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THE (*a*, *b*)-KULLI-BASAVA INDEX OF GRAPHS

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ABSTRACT

New degree based graph indices called Kulli-Basava indices were studied their chemical and mathematical properties which have good response with mean isomer degeneracy. In this paper, we introduce the symmetric division Kulli-Basava index, first and second Kulli-Gourava indices, general first and second Kulli-Basava indices, (a, b)-Kulli-Basava index of a graph and exact formulas for regular graphs, wheel, gear, helm graphs.

KEYWORDS: Symmetric division Kulli-Basava index, Kulli-Gourava indices, (*a*, *b*)-Kulli-Basava index, graph.
Mathematics Subject Classification: 05*C*05, 05*C*07, 05*C*12. 05*C*35.

1. INTRODUCTION

A graph index is a numerical parameter mathematically derived from the graph structure. Several graph indices have been considered in Mathematical Chemistry, see [1, 2].

Throughout this paper, G is a finite, simple, connected graph. We denote the set of vertices of G by V(G) and the set of edges of G by E(G). Let $d_G(v)$ denote the degree of a vertex v. The degree of an edge e = uv in a graph G is defined by $d_G(e) = d_G(u) + d_G(v) – 2$. Let $S_e(u)$ denote the sum of the degrees of all edges incident to a vertex u. The terms and concepts not given here, we refer [3].

The first and second Kulli-Basava indices were proposed in [4], defined as

$$KB_1(G) = \sum_{uv\in E(G)} \left[S_e(u)+S_e(v)\right], \quad KB_2(G) = \sum_{uv\in E(G)} S_e(u)S_e(v).$$

The second hyper Kulli-Basava index introduced in [5], defined as

$$HKB_2(G) = \sum_{uv\in E(G)} \left[S_e(u)S_e(v)\right]^2.$$

The F_1-Kulli-Basava index of a graph was proposed by Kulli in [6], defined as

$$F_1KB(G) = \sum_{uv\in E(G)} \left[S_e(u)^2+S_e(v)^2\right].$$

In [7], Kulli introduced the product connectivity Kulli-Basava index of a graph G, defined as

$$PKB(G) = \sum_{uv\in E(G)} \frac{1}{\sqrt{S_e(u)S_e(v)}}.$$

We introduce the symmetric division Kulli-Basava index of a graph G and it is defined as

$$SDKB(G) = \sum_{uv\in E(G)} \left(\frac{S_e(u)}{S_e(v)}+\frac{S_e(v)}{S_e(u)}\right).$$

We also propose the first and second Kulli-Gourava indices of a graph G and they are defined as

$$KGO_1(G) = \sum_{uv\in E(G)} \left[S_e(u)+S_e(v)+S_e(u)S_e(v)\right],$$

$$KGO_2(G) = \sum_{uv\in E(G)} \left(S_e(u)+S_e(v)\right)S_e(u)S_e(v).$$

We propose the general first and second Kulli-Basava indices of a graph, defined as

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$$KB_1^a(G) = \sum_{uv\in E(G)} \left[S_e(u)+S_e(v)\right]^a,$$

$$KB_2^a(G) = \sum_{uv\in E(G)} \left[S_e(u)S_e(v)\right]^a.$$

Based on Kulli-Basava indices, we introduce the (a, b)- Kulli-Basava index and it is defined as

$$N_{a,b}(G) = \sum_{uv\in E(G)} \left[S_e(u)^a S_e(v)^b + S_e(u)^b S_e(v)^a\right]$$

where a, b are real numbers.

Recently, some variants of Kulli-Basava indices were introduced and studied such as multiplicative F-Kulli Basava index [8], general Kulli-Basava index [9], multiplicative Kulli-Basava indices [10], multiplicative product connectivity Kulli-Basava index [11], multiplicative (a, b)-Kulli-Basava index [12].

Recently some new graph indices were studied, for example, in [13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36].

In this paper, the symmetric division Kulli-Basava index, first and second Kulli-Gourava indices, (a, b)-Kulli-Basava index of regular graphs, wheel, gear, helm graphs are computed.

2. OBSERVATIONS

We observe the following relations between (a, b)-Kulli Basava index with some other Kulli-Basava indices.

i) $KB_1(G) = N_{1,0}(G).$

ii) $KB_2(G) = \frac{1}{2}N_{1,1}(G).$

iii) $HKB_2(G) = \frac{1}{2}N_{2,2}(G).$

iv) $KB_2^a(G) = \frac{1}{2}N_{a,a}(G).$

v) $PKB(G) = \frac{1}{2}N_{-\frac{1}{2},-\frac{1}{2}}(G).$

vi) $SDKB(G) = N_{1,-1}(G).$

vii) $KGO_2(G) = N_{2,1}(G).$

viii) $F_1KB(G) = N_{2,0}(G).$

3. RESULTS FOR REGULAR GRAPHS

Theorem 1. Let G be an r-regular graph with n vertices. Then the (a, b)-Kulli-Basava index of G is given by

$$N_{a,b}(G) = nr\left[2r(r-1)\right]^{a+b}. \quad (1)$$

Proof: If G is an r-regular graph with n vertices, then G has $\frac{nr}{2}$ edges and for any vertex u in G, $S_e(u) = 2r(r-1)$. Therefore

$$N_{a,b}(G) = \sum_{uv\in E(G)} \left[S_e(u)^a S_e(v)^b + S_e(u)^b S_e(v)^a\right]$$

$$=\frac{nr}{2}\left[\{2r(r-1)\}^a\{2r(r-1)\}^b+\{2r(r-1)\}^b\{2r(r-1)\}^a\right]$$

$$=nr[2r(r-1)]^{a+b}.$$

We obtain the following results by using Theorem 1 and observations.

Corollary 1.1. Let G be an r-regular graph with n vertices and $\frac{nr}{2}$ edges. Then

i) $KB_1(G)=N_{1,0}(G)=2nr^2(r-1).$

ii) $KB_2(G)=\frac{1}{2}N_{1,1}(G)=2nr^3(r-1)^2.$

iii) $HKB_2(G)=\frac{1}{2}N_{2,2}(G)=8nr^5(r-1)^4.$

iv) $KB_2^a(G)=\frac{1}{2}N_{a,a}(G)=\frac{1}{2}nr[2r(r-1)]^{2a}.$

v) $PKB(G)=\frac{1}{2}N_{-\frac{1}{2},-\frac{1}{2}}(G)=\frac{n}{4(r-1)}.$

vi) $SDKB(G)=N_{1,-1}(G)=nr.$

vii) $KGO_2(G)=N_{2,1}(G)=8nr^4(r-1)^3.$

viii) $F_1KB(G)=N_{2,0}(G)=4nr^3(r-1)^2.$

Corollary 1.2. The (a, b)-Kulli-Basava index of a complete graph K_n is given by

$$N_{a,b}(K_n)=n(n-1)[2(n-1)(n-2)]^{a+b}. \quad (2)$$

Proof: Put r = n – 1 in equation (1), we get the desired result.

Note 1. We obtain the values of $KB_1(K_n)$, $KB_2(K_n)$, $HKB_2(K_n)$, $KB_2^a(K_n)$, $PKB(K_n)$, $SDKB(K_n)$, $KGO_2(K_n)$, $F_1KB(K_n)$ by using equation (2) and observations.

Corollary 1.3. The (a, b)-Kulli-Basava index of a cycle C_n is given by

$$N_{a,b}(C_n) = 2n\times 4a+b . \quad (3)$$

Proof: Put r = 2 in equation (1), we obtain the desired result.

Note 2: We find the values of $KB_1(C_n)$, $KB_2(C_n)$, $HKB_2(C_n)$, $KB_2^a(C_n)$, $PKB(C_n)$, $SDKB(C_n)$, KGO2(C_n), F $_1$KB(C_n) by using equation (3) and observations.

Theorem 2. The first Kulli-Gourava index of an r-regular graph G is given by

$$KGO_1(G)=2nr^2(r-1)(r^2-r+1). \quad (4)$$

Proof: Let G be an r-regular graph with n vertices and $\frac{nr}{2}$ edges. For any vertex u in G, $S_e(u)$ = 2r(r – 1). Therefore

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$$KGO_1(G) = \sum_{uv \in E(G)} \left[S_e(u) + S_e(v) + S_e(u) S_e(v) \right]$$

$$= \frac{nr}{2}\left[2r(r-1) + 2r(r-1) + 2r(r-1)2r(r-1)\right]$$

$$= 2nr^2(r-1)(r^2 - r + 1).$$

Corollary 2.1. The first Kulli-Gourava index of a complete graph K_n is

$$KGO_1(K_n) = 2n(n-1)^2(n-2)(n^2 - 3n + 3).$$

Proof: Put r = n – 1 in equation (4), we get the desired result.

Corollary 2.2. The first Kulli-Gourava index of a cycle C_n is

$$KGO_1(C_n) = 24n.$$

Proof: Put r = 2 equation (4), we obtain the desired result.

4. RESULTS FOR WHEEL GRAPHS

A wheel graph W_n is the join of C_n and K_1. Clearly W_n has n+1 vertices and 2n edges. A graph W_n is shown in Figure 1. The vertices of C_n are called rim vertices and the vertex of K_1 is called apex.

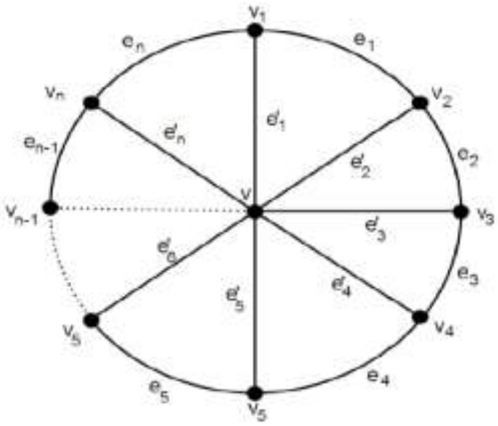

Figure 1. Wheel graph Wn

In W_n, there two types of edges as follows:
$E_1 = \{uv \in E(W_n) \mid S_e(u) = n+9,\ S_e(v) = n(n+1)\}$, $|E_1| = n$.
$E_2 = \{uv \in E(W_n) \mid S_e(u) = S_e(v) = n+9\}$, $|E_2| = n$.

Theorem 3. Let W_n be a wheel graph with n+1 vertices and 2n edges. Then the (a, b)-Kulli-Basava index of W_n is

$$N_{a,b}(W_n) = n\left[(n+9)^a \{n(n+1)\}^b + (n+9)^b \{n(n+1)\}^a\right] + 2n(n+9)^{a+b}.$$

Proof: From definition and by cardinalities of the edge partition of W_n, we derive

$$N_{a,b}(W_n) = \sum \left[S_e(u)^a S_e(v)^b + S_e(u)^b S_e(v)^a \right]$$

$$= |E_1|\left[(n+9)^a \{n(n+1)\}^b + (n+9)^b \{n(n+1)\}^a\right] + |E_2|\left[(n+9)^a (n+9)^b + (n+9)^b (n+9)^a\right]$$

$$= n\left[(n+9)^a\{n(n+1)\}^b + (n+9)^b\{n(n+1)\}^a\right] + 2n(n+9)^{a+b}.$$

We find the following results by using Theorem 2 and observations.

Corollary 3.1. Let W_n be a wheel graph with n+1 vertices and 2n edges. Then

i) $$KB_1(W_n) = N_{1,0}(W_n) = n(n^2+4n+27).$$

ii) $$KB_2(W_n) = \frac{1}{2}N_{1,1}(W_n) = n(n+9)(n^2+2n+9).$$

iii) $$HKB_2(W_n) = \frac{1}{2}N_{2,2}(W_n) = n(n+9)^2\left[n^2(n+1)^2+(n+9)^2\right].$$

iv) $$KB_2^a(W_n) = \frac{1}{2}N_{a,a}(W_n) = n(n+9)^a\left[n^a(n+1)^a+(n+9)^a\right].$$

v) $$PKB(W_n) = \frac{1}{2}N_{-\frac{1}{2},-\frac{1}{2}}(W_n) = \frac{n}{\sqrt{n(n+1)(n+9)}} + \frac{n}{n+9}.$$

vi) $$SDKB(W_n) = N_{1,-1}(W_n) = \frac{n^4+2n^3+2n^2+18n+81}{(n+1)(n+9)} + 2n.$$

vii) $$KGO_2(W_n) = N_{2,1}(W_n) = n^2(n+9)(n+1)(n^2+2n+9) + 2n(n+9)^3.$$

viii) $$F_1KB(W_n) = N_{2,0}(W_n) = n(n^3+5n^2+55n+243).$$

Theorem 4. The first Kulli-Gourava index of a wheel graph W_n is

$$KGO_1(W_n) = n(n^3+12n^2+31n+108).$$

Proof: Let W_n be a wheel graph with n+1 vertices and 2n edges. From definition and by cardinalities of the edge partition of W_n, we obtain

$$KGO_1(W_n) = \sum_{uv\in E(W_n)}\left[S_e(u)+S_e(v)+S_e(u)S_e(v)\right]$$

$$= |E_1|\left[(n+9)+n(n+1)+(n+9)n(n+1)\right] + |E_2|\left[n+9+n+9+(n+9)(n+9)\right]$$

$$= n(n^3+12n^2+31n+108).$$

5. RESULTS FOR GEAR GRAPHS

A graph is a gear graph obtained from W_n by adding a vertex between each pair of adjacent rim vertices and it is denoted by G_n. A graph G_n is shown in Figure 2.

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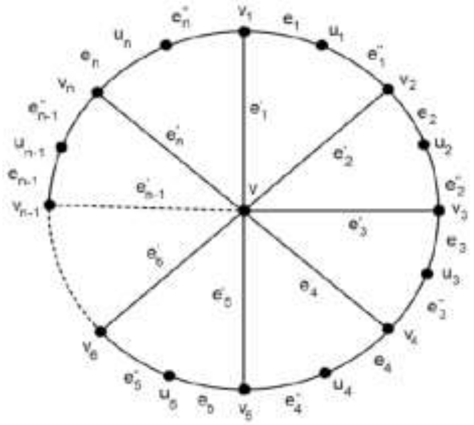

Figure 2. Gear graph Gn

A gear graph G_n has 2n+1 vertices and 3n edges, and it has to types of edges as follows:

$E_1 = \{uv \in E(G_n) \mid S_e(u) = n(n+1), S_e(v) = n+7\}$, $|E_1| = n$.

$E_2 = \{uv \in E(G_n) \mid S_e(u) = n+7, S_e(v) = 6\}$, $|E_2| = 2n$.

Theorem 5. Let G_n be a gear graph with 2n + 1 vertices and 3n edges. Then the (a, b)-Kulli-Basava index of a gear graph G_n is

$$N_{a,b}(G_n) = n\left[\{n(n+1)\}^a (n+7)^b + \{n(n+1)\}^b (n+7)^a\right] + 2n\left[(n+7)^a 6^b + (n+7)^b 6^a\right].$$

Proof: From definition and by cardinalities of the edge partition of G_n, we deduce

$$N_{a,b}(G_n) = \sum_{uv\in E(G_n)} \left[S_e(u)^a S_e(v)^b + S_e(u)^b S_e(v)^a\right]$$

$$= |E_1|\left[\{n(n+1)\}^a (n+7)^b + \{n(n+1)\}^b (n+7)^a\right] + |E_2|\left[(n+7)^a 6^b + (n+7)^b 6^a\right]$$

$$= n\left[\{n(n+1)\}^a (n+7)^b + \{n(n+1)\}^b (n+7)^a\right] + 2n\left[(n+7)^a 6^b + (n+7)^b 6^a\right].$$

We establish the following results by using Theorem 5 and observations.

Corollary 5.1. Let G_n be a gear graph with 2n +1 vertices and 3n edges. Then

i) $KB_1(G_n) = N_{1,0}(G_n) = n^3 + 4n^2 + 33n.$

ii) $KB_2(G_n) = \frac{1}{2}N_{1,1}(G_n) = n(n+7)(n^2 + 2n + 12).$

iii) $HKB_2(G_n) = \frac{1}{2}N_{2,2}(G_n) = n(n+7)^2\left[n^2(n+1)^2 + 72\right].$

iv) $KB_2^a(G_n) = \frac{1}{2}N_{a,a}(G_n) = n(n+7)^a\left[n^a(n+1)^a + 2\times 6^a\right].$

v) $PKB(G_n) = \frac{1}{2}N_{-\frac{1}{2},-\frac{1}{2}}(G_n) = \frac{n}{\sqrt{n(n+1)(n+7)}} + \frac{2n}{\sqrt{6(n+7)}}.$

vi) $SDKB(G_n) = N_{1,-1}(G_n) = \frac{n^2(n+1)^2 + (n+7)^2}{(n+1)(n+7)} + \frac{n\left[(n+7)^2 + 36\right]}{3(n+7)}.$

vii) $KGO_2(G_n) = N_{2,1}(G_n) = n(n+7)\left[(n^2 + 2n + 7)(n+1)n + 12(n+13)\right].$

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viii) $F_1KB(G_n) = N_{2,0}(G_n) = n(n^4 + 2n^3 + 4n^2 + 42n + 219).$

Theorem 6. The first Kulli-Gourava index of a gear graph G_n is given by

$$KGO_1(G_n) = n^4 + 9n^3 + 23n^2 + 110n + 7.$$

Proof: From definition and by cardinalities of the edge partition of G_n, we obtain

$$KGO_1(G_n) = \sum_{uv \in E(G_n)} [S_e(u) + S_e(v) + S_e(u)S_e(v)]$$

$$= |E_1|[n(n+1) + n + 7 + n(n+1)(n+7)] + |E_2|[n + 7 + 6 + (n+7)6]$$

$$= n^4 + 9n^3 + 23n^2 + 110n + 7.$$

6. RESULTS FOR HELM GRAPHS

A helm graph, denoted by H_n, is a graph obtained from a wheel graph W_n by attaching an end edge to each rim vertex. A helm graph H_n is shown in Figure 3.

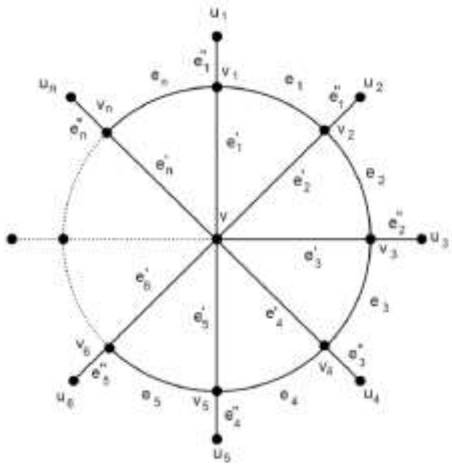

Figure 3. Helm graph Hn

Clearly, a helm graph H_n has 2n+1 vertices and 3n edges. In H_n , there are three types of edges as follows:

$E_1 = \{uv \in E(H_n) \mid S_e(u) = n(n+2),\ S_e(v) = n+17\}$, $|E_1| = n$.

$E_2 = \{uv \in E(H_n) \mid S_e(u) = S_e(v) = n+17\}$, $|E_2| = n$.

$E_3 = \{uv \in E(H_n) \mid S_e(u) = n+17,\ S_e(v) = 3\}$, $|E_3| = n$.

Theorem 7: Let H_n be a helm graph with 2n+1 vertices and 3n edges. Then the (a, b)-Kulli-Basava index of a helm graph H_n is

$$N_{a,b}(H_n) = n\left[\{n(n+2)\}^a (n+17)^b + \{n(n+2)\}^b (n+17)^a\right] + 2n(n+17)^{a+b} + n\left[(n+17)^a 3^b + (n+17)^b 3^a\right].$$

Proof: From definition and by cardinalities of a helm graph H_n, we derive

$$N_{a,b}(H_n) = \sum_{uv \in E(H_n)} \left[S_e(u)^a S_e(v)^b + S_e(u)^b S_e(v)^a\right]$$

$$= |E_1|\left[\{n(n+2)\}^a (n+17)^b + \{n(n+2)\}^b (n+17)^a\right] + |E_2|\left[(n+17)^a (n+17)^b + (n+17)^b (n+17)^a\right]$$

$$+ |E_3|\left[(n+17)^a 3^b + (n+7)^b 3^a\right]$$

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$$=n\left[\{n(n+2)\}^{a}(n+17)^{b}+\{n(n+2)\}^{b}(n+17)^{a}\right]+2n(n+17)^{a+b}+n\left[(n+17)^{a}3^{b}+(n+17)^{b}3^{a}\right].$$

From Theorem 7 and by using observations, we establish the following results.

Corollary 7.1. Let H_n be a helm graph with 2n+1 vertices and 3n edges. Then

i) $KB_1(H_n)=N_{1,0}(H_n)=3n^3+4n^2+71n.$

ii) $KB_2(H_n)=\frac{1}{2}N_{1,1}(H_n)=n(n+17)(n^2+3n+20).$

iii) $HKB_2(H_n)=\frac{1}{2}N_{2,2}(H_n)=n(n+17)^2\left[n^2(n+2)^2+(n+17)^2+9\right].$

iv) $KB_2^a(H_n)=\frac{1}{2}N_{a,a}(H_n)=n(n+17)^a\left[n^a(n+2)^a+(n+17)^a+3^a\right].$

v) $PKB(H_n)=\frac{1}{2}N_{-\frac{1}{2},-\frac{1}{2}}(H_n)=\frac{n}{\sqrt{n(n+2)(n+17)}}+\frac{n}{n+17}+\frac{n}{\sqrt{3(n+17)}}.$

vi) $SDKB(H_n)=N_{1,-1}(H_n)=\frac{n^2(n+2)^2+(n+17)^2}{(n+2)(n+17)}+2n+\frac{n\left[(n+17)^2+9\right]}{3(n+17)}.$

vii) $KGO_2(H_n)=N_{2,1}(H_n)=n^2(n+17)(n+2)(n^2+3n+17)+2n(n+17)^3+3n(n+17)(n+20).$

viii) $F_1KB(H_n)=N_{2,0}(H_n)=n\left[n^2(n+2)^2+(n+17)^2\right]+2n(n+17)^2+n\left[(n+17)^2+9\right]$

Theorem 8. The first Kulli-Gourava index of a helm graph H_n is given by

$$KGO_1(H_n)=n(n^3+21n^2+77n+411).$$

Proof: From definition and by cardinalities of the edge partition of H_n , we derive

$$KGO_1(H_n)=\sum_{uv\in E(H_n)}\left[S_e(u)+S_e(v)+S_e(u)S_e(v)\right]$$

$$=|E_1|\left[n(n+2)+n+17+n(n+2)(n+17)\right]+|E_2|\left[n+17+n+17+(n+17)(n+17)\right]$$

$$+|E_3|\left[n+17+3+(n+17)3\right]$$

$$=n(n^3+21n^2+77n+411).$$

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