Anti Q-fuzzy PMS- ideals in PMS-algebras

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Abstract: *In this paper, we introduce the concept of Anti Q-fuzzy PMS-ideals of PMS-algebras, lower level cuts of a fuzzy set and proved some results. We discussed few results of anti Q-fuzzy PMS-ideals of PMS-algebras in homomorphism and Cartesian product.*

Keywords: *PMS-algebra, fuzzy PMS- ideal, Anti Q-fuzzy PMS-ideal, lower level cuts, homomorphism, Cartesian product.*

1. Introduction

The concept of fuzzy set was introduced by L.A.Zadeh in 1965 **[19]**. Since then these ideas have been applied to other algebraic structures such as groups, rings, modules, vector spaces and topologies. K.Iseki and S.Tanaka **[2]** introduced the concept of BCK-algebras in 1978 and K.Iseki **[3]** introduced the concept of BCI-algebras in 1980. It is known that the class of BCK –algebras is a proper subclass of the class of BCI algebras in 2002. P.M.Sithar Selvam and K.T.Nagalakshmi **[5,6]** introduced the concept of PMS-algebras , which is a generalization of BCK / BCI / TM / KUS / PS algebras in 2015.R.Biswas**[1]** introduced the concept of Anti fuzzy subgroups of groups. Modifying his idea, in this paper we applied the idea in PMS-algebras. We introduced the notion of Anti Q- fuzzy PMS-ideals of PMS-algebras and investigate how to deal with the homomorphic, Anti homomorphic and inverse image of Anti Q-fuzzy PMS-ideals of PMS-algebras.

2. Preliminaries

In this section we site the fundamental definitions that will be used in the development of this paper.

Definition 2.1 :[5,6] A nonempty set X with a constant 0 and a binary operation ‘ $*$ ’ is called PMS – algebra if it satisfies the following axioms.

1. $0 * x = x$
2. $(y * x) * (z * x) = z * y$, $\forall$ x , y, z $\in$ X.

In X, we define a binary relation $\leq$ by : $x \leq y$ if and only if $x * y = 0$.

Definition 2.2:[5,6] Let X be a PMS - algebra and I be a subset of X, then I is called a PMS - ideal of X if it satisfies the following conditions:

1. $0 \in I$
2. $z * y \in I$ and $z * x \in I \Rightarrow y * x \in I$ for all x, y, z $\in$ X.

Example 2.3:[5,6] Let X = {0, a, b, c} be the set with the following table.

*	0	a	b	c
0	0	a	b	c
a	b	0	a	b
b	a	b	0	c
c	c	c	a	0

Then (X, $*$, 0) is a PMS – algebra and I = {0,a,b} is a PMS-ideal.

Definition 2.4:[**7,8**] **:** Let S be a non empty subset of a PMS -algebra X , then S is called a PMS-sub algebra of X if $x * y \in S$,for all x ,y $\in$ S.

Definition 2.5 [17,19] : Let X be a non-empty set**.** A fuzzy subset μ of the set X is a mapping

$\mu : X \rightarrow [0, 1]$.

Definition 2.6 [11,12,13] : Let Q and G be any two sets. A mapping β: G x Q $\rightarrow$[0, 1] is called a Q –fuzzy set in G.

MAIN RESULTS

3. ANTI Q-FUZZY PMS – IDEALS OF PMS ALGEBRAS

Definition 3.1 : A Q- fuzzy set μ in X is called a Q-fuzzy PMS- ideal of X if

(i) $\mu(0, q) \geq \mu(x, q)$

(ii) $\mu(y * x, q) \geq \min \{\mu(z * y, q), \mu(z * x, q)\}$, for all x, y, z$\in$ X and q $\in$ Q.

Definition 3.2 : A Q-fuzzy set μ of X is called an anti Q-fuzzy PMS-ideal of X if

(i) $\mu(0, q) \leq \mu(x, q)$

(ii) $\mu(y * x, q) \leq \max \{\mu (z * y, q), \mu(z * x, q)\}$, for all x, y, z$\in$ X and q $\in$ Q.

Theorem 3.1 : Every Anti Q - Fuzzy PMS- ideal μ of a PMS-algebra X is order preserving.

Proof : Let μ be an anti Q-Fuzzy PMS- ideal of a PMS-algebra X and let x, y $\in$ X and q $\in$ Q be such that $x \leq y$, then $x * y = 0$.

Now $\mu(x, q) = \max \{\mu(0 * x, q)\}$

$\leq \max \{\mu(z * 0, q), \mu((x * y)* (z * y), q)\}$

$= \max \{\mu(z * 0, q), \mu(0 * (z * y), q)\}$

$= \max \{\mu(z * 0, q), \mu(z * y, q)\}$

$= \max \{\mu(0 * 0, q), \mu(0 * y, q)\}$ (Taking z = 0)

$= \max \{\mu(0, q), \mu(y, q)\}$

$= \mu(y, q)$

$\mu(x,q) \leq \mu (y,q)$.

Theorem 3.2 : μ is a Q-fuzzy PMS-ideal of a PMS-algebra X iff μ^c is an anti Q-fuzzy PMS-ideal of X.

Proof: Let μ be a Q-Fuzzy PMS- ideal of X and let x , y , z $\in$ X and q $\in$ Q.

$\mu (0, q) \geq \mu(x, q)$

$1- \mu^c (0, q) \geq 1 - \mu^c (x, q)$

$\mu^c (0, q) \leq \mu^c (x, q)$

and $\mu^c (y * x, q) = 1 - \mu(y * x, q)$

$\leq 1 - \min \{\mu (z * y, q), \mu (z * x, q)\}$

$= 1 - \min \{1 - \mu^c (z * y, q), 1 - \mu^c (z * x, q)\}$

$= \max \{\mu^c (z * y, q), \mu^c (z * x, q)\}$

Thus μ^c is an anti Q-fuzzy PMS-ideal of X. The converse also can be proved similarly.

Theorem 3.3: Let X be a PMS-algebra. For any anti Q- fuzzy PMS-ideal μ of X, $N_\mu = \{x\in X$ and $q \in Q /\mu(x, q) = \mu (0,q) \}$ is a PMS-ideal of X.

Proof: Let $z * y, z * x \in N_\mu$. Then $\mu(z * y, q) = \mu(z * x, q) = \mu (0, q)$

Since μ is an anti Q-fuzzy PMS-ideal of X ,

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

$= \max \{ \mu (0,q) , \mu (0,q) \}$

$= \mu (0,q)$

Hence $y * x \in N_\mu$. Therefore N_μ is a PMS-ideal of X.

Theorem 3.4 : If λ and μ are anti Q-fuzzy PMS ideals of a PMS-algebra X, then $\lambda \cap \mu$ is also an anti Q-fuzzy PMS-ideal of X.

Proof : Let x, y, z $\in$ X and q $\in$ Q. Then

$(\lambda \cap \mu) (0, q) = \min \{ \lambda (0, q) , \mu(0, q)\}$

$\leq \min \{ \lambda (x, q) , \mu(x, q)\}$

$= (\lambda \cap \mu)(x, q)$

$(\lambda\cap \mu)(y*x, q) = \min \{\lambda(y * x, q), \mu(y * x, q)\}$

$\leq \min \{\max \{\lambda(z * x, q), \lambda(z * y, q)\}, \max \{\mu(z * x, q), \mu(z * y, q)\}\}$

$= \min \{\max \{\lambda(z * x, q), \mu(z * x, q)\}, \max \{\lambda(z * y, q), \mu(z * y, q)\}\}$

$\leq \max \{\min \{\lambda(z * x, q), \mu(z * x, q)\}, \min \{\lambda(z * y, q), \mu(z * y, q)\}\}$

$= \max \{(\lambda\cap\mu)(z *x, q), (\lambda\cap\mu)(z * y, q)\}.$

$\Rightarrow (\lambda\cap\mu)(y * x, q) \leq \max \{(\lambda\cap\mu)(z * y, q), (\lambda\cap\mu)(z * x, q)\}.$

$\Rightarrow (\lambda \cap \mu)$ is also an anti Q-fuzzy PMS ideal of X.

Theorem 3.5: The union of any set of anti Q-fuzzy PMS-ideals in PMS-algebra X is also an anti Q-fuzzy PMS-ideal.

Proof : Let $\{\mu_i\}$ be a family of anti Q-fuzzy PMS-ideals of PMS-algebras X.

Then for any $x, y, z \in X$ and $q \in Q$.

$(\cup \mu_i)(0, q) = \sup (\mu_i(0, q))$

$\leq \sup (\mu_i(x, q))$

$= (\cup \mu_i)(x, q)$

$(\cup \mu_i)(y * x, q) = \operatorname{Sup} (\mu_i(y * x, q))$

$\leq \operatorname{Sup} \{\max \{\mu_i(z * y, q), \mu_i(z * x, q)\}\}$

$= \max \{\operatorname{Sup} (\mu_i(z * y, q)), \operatorname{Sup} (\mu_i(z * x, q))\}$

$= \max \{(\cup \mu_i)(z * y, q), (\cup \mu_i)(z * x, q)\}$

This completes the proof.

Definition 3.6: Let μ be a Q-fuzzy set of X. For a fixed $t \in [0, 1]$, the set $\mu_t = \{x \in X \mid \mu(x,q) \leq t$ for all $q \in Q\}$ is called the lower level subset of μ. Clearly $\mu^t \cup \mu_t = X$ for $t\in[0,1]$ if $t_1 < t_2$, then $\mu_{t1} \subseteq \mu_{t2}$.

Theorem 3.7 : If μ is an anti Q-fuzzy PMS-ideal of PMS-algebra X, then μ_t is a PMS-ideal of X for every $t\in [0,1]$.

Proof : Let μ be an anti Q-fuzzy PMS-ideal of PMS-algebra X.

Clearly $0 \in \mu_t$.

Let $z * x \in \mu_t$ and $z * y \in \mu_t$, for all $x, y \in X$ and $q \in Q$.

$\Rightarrow \mu(z * x, q) \leq t$ and $\mu(z * y, q) \leq t$.

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

$\Rightarrow y * x \in \mu_t$.

Hence μ_t is an PMS- ideal of X for every $t\in [0,1]$.

Theorem 3.8 : Let μ be a Q-fuzzy set of PMS- algebra X. If for each $t \in [0, 1]$, the lower level cut μ_t is a PMS-ideal of X, then μ is an anti Q- fuzzy PMS-ideal of X.

Proof : Let μ_t be a PMS-ideal of X.

If $\mu(0,q) > \mu(x, q)$ for some $x \in X$ and $q \in Q$, then $\mu(0, q) > t_0 > \mu(x, q)$ by taking

$t_0 = \frac{1}{2}\{\mu(0,q) + \mu(x, q)\}.$

Hence $0 \notin \mu_{t0}$ and $x \in \mu_{t0}$, which is a contradiction.

Therefore, $\mu(0, q) \leq \mu(x, q)$.

Let $x, y, z \in X$ and $q \in Q$ be such that $\mu(y * x, q) > \max \{\mu(z * y, q), \mu(z * x, q)\}$.

Taking $t_1 = \frac{1}{2}\{\mu(y * x, q) + \max \{\mu(z * y), q), \mu(z * x, q)\}\}$

$\Rightarrow \mu(y * x, q) > t_1 > \max \{\mu(z * y, q), \mu(z * x, q)\}.$

It follows that $z * y, z * x \in \mu_{t1}$ and $y * x \notin \mu_{t1}$. This is a contradiction.

Hence $\mu(y * x, q) \leq \max \{\mu(z * y, q), \mu(z * x, q)\}$

Therefore μ is an anti Q-fuzzy PMS-ideal of X.

4. HOMOMORPHISM AND ANTI HOMOMORPHISM ON ANTI Q-FUZZY PMS- ALGEBRAS

In this section, we discussed about ideals in PMS-algebra under homomorphism and anti homomorphism and some of its properties.

Definition 4.1 : Let (X,*,0) and (Y ,Δ ,0) be PMS– algebras. A mapping f: X → Y is said to be a homomorphism if f(x * y) = f(x) * f(y) for all x, y ∈ X.

Definition 4.2 : Let (X,*, 0) and (Y,Δ,0) be PMS–algebras. A mapping f: X → Y is said to be an anti homomorphism if f(x * y) = f(y) Δ f(x) for all x, y ∈ X.

Definition 4.3 : Let f: X → X be an endomorphism and μ be a fuzzy set in X. We define a new fuzzy set in X by μ_f in X as $\mu_f(x) = \mu(f(x))$ for all x in X.

Theorem 4.4 : Let f be an endomorphism of a PMS- algebra X. If μ is an anti Q- fuzzy PMS-ideal of X, then so is μ_f .

Proof: Let μ be an anti Q-fuzzy PMS-ideal of X.

Now, $\mu_f(0, q) = \mu(f(0,q))$

$\leq \mu(f(x, q)) = \mu_f(x, q)$, for all x, y ∈ X and q∈Q.

Let x, y, z ∈ X and q∈ Q.

Then $\mu_f(y * x, q) = \mu(f(y * x, q))$

$= \mu(f(y, q) * f(x, q))$

$\leq \max\{\mu(f(z, q) * f(y, q)), \mu(f(z, q) * f(x, q))\}$

$= \max\{\mu(f(z * y, q)), \mu(f(z * x, q))\}$

$= \max\{\mu_f(z * y, q), \mu_f(z * x, q)\}$

$\therefore \mu_f(y * x, q) \leq \max\{\mu_f(z * y, q), \mu_f(z * x, q)\}$

Hence μ_f is an anti Q- fuzzy PMS-ideal of X.

Theorem 4.5 : Let f: X → Y be an epimorphism of PMS- algebra. If μ_f is an anti Q-fuzzy PMS-ideal of X, then μ is an anti Q-fuzzy PMS-ideal of Y.

Proof: Let μ_f be an anti Q-fuzzy PMS-ideal of X.

Let y ∈ Y and q∈ Q. Then there exists x ∈ X such that f(x, q) = (y, q).

Now, $\mu(0, q) = \mu(f(0, q))$

$= \mu_f(0, q)$

$\leq \mu_f(x, q) = \mu(f(x, q)) = \mu(y, q)$

$\therefore \mu(0, q) \leq \mu(y, q)$

Let $y_1, y_2, y_3 \in Y$.

$\mu(y_2 \Delta y_1, q) = \mu(f(x_2) \Delta f(x_1), q)$

$= \mu(f(x_2 * x_1, q)$

$= \mu_f(x_2 * x_1, q)$

$\leq \max\{\mu_f(x_3 * x_2, q), \mu_f(x_3 * x_1, q)\}$

$= \max\{\mu[f(x_3 * x_2, q)], \mu[f(x_3 * x_1, q)]\}$

$= \max\{\mu[f(x_3, q) \Delta f(x_2, q)], \mu[f(x_3, q) \Delta f(x_1, q)]\}$

$= \max\{\mu[(y_3, q) \Delta (y_2, q)], \mu[(y_3, q) \Delta (y_1, q)]\}$

⇒ μ is an anti Q- fuzzy PMS-ideal of Y.

Theorem 4.6 : Let f: X → Y be a homomorphism of PMS- algebra. If μ is an anti Q-fuzzy PMS-ideal of Y then μ_f is an anti Q-fuzzy PMS-ideal of X.

Proof: Let μ be an anti Q- fuzzy PMS-ideal of Y.

Let $x, y, z \in X$.

$\mu_f(0, q) = \mu(f(0, q))$

$\leq \mu(f(x, q)) = \mu_f(x, q)$

$\Rightarrow \mu_f(0, q) \leq \mu_f(x, q)$.

$\mu_f(y * x, q) = \mu[f(y * x, q)]$

$= \mu[f(y, q) \Delta f(x, q)]$

$\leq \max\{\mu(f(z, q) \Delta f(y, q)), \mu(f(z, q) \Delta f(x, q))\}$

$= \max\{\mu(f(z * y, q)), \mu(f(z * x, q))\}$

$= \max\{\mu_f(z * y, q), \mu_f(z * x, q)\}$

$\therefore \mu_f(y * x, q) \leq \max\{\mu_f(z * y, q), \mu_f(z * x, q)\}$.

Hence μ_f is an anti Q-fuzzy R-closed PMS-ideal of X.

5. CARTESIAN PRODUCT OF ANTI Q-FUZZY PMS-IDEALS OF PMS–ALGEBRAS

In this section, we introduce the concept of Cartesian product of anti Q-fuzzy PMS-ideals of PMS-algebra.

Definition 5.1 : Let μ and δ be the fuzzy sets in X. The Cartesian product $\mu \times \delta : X \times X \to [0,1]$ is defined by $(\mu \times \delta)(x, y) = \min\{\mu(x), \delta(y)\}$, for all $x, y \in X$.

Definition 5.2 : Let μ and δ be the anti fuzzy sets in X. The Cartesian product $\mu \times \delta : X \times X \to [0,1]$ is defined by $(\mu \times \delta)(x, y) = \max\{\mu(x), \delta(y)\}$, for all $x, y \in X$.

Definition 5.3: Let μ and δ be the anti Q-fuzzy sets in X. The Cartesian product $\mu \times \delta : X \times X \to [0,1]$ is defined by $(\mu \times \delta)((x, y), q) = \max\{\mu(x, q), \delta(y, q)\}$, for all $x, y \in X$ and $q \in Q$.

Theorem 5.4 : If μ and δ are anti Q-fuzzy PMS-ideals in a PMS– algebra X, then $\mu \times \delta$ is an anti Q-fuzzy PMS-ideal in X x X.

Proof: Let $(x_1, x_2) \in X \times X$ and $q \in Q$.

$(\mu \times \delta)((x_1 * 0, x_2 * 0), q) = \max\{\mu(x_1 * 0, q), \delta(x_2 * 0, q)\}$

$\leq \max\{\mu(x_1, q), \delta(x_2, q)\}$

$= (\mu \times \delta)((x_1, x_2), q)$

$\therefore (\mu \times \delta)((x_1 * 0, x_2 * 0), q) \leq (\mu \times \delta)((x_1, x_2), q)$

Let $(x_1, x_2), (y_1, y_2), (z_1, z_2) \in X \times X$.

$(\mu \times \delta)[(y_1, y_2)*(x_1, x_2), q] = (\mu \times \delta)[(y_1 * x_1, y_2 * x_2), q]$

$= \max\{\mu(y_1 * x_1, q), \delta(y_2 * x_2, q)\}$

$\leq \max\{\max\{\mu(z_1 * y_1, q), \mu(z_1 * x_1, q)\}, \max\{\delta(z_2 * y_2, q), \delta(z_2 * x_2, q)\}\}$

$= \max\{\max\{\mu(z_1 * y_1, q), \delta(z_2 * y_2, q)\}, \max\{\mu(z_1 * x_1, q), \delta(z_2 * x_2, q)\}\}$

$= \max\{(\mu \times \delta)((z_1 * y_1, q), (z_2 * y_2, q)), (\mu \times \delta)((z_1 * x_1, q), (z_2 * x_2, q))\}$

$= \max\{(\mu \times \delta)[((z_1, z_2), q) * ((y_1, y_2), q)], (\mu \times \delta)[((z_1, z_2), q) * ((x_1, x_2), q)]\}$

Hence, $\mu \times \delta$ is an anti Q-fuzzy PMS- ideal in X x X.

Theorem 5.5: Let μ & δ be fuzzy sets in a PMS-algebra X such that $\mu \times \delta$ is an anti Q-fuzzy PMS-ideal of X x X. Then (i) Either $\mu(0,q) \leq \mu(x, q)$ (or) $\delta(0,q) \leq \delta(x, q)$ for all $x \in X$ and $q \in Q$.

(ii) If $\mu(0,q) \leq \mu(x, q)$ for all $x \in X$ and $q \in Q$, then either $\delta(0,q) \leq \mu(x, q)$ (or) $\delta(0,q) \leq \delta(x, q)$

(iii) If $\delta(0,q) \leq \delta(x, q)$ for all $x \in X$ and $q \in Q$, then either $\mu(0,q) \leq \mu(x, q)$ (or) $\mu(0,q) \leq \delta(x, q)$.

Proof: Straightforward.

Theorem 5.6: Let μ & δ be fuzzy sets in a PMS-algebra X such that $\mu \times \delta$ is an anti Q-fuzzy PMS-ideal of X x X. Then either μ or δ is an anti Q-fuzzy PMS-ideal of X.

Proof: First we prove that δ is an anti Q- fuzzy PMS-ideal of X.

Since by 5.5(i) either $\mu(0,q) \le \mu(x, q)$ or $\delta(0,q) \le \delta(x, q)$ for all $x\in X$ and $q\in Q$.

Assume that $\delta(0,q) \le \delta(x, q)$ for all $x\in X$ and $q\in Q$. It follows from 6.2(iii) that either

$\mu(0,q) \le \mu(x,q)$ (or) $\mu(0,q) \le \delta(x,q)$.

If $\mu(0,q) \le \delta(x, q)$, for any $x\in X$ and $q\in Q$,then

$\delta(x, q) = \max\{\mu(0,q), \delta(x, q)\}= (\mu \times \delta)((0, x),q)$

$$\begin{aligned}
\delta(y * x, q) &= (\mu \times \delta)[(0, y * x), q] \\
&\le \max\{(\mu \times \delta)[((0,z),q) * ((0,y), q)], (\mu \times \delta)[((0,z), q) * ((0, x), q)]\} \\
&= \max\{(\mu \times \delta)[(0*0, z*y), q], (\mu \times \delta)[(0 * 0,z * x), q]\} \\
&= \max\{(\mu \times \delta)[(0,z*y), q], (\mu \times \delta)[(0, z*x),q]\} \\
&= \max\{\delta(z * y, q), \delta(z * x, q)\}
\end{aligned}$$

$\Rightarrow \delta(y * x, q) \le \max\{\delta(z * y, q), \delta(z * x, q)\}$

Hence δ is an anti fuzzy PMS-ideal of X.

Similarly we will prove that μ is an anti Q- fuzzy PMS-ideal of X.

6. CONCLUSION

In this article we have discussed anti Q-fuzzy PMS- ideal of PMS-algebras and its lower level cuts in detail. We hope that this work would lay other foundations for further study of the theory of PMS-algebras. In our future study of fuzzy structure of PMS-algebra, can be extended to the topics, intuitionistic fuzzy set, interval valued fuzzy sets, for more interesting results.

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