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Anti Fuzzy BG-ideals in BG-algebra

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Abstaract − In this paper, we introduce the concept of anti fuzzy BG-ideals in BG-algebra and we have discussed some of their properties. Relation between anti fuzzy BG-ideal and cartessian product of anti fuzzy BG-ideals is developed.

Keywords − *BG-algebra, sub BG-algebra, BG-ideals, anti fuzzy BG-ideals, anti fuzzy BG-bi-ideal.*

1 Introduction

In 1965, Zadeh [20] introduced the notion of a fuzzy set and fuzzy subset of a set as a method for representing uncertainty in real physical world. Since then its application have been growing rapidly over many disciplines. As a generalization of this, intuitionistic fuzzy subset was defined by K. T. Atanassov [3, 2, 4] in 1986. In 1971, Rosenfield [17] introduced the concept of fuzzy subgroup. Motivated by this, many mathematicians started to review various concepts and theorems of abstract algebra in the broader frame work of fuzzy settings. K. Iseki and Jun et al. introduced three classes of abstract algebras: BCI-algebras, BH-algebras and BCK-algebras [8, 10, 13], respectively. It is known that the class of BCK-algebras is a proper subclass of the class of BCI-algebras. Further, the notion of intutionistic fuzzy ideals was introduced by Jun and Kim in BCK-algebras [9]. In [7, 6] Hu and Li introduced a wide class of abstract algebras: BCH-algebras. They have shown that the class of BCI-algebras is a proper subclass of the class of BCH-algebras. Neggers and HKim [15, 16] introduced the notion of B-algebras and d-algebras which is

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another generalization of BCK-algebras, and they also investigated several relations between d-algebras and BCK-algebras as well as some other interesting relations between d-algebras and oriented digraphs. Ahn and Lee studied fuzzy subalgebra of BG-algebra in [1]. The fuzzy ideals in BCI-algebras and MV-algebras was studied by Hoo in [5]. The concept of anti fuzzy filters of pseudo-BL-algebras was introduced by Rysiawa in [18].

In this paper we initiate the study of anti fuzzy BG-ideal in BG-algebra. This paper comprises of four section. In section 2, we recall some basic definitions of BG-algebras. In section 3, we define anti fuzzy subalgebras and also give example of anti fuzzy subalgebras. In section 4, we define anti fuzzy BG-ideals and provided a condition for a every anti fuzzy BG-bi-ideals is an anti fuzzy BG-ideal

2 Preliminary

In this section we site the basic definitions that will be used in the sequel.

Definition 2.1. A nonempty set X with a constant 0 and a binary operation '$*$' is called a BG-algebra if it satisfies the following axioms:

1. $x * x = 0$,
2. $x * 0 = x$,
3. $(x * y) * (0 * y) = x$ for all $x, y \in X$.

Example 2.2. Let $X = \{0, 1, 2\}$ be the set with the following table.

$*$	0	1	2
0	0	1	2
1	1	0	1
2	2	2	0

Then $(X, *, 0)$ is a BG-algebra.

Definition 2.3. [14] Let S be a non empty subset of a BG -algebra X then S is called a subalgebra of X if $x * y \in S$, for all $x, y \in S$.

Definition 2.4. [14] Let X be a BG-algebra and I be a subset of X, then I is called a BG-ideal of Xif it satisfies following conditions:

1. $0 \in I$
2. $x * y \in I$ and $y \in I \Longrightarrow x \in I$,
3. $x \in I$ and $y \in X \Longrightarrow x * y \in I$.

Definition 2.5. [14] A mapping $f : X \to Y$ of a BG-algebra is called a homomorphism if $f(x * y) = f(x) * f(y)$ for all$x, y \in X$.

Remark 2.6. If $f : X \to Y$ is a homomorphism of BG-algebra, then $f(0) = 0$.

Definition 2.7. [14] Let X be a non-empty set. A fuzzy subset μ of the set X is a mapping $X \to [0, 1]$.

Definition 2.8. [14] A fuzzy set μ in X is said to be a fuzzy BG-bi-ideal if

$$\mu(x * w * y) \geq \min\{\mu(x), \mu(y)\} \text{ for all } x, y, w \in X.$$

3 Anti Fuzzy Subalgebras

Definition 3.1. Let μ be a fuzzy set in BG-algebra. Then μ is called an anti fuzzy subalgebra of X if

$$\mu(x * y) \leq \max\{\mu(x), \mu(y)\} \text{ for all } x, y \in X.$$

Example 3.2. Let $X = \{0, 1, 2, 3\}$ be the set with the following table.

*	0	1	2	3
0	0	1	2	3
1	1	0	1	1
2	2	2	0	2
3	3	3	3	0

Then $(X, *, 0)$ is a BG-algebra. Define a fuzzy set $\mu : X \to [0, 1]$ by

$$\mu(x) = \begin{cases} t_0 & \text{if } x \in \{2, 3\} \\ t_1 & \text{if } x \in \{0, 1\} \end{cases}$$

for t_0, $t_1 \in [0, 1]$, with $t_0 > t_1$. Then μ is an anti fuzzy subalgebra of X.

Definition 3.3. Let μ be a fuzzy set in a set X For $t \in [0, 1]$, the set

$$\mu_t = \{x \in X : \mu(x) \leq t\}$$

is called a lower level subset of μ.

4 Anti Fuzzy BG-ideals

Definition 4.1. A fuzzy set μ in X is called an anti fuzzy BG-ideals of X if it satisfies the following inequalities:

1. $\mu(0) \leq \mu(x)$,
2. $\mu(x) \leq \max\ \{\mu(x * y), \mu(y)\}$,
3. $\mu(x * y) \leq \max\{\mu(x), \mu(y)\}$for all $x, y \in X$.

Example 4.2. Let $X = \{0, 1, 2, 3\}$be the set with the following table.

*	0	1	2	3
0	0	1	2	3
1	1	0	1	1
2	2	2	0	2
3	3	3	3	0

Then $(X, *, 0)$ is a BG-algebra. Define a fuzzy set $\mu : X \to [0, 1]$ by

$$\mu(x) = \begin{cases} \alpha & \text{if } x \in \{2, 3\} \\ \beta & \text{if } x \in \{0, 1\} \end{cases}$$

for α,$\beta \in [0, 1]$, with $\alpha > \beta$. Then μ is an anti fuzzy BG-ideal of X.

Example 4.3. Let $X = \{0, 1, 2\}$be the set with the following table:

$*$	0	1	2
0	0	1	2
1	1	0	1
2	2	2	0

Then $(X, *, 0)$ is a BG-algebra. We define a fuzzy set$\mu : X \to [0, 1]$ by

$$\mu(x) = \begin{cases} 0.2 & \text{if } x = 0 \\ 0.8 & \text{otherwise.} \end{cases}$$

Then μ is an anti fuzzy BG-ideal of X.

Definition 4.4. Let μ and λbe the fuzzy sets in a set X. The Cartesian product $\lambda \times \mu$: $X \times X \to [0, 1]$ is defined by $(\lambda \times \mu)(x, y) = \max\ \{\lambda(x), \mu(y)\}$ for all $x, y \in X$.

Theorem 4.5. If λ and μ are anti fuzzy BG-ideal of a BG-algebra X, then $\lambda \times \mu$ is an anti fuzzy BG-ideal of $X \times X$.

Proof. For any $(x, y) \in X \times X$ we have

$$\begin{aligned} (\lambda \times \mu)(0, 0) &= \max\{\lambda(0), \mu(0)\} \\ &\leq \max\{\lambda(x), \mu(y)\} \\ &= (\lambda \times \mu)(x, y). \end{aligned}$$

That is,

$$(\lambda \times \mu)(0, 0) \leq (\lambda \times \mu)(x, y).$$

Let (x_1, x_2) and $(y_1, y_2) \in X \times X$.Then,

$$\begin{aligned} (\lambda \times \mu)(x_1, x_2) &= \max\{\lambda(x_1), \mu(x_2)\} \\ &\leq \max\{\max\{\lambda(x_1 * y_1), \lambda(y_1)\}, \max\{\mu(x_2 * y_2), \mu(y_2)\}\} \\ &= \max\{\max\{\lambda(x_1 * y_1), \mu(x_2 * y_2)\}, \max\{\lambda(y_1), \mu(y_2)\}\} \\ &= \max\{(\lambda \times \mu)((x_1 * y_1, x_2 * y_2)), (\lambda \times \mu)(y_1, y_2)\} \\ &= \max\{(\lambda \times \mu)((x_1, x_2) * (y_1, y_2)), (\lambda \times \mu)(y_1, y_2)\} \end{aligned}$$

That is,

$$(\lambda \times \mu)(x_1, x_2) \leq \max\{(\lambda \times \mu)((x_1, x_2) * (y_1, y_2)), (\lambda \times \mu)(y_1, y_2)\}$$

and

$$\begin{aligned} (\lambda \times \mu)((x_1, x_2) * (y_1, y_2)) &= (\lambda \times \mu)(x_1 * y_1, x_2 * y_2) \\ &= \max\{\lambda(x_1 * y_1), \mu(x_2 * y_2)\} \\ &\leq \max\{\max\{\lambda(x_1), \lambda(y_1)\}, \max\{\mu(x_2), \mu(y_2)\}\} \\ &= \max\{\max\{\lambda(x_1), \mu(x_2)\}, \max\{\lambda(y_1), \mu(y_2)\}\} \\ &= \max\{(\lambda \times \mu)((x_1, x_2)), (\lambda \times \mu)((y_1, y_2))\}. \end{aligned}$$

That is,

$$\begin{aligned} & (\lambda \times \mu)((x_1, x_2) * (y_1, y_2)) \\ \leq\ & \max\{(\lambda \times \mu)(x_1, x_2), (\lambda \times \mu)(y_1, y_2)\} \end{aligned}$$

Hence $\lambda \times \mu$ is an anti fuzzy BG-ideal of $X \times X$. $\square$

Theorem 4.6. Let λ *and* μ be fuzzy sets in a BG-algebra such that $\lambda \times \mu$ is an anti fuzzy BG-ideal of $X \times X$. Then

I. $\lambda(0) \leq \lambda(x)$ and $\mu(0) \leq \mu(x)$ for all $x \in X$.
II. If $\lambda(0) \leq \lambda(x)$ then $\mu(0) \leq \lambda(x)$ and $\mu(0) \leq \mu(x)$ for all $x \in X$.
III. If $\mu(0) \leq \mu(x)$ then $\lambda(0) \leq \lambda(x)$ and $\lambda(0) \leq \mu(x)$ for all $x \in X$.

Proof. I. Assume $\lambda(x) < \lambda(0)$ or $\mu(y) < \mu(0)$for some $x, y \in X$. Then

$$\begin{aligned} (\lambda \times \mu)(x, y) &= \max\ \{\lambda(x), \mu(y)\} \\ &< \max\{\lambda(0), \mu(0)\} \\ &= (\lambda \times \mu)(0, 0). \end{aligned}$$

Thus $(\lambda \times \mu)(x, y) < (\lambda \times \mu)(0, 0)$ for all $x, y \in X$ Which is a contradiction to $(\lambda \times \mu)$ is an anti fuzzy BG-ideal of $X \times X$. Therefore, $\lambda(0) \leq \lambda(x)$ and $\mu(0) \leq \mu(y)$for all $x, y \in X$.

II. Assume either $\mu(0) > \lambda(x)$ or $\mu(0) > \mu(y)$ for all $x, y \in X$. Then

$$\begin{aligned} (\lambda \times \mu)(0, 0) &= \max\{\lambda(0), \mu(0)\} \\ &= \mu(0) \end{aligned}$$

and

$$\begin{aligned} (\lambda \times \mu)(x, y) &= \max\ \{\lambda(x), \mu(y)\} < \mu(0) \\ &= (\lambda \times \mu)(0, 0). \end{aligned}$$

This implies

$$(\lambda \times \mu)(x, y) < (\lambda \times \mu)(0, 0).$$

Which is a contradiction to $\lambda \times \mu$ is an anti fuzzy BG-ideal of $X \times X$. Hence if

$$\lambda(0) \leq \lambda(x) \text{ for all } x \in X,$$

then

$$\mu(0) \leq \lambda(x) \text{ and } \mu(0) \leq \mu(x)$$

III. The proof is quite similar to (ii). □

Theorem 4.7. If $\lambda \times \mu$ is an anti fuzzy BG-ideals of $X \times X$, then λ and μ is an anti fuzzy BG-ideals of X.

Proof. Firstly to prove that μ is an anti fuzzy BG-ideal of X. Given $\lambda \times \mu$ is an anti fuzzy BG-ideals of $X \times X$, then by Theorem 4.6 (i)

$$\lambda(0) \leq \lambda(x) \text{ and } \mu(0) \leq \mu(x) \text{ for all } x \in X.$$

Let $\mu(0) \leq \mu(x)$. By Theorem 4.6 (iii), then $\lambda(0) \leq \lambda(x)$ and $\lambda(0) \leq \mu(x)$.Now

$$\begin{aligned} \mu(x) &= \max\{\lambda(0), \mu(x)\} \\ &= (\lambda \times \mu)(0, x) \\ &\leq \max\{(\lambda \times \mu)((0, x) * (0, y)),\ (\lambda \times \mu)(0, y)\} \\ &= \max\{(\lambda \times \mu)(0 * 0, x * y),\ (\lambda \times \mu)(0, y)\} \\ &= \max\{(\lambda \times \mu)(0, x * y),\ (\lambda \times \mu)(0, y)\} \\ &= \max\{(\lambda \times \mu)(0 * 0,\ x * y), (\lambda \times \mu)(0, y)\} \\ &= \max\{\mu(x * y),\ \mu(y)\}. \end{aligned}$$

That is,

$$\begin{aligned}\mu(x) &\leq \max\{\mu(x*y),\ \mu(y)\}\\ \mu(x*y) &= \max\{\lambda(0), \mu(x*y)\}\\ &= (\lambda\times\mu)(0, x*y)\\ &= (\lambda\times\mu)(0*0, x*y)\\ &= (\lambda\times\mu)(0,x)*(0,y)\end{aligned}$$

$$\begin{aligned}\mu(x*y) &\leq \max\{(\lambda\times\mu)(0,x), (\lambda\times\mu)(0,y)\}\\ &= \max\{\mu(x), \mu(y)\}.\end{aligned}$$

That is,

$$\mu(x*y) \leq \max\{\mu(x), \mu(y)\}.$$

This proves that μ is an anti fuzzy BG-ideal of X. Secondly to prove that λ is an anti fuzzy BG-ideal of X. Given $\lambda\times\mu$ is an anti fuzzy BG-ideal of $X\times X$, then by Theorem 4.6 (i), we have
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$$\lambda(0) \leq \lambda(x) \text{ and } \mu(0) \leq \mu(x) \text{ for all } x \in X.$$

Let $\lambda(0) \leq \lambda(x)$.By Theorem 4.6 (ii), then $\mu(0) \leq \lambda(x)$ and $\mu(0) \leq \mu(x)$.Now

$$\begin{aligned}\lambda(x) &= \max\{\lambda(x), \mu(0)\} = (\lambda\times\mu)(x,0)\\ &\leq \max\{(\lambda\times\mu)((x,0)*(y,0)),\ (\lambda\times\mu)(0,y)\}\\ &= \max\{(\lambda\times\mu)(x*y, 0*0),\ (\lambda\times\mu)(0,y)\}\\ &= \max\{(\lambda\times\mu)(x*y, 0),\ (\lambda\times\mu)(0,y)\}\\ &= \max\{\lambda(x*y),\ \lambda(y)\}\end{aligned}$$

That is,

$$\begin{aligned}\lambda(x) &\leq \max\{\lambda(x*y),\ \lambda(y)\}.\\ \lambda(x*y) &= \max\{\lambda(x*y), \mu(0)\}\\ &= (\lambda\times\mu)(x*y, 0)\\ &= (\lambda\times\mu)(x*y, 0*0)\\ &= (\lambda\times\mu)\left((x,0)*(y,0)\right)\end{aligned}$$

$$\begin{aligned}\lambda(x*y) &\leq \max\{(\lambda\times\mu)(x,0), (\lambda\times\mu)(y,0)\}\\ &= \max\{\lambda(x), \lambda(y)\}\end{aligned}$$

That is

$$\lambda(x*y) \leq \max\{\lambda(x), \lambda(y)\}.$$

This proves that λ is an anti fuzzy BG-ideal of X. $\square$

Theorem 4.8. If μ is an anti fuzzy BG-ideal of X then μ_t is a BG-ideal of X for all $t \in [0,1]$.

Proof. Let μbe anti fuzzy BG-ideal of X and $x, y \in X$. If $x, y \in \mu_t$ then

$$\mu(0) \leq \mu(x) \leq t \text{ implies } 0 \in \mu_t \text{ for all } t \in [0,1].$$

Let $x * y \in \mu_t$ and $y \in \mu_t$. Therefore, $\mu(x * y) \leq t$ and $\mu(y) \leq t$. Now

$$\mu(x) \leq \max\{\mu(x * y), \mu(y)\} \leq \max\{t, t\} \leq t.$$

Hence $\mu(x) \leq t$. That is, $x \in \mu_t$.

Let $x \in \mu_t$, $y \in X$. Choose y in X such that $\mu(y) \leq t$. Since $x \in \mu_t$implies $\mu(x) \leq t$. We know that

$$\begin{aligned} \mu(x * y) &\leq \max\{\mu(x), \mu(y)\} \\ &\leq \max\{t, t\} \leq t. \end{aligned}$$

That is

$$\mu(x * y) \leq t \text{ implies } x * y \in \mu_t.$$

Hence μ_t is a BG-ideal of X. □

Theorem 4.9. If X be a BG-algebra, $t \in [0,1]$,and μ_t is a BG-ideal of X, then μ is an anti fuzzy BG-ideals of X.

Proof. Let μ_t be a BG-ideal of X. Let $x, y \in \mu_t$. Then $\mu(x) \leq t$ and $\mu(y) \leq t$. Let $\mu(x) = t_1$ and $\mu(y) = t_2$, without loss of generality let $t_1 \leq t_2$. Then $x \in \mu_{t_2}$. Now $x \in \mu_{t_2}$ and $y \in X$ implies $x * y \in \mu_{t_2}$. That is,

$$\begin{aligned} \mu(x * y) &\leq t_2 \\ &= \max\{t_1,\ t_2\} \\ &= \max\{\mu(x), \mu(y)\}. \end{aligned}$$

That is,

$$\mu(x * y) \leq \max\{\mu(x), \mu(y)\}.$$

Now let

$$\begin{aligned} \mu(0) &= \mu(x * x) \\ &\leq \max\ \{\mu(x), \mu(x)\} \\ &= \mu(x). \end{aligned}$$

That is $\mu(0) \leq \mu(x)$ for all $x \in X$.
Further

$$\begin{aligned} \mu(x) &= (\mu(x * y) * (0 * y)) \\ &\leq \max\{\mu(x * y), \mu(0 * y)\} \\ &\leq \max\{\mu(x * y), \max\{\mu(0), \mu(y)\}\} \\ &\leq \max\{\mu(x * y), \mu(y)\}. \end{aligned}$$

Hence μ is an anti fuzzy BG-ideal of X. □

Definition 4.10. A fuzzy set μ in X is said to be an anti fuzzy BG-bi-ideal if $\mu(x * y * w) \leq \max\{\mu(x), \mu(y)\}$ for all $x, y, w \in X$.

Theorem 4.11. Every anti fuzzy BG-bi-ideal is an anti fuzzy BG-ideal.

Proof. It is trivial. □

Remark 4.12. The following example shows that the converse of Theorem 4.11 is not true in general.

Example 4.13. Let $X = \{0, 1, 2\}$ be the set with the following table:

$*$	0	1	2
0	0	1	2
1	1	0	1
2	2	2	0

Then $(X, *, 0)$ is a BG-algebra. We define a fuzzy set $\mu : X \to [0, 1]$ by

$$\mu(x) = \begin{cases} 0.3 & \text{if } x = 0 \\ 0.8 & \text{otherwise.} \end{cases}$$

Clearly μ is anti fuzzy BG-ideals of X. But is not an anti fuzzy BG-bi-ideal of X. Now let $x = 0, w = 1, y = 0$.Then $\mu(x * w * y) = \mu(0 * 1 * 0) = \mu(0 * 1)\mu(1) = 0.8$. $\max\{\mu(x), \mu(y)\} = \max\{\mu(0), \mu(0)\} = \mu(0) = 0.2$. Hence $\mu(x * w * y) \geq \max\{\mu(x), \mu(y)\}$. Hence μ is not an anti fuzzy BG-bi-ideal of X.

Definition 4.14. Let $f : X \to Y$ be a mapping of BG-algebra and μ be a fuzzy set of Y then μ^f is the pre-image of μ under f if $\mu^f(x) = \mu(f(x))$ for all $x \in X$.

Theorem 4.15. Let $f : X \to Y$ be a homomorphism of BG-algebra. If μ is an anti fuzzy BG-ideals of Y. Then μ^f is an anti fuzzy BG-ideal of X.

Proof. For any $x \in X$, we have

$$\mu^f(x) = \mu(f(x)) \geq \mu(0) = \mu(f(0)) = \mu^f(0).$$

Let $x, y \in X$, then

$$\begin{aligned} \max\{\mu^f(x * y), \mu^f(y)\} &= \max\{\mu(f(x * y)), \mu(f(y))\} \\ &= \max\{\mu(f(x) * f(y)), \mu(f(y))\} \\ &\geq \mu(f(x)) \\ &= \mu^f(x). \end{aligned}$$

That is,

$$\begin{aligned} \mu^f(x) &\leq \max\{\mu^f(x * y), \mu^f(y)\}. \\ \max\{\mu^f(x), \mu^f(y)\} &= \max\{\mu(f(x)), \mu(f(y))\} \\ &\geq \mu(f(x) * f(y)) \\ &= \mu(f(x * y)) \\ &= \mu^f(x * y). \end{aligned}$$

That is,

$$\mu^f(x * y) \leq \max\{\mu^f(x), \mu^f(y)\}.$$

Hence μ^f is an anti fuzzy BG-ideal of X. □

Theorem 4.16. Let $f : X \to Y$ be an epimorphism of BG-algebra. If μ^f is an anti fuzzy BG-ideal of X, then $\mu$is an anti fuzzy BG-ideal of Y.

Proof. Let $y \in Y$. By hypothesis there exist $x \in X$ such that $f(x) = y$, then

$$\begin{aligned} \mu(y) &= \mu(f(x)) \\ &= \mu^f(x) \\ &\geq \mu^f(0) \\ &= \mu(f(0)) = \mu(0). \end{aligned}$$

Let $x, y \in Y$. By hypothesis there exist $a, b \in X$such that $f(a) = x$ and $f(b) = y$. It follows that

$$\begin{aligned} \mu(x) &= \mu(f(a)) \\ &= \mu^f(a) \\ &\leq \max\{\mu^f(a * b), \mu^f(b)\} \\ &= \max\{\mu(f(a * b)), \mu(f(b))\} \\ &= \max\{\mu(f(a) * f(b)), \mu(f(b)\} \\ &= \max\{\mu(x * y), \mu(y)\}. \end{aligned}$$

That is, $\mu(x) \leq \max\ \{\mu(x * y), \mu(y)\}$.

$$\begin{aligned} \mu(x * y) &= \mu(f(a) * f(b)) \\ &= \mu(f(a * b)) \\ &= \mu^f(a * b) \\ &\leq \max\{\mu^f(a), \mu^f(b)\} \\ &= \max\{\mu(f(a)), \mu(f(b))\} \\ &= \max\{\mu(x), \mu(y)\}. \end{aligned}$$

Thus $\mu(x * y) \leq \max\ \{\mu(x), \mu(y)\}$. Hence μ is anti fuzzy BG-ideals of Y. □

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