positive numbers a and b,

$$\frac{1}{\sqrt{2}}(a+b) \le \sqrt{a^2+b^2} \le a+b.$$

For a=T(u) and b=T(v) , the above inequality becomes

$$\frac{1}{\sqrt{2}}(T(u)+T(v)) \le \sqrt{\left(T(u)^2+T(v)^2\right)} \le (T(u)+T(v)).$$

By the definitions, we have

$$\frac{1}{\sqrt{2}} \sum_{uv\in E(G)} [T(u)+T(v)] \le \sum_{uv\in E(G)} \sqrt{T(u)^2+T(v)^2} \le \sum_{uv\in E(G)} [T(u)+T(v)].$$

Thus we get the desired result.

Theorem 6. Let G be connected graph of order n and size m. Then

$$\frac{1}{\sqrt{2}} TMPI(G) \le TN(G) \le TMPI(G).$$

Proof: Let a and b be any two non-negative real numbers. Then

$$\sqrt{a+b} \ge \frac{1}{\sqrt{2}}(\sqrt{a}+\sqrt{b})$$

with equality if and only if $a = b$.

If $a = T(u)$ and $b = T(v)$, then the above inequality becomes

$$\sqrt{T(u)+T(v)} \ge \frac{1}{\sqrt{2}}\left(\sqrt{T(u)}+\sqrt{T(v)}\right).$$

By the definition of Nirmala index, we have

$$TN(G) = \sum_{uv\in E(G)} \sqrt{T(u)+T(v)} \ge \frac{1}{\sqrt{2}}\left(\sqrt{T(u)}+\sqrt{T(v)}\right) = \frac{1}{\sqrt{2}} TMPI(G).$$

Also, by the definition of Nirmala index, we have

$$TN(G) = \sum_{uv\in E(G)} \sqrt{T(u)+T(v)}$$

$$= \sum_{uv\in E(G)} \left[\left(\sqrt{T(u)}+\sqrt{T(u)}\right)^2 - 2\sqrt{T(u)T(v)}\right]^{1/2}$$

$$\le \sum_{uv\in E(G)} \left(\sqrt{T(u)}+\sqrt{T(u)}\right) = TMPI(G).$$

Theorem 7. Let G be a connected graph. Then

$$T_1(G) - 2ISI_T(G) < TSO(G) \le \sqrt{2}T_1(G) - 2\sqrt{2}ISI_T(G).$$

Proof: For any two numbers a, b>0, we have

$$a^2+b^2 < (a+b)^2 \le 2(a^2+b^2).$$

Thus $\sqrt{a^2+b^2} < a+b \le \sqrt{2}\sqrt{a^2+b^2}$

and

$$(T(u)+T(v))^2 = \sqrt{T(u)^2+T(v)^2}\sqrt{T(u)^2+T(v)^2} + 2T(u)T(v).$$

Thus $(T(u)+T(v))^2$

$$< (T(u)+T(v))\sqrt{T(u)^2+T(v)^2}$$

$$+2T(u)T(v).$$

Hence $(T(u)+T(v))$

$$< \sqrt{T(u)^2+T(v)^2} + \frac{2T(u)T(v)}{T(u)+T(v)}.$$

By the definitions, we have

$$T_1(G) < TSO(G) + 2ISI_T(G).$$

Also we have

$$\frac{1}{\sqrt{2}}(T(u)+T(v))\sqrt{T(u)^2+T(v)^2}$$

$$+2T(u)T(v) \le (T(u)+T(v))^2.$$

Thus

$$\sqrt{T(u)^2+T(v)^2} + \frac{2\sqrt{2}T(u)T(v)}{T(u)+T(v)}$$

$$\le \sqrt{2}(T(u)+T(v)).$$

By the definitions, we have

$$TSO(G) + 2\sqrt{2}ISI_T(G) \le \sqrt{2}T_1(G).$$

This completes the proof.

V. CONCLUSION

In this paper, we have introduced the temperature Sombor index, the modified temperature Sombor index and temperature Nirmala index of a graph. We have computed these indices for some standard graphs and tetrameric 1,3-adamantane *TA* [*n*]. Also we have obtained some properties of the temperature Sombor index and the temperature Nirmala index.

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