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ON FUZZY TOPOLOGICAL *BRK*-IDEAL

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ABSTRACT. In this article, the notion of fuzzy topological BRK-ideal of a BRK-algebra in a topology is introduced. Some theorems and properties of $f\tau BRKI$ are stated and proved. The epimorphic and into homomorphic inverse images of a $f\tau BRKI$ is also studied well. Also, we introduced a Cartesian product of a $f\tau BRKI$ and studied their properties.

1. INTRODUCTION

Imai and Iseki [3] subjected two classes of abstract algebras: BCK-algebras and BCI-algebras in the year of 1996. In 1983, the notion of a BCH-algebra was introduced by Hu and Li [2], which is a generalization of BCK and BCI-algebras. In 2002, a new notion B-algebra was introduced by Neggers and Kim [8]. Also a BF-algebra and BG-algebra was introduced by Walendziak [11] in 2007 and C. B. Kim and H. S. Kim [5], which is a generalization of B-algebra. In 2012, R. K. Bandaru [9] introduced BRK-algebra, which is a generalization of $BCK/BCI/BCH/Q/QS/BM$-algebras [4,6,7]. In [1], El-Gendy introduced the notion of fuzzy BRK-ideal of BRK-algebra. S. Sivakumar et al. introduced a topology on BRK-algebra [10] and also studied several concepts. In this present paper we introduce a new notion of $f\tau BRKI$ of a $\tau BRK\ Alg$. Also study some related properties in a $f\tau BRKI$. At last we introduce the Cartesian product of a $f\tau BRKI$ and their properties.

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2. Preliminaries

Definition 2.1. *[9] A BRK-algebra (briefly, $BRK\ Alg$) $(I, \star, 0)$ is a non-empty set I with a constant 0 and a binary operation $\star$ satisfying the following axioms:*

$$(BRK_1)\ i_1 \star 0 = i_1, \tag{2.1}$$

$$(BRK_2)\ (i_1 \star i_2) \star i_1 = 0 \star i_2 \tag{2.2}$$

for any $i_1, i_2 \in I$. In a $BRK\ Alg$ I, $\leq$ a partially ordered relation can be defined by $i_1 \leq i_2$ iff $i_1 \star i_2 = 0$.

Definition 2.2. *[10] Let $(I, \star, 0)$ be a $BRK\ Alg$ and τ a topology on I. Then $I = (I, \star, 0, \tau)$ is called a topological $BRK\ Alg$ (briefly, $\tau BRK\ Alg$), if "$\star$" is continuous or equivalently, for any $m, n \in X$ and $\forall\ O$ open set of $m \star n$, $\exists$ two open sets M and N respectively, such that $M \star N$ is a subset of O.*

Definition 2.3. *[10] Let I be a $\tau BRK\ Alg$ and D be a subset of I, then D is called a τBRK-ideal (briefly, $\tau BRK\ I$) of I, if for any $i_{11}, i_{22} \in I$:*

(i) $0 \in D$,

(ii) $0 \star (i_{11} \star i_{22}) \in D$ *and* $0 \star i_{22} \in D$ *imply* $i_{11}, i_{22} \in I$.

Definition 2.4. *[1] Let I be a set. A function $\mu_I : I \to [0, 1]$ where μ_I a fuzzy set in I.*

Definition 2.5. *[1] Let $(I, \star, 0)$ be a $BRK\ Alg$. A fuzzy set μ_I in I is called a fuzzy BRK-ideal (briefly, $fBRKI$) of I if*

$$(BRKFI_1)\ \mu_I(0) \geq \mu_I(i_1),$$

$$(BRKFI_2)\ \mu_I(0 \star i_1) \geq \min\{\mu_I(0 \star (i_1 \star i_2)), \mu_I(0 \star i_2)\},\ \textit{for all } i_1, i_2 \in I.$$

3. Fuzzy τBRK-Ideal

Definition 3.1. *Let $(I, \star, 0, \tau)$ be a $\tau BRK\ Alg$. A fuzzy set μ_I in I is called an fuzzy topological BRK-ideal (briefly, $f\tau BRKI$) of I if*

$$\mu_I(0) \geq \mu_I(i_1), \tag{3.1}$$

$$\mu_I(0 \star i_1) \geq \min\{\mu_I(0 \star (i_1 \star i_2)), \mu_I(0 \star i_2)\},\ \textit{for all } i_1, i_2 \in I. \tag{3.2}$$

Definition 3.2. *Let $(I, \star, 0, \tau)$ be a $\tau BRK\ Alg$. A fuzzy set μ_I in I is called an Anti fuzzy topological BRK-ideal (briefly, $Af\tau BRK\ I$) of I if*

$$\mu_I(0) \leq \mu_I(i_1), \tag{3.3}$$

$$\mu_I(0 \star i_1) \leq \max\{\mu_I(0 \star (i_1 \star i_2)), \mu_I(0 \star i_2)\}, \text{ for all } i_1, i_2 \in I. \tag{3.4}$$

Example 1. *Let $(I = \{0, a_1, b_1, c_1\}, \star, 0)$ be a $BRK\ Alg$ defined by*

$\star$	0	a_1	b_1	c_1
0	0	0	b_1	b_1
a_1	a_1	0	b_1	b_1
b_1	b_1	b_1	0	0
c_1	c_1	c_1	a_1	0

Define a topology $\tau = \{\phi, I, \{b_1\}, \{c_1\}, \{b_1, c_1\}, \{0, a_1\}, \{0, a_1, b_1\}, \{0, a_1, c_1\}\}$ is a $\tau BRK\ Alg$. Now define $\mu_I : I \to [0, 1]$ by $\mu_I(0) = K_1$, $\mu_I(a_1) = \mu_I(b_1) = \mu_I(c_1) = K_2$, where $K_1, K_2 \in [0, 1]$ with $K_1 > K_2$ gives that μ_I is an $f\tau BRKI$.

Proposition 3.1. *Let μ_I be an $f\tau BRKI$ of $\tau BRK\ Alg\ I$ and if $i_1 \geq i_2$, then $\mu_I(0 \star i_1) \geq \mu_I(0 \star i_2)$, $\forall\, i_1, i_2 \in I$.*

Proof. Let μ_I be an $f\tau BRKI$ of a $\tau BRK\ Alg\ I$. For any $i_1, i_2 \in I$ such that $i_1 \geq i_2$. Since $i_1 \geq i_2$, then $i_1 \star i_2 = 0$.

$$\begin{aligned}
\mu_I(0 \star i_1) &\geq \min\{\mu_I(0 \star (i_1 \star i_2)), \mu_I(0 \star i_2)\} \\
&= \min\{\mu_I(0 \star 0), \mu_I(0 \star i_2)\} \\
&= \min\{\mu_I(0), \mu_I(0 \star i_2)\} \\
&= \mu_I(0 \star i_2).
\end{aligned}$$

Hence $\mu_I(0 \star i_1) \geq \mu_I(0 \star i_2)$. □

Theorem 3.1. *A fuzzy subset μ_I of a $\tau BRK\ Alg\ I$ is a $Af\tau BRK\ I$ of I iff μ_I^c is an $f\tau BRKI$ of I.*

Proof. Let μ_I be a $Af\tau BRK\ I$ of a $\tau BRK\ Alg\ I$, and let $i_1, i_2 \in I$. Then Since $\mu_I(0) \leq \mu_I(i_1)$ then

$$1 - \mu_I(0) \geq 1 - \mu_I(i_1)$$

$$\mu_I^c(0) \geq \mu_I^c(i_1). \tag{3.5}$$

Further,

$$\mu_I(0\star i_1) \leq \max\{\mu_I(0\star(i_1\star i_2)), \mu_I(0\star i_2)\}$$
$$1-\mu_I(0\star i_1) \geq 1-\max\{\mu_I(0\star(i_1\star i_2)), \mu_I(0\star i_2)\}$$
$$\mu_I^c(0\star i_1) \geq \min\{1-\mu_I(0\star(i_1\star i_2)), 1-\mu_I(0\star i_2)\}$$

$$\mu_I^c(0\star i_1) \geq \min\{\mu_I^c(0\star(i_1\star i_2)), \mu_I^c(0\star i_2)\} \tag{3.6}$$

So, μ_I^c is an $f\tau BRKI$ of I.

Now let μ_I^c is an $f\tau BRKI$ of a $\tau BRK\ Alg\ I$, and let $i_3, i_4 \in I$. Then Since $\mu_I^c(0) \geq \mu_I^c(i_3)$ then

$$1-\mu_I^c(0) \leq 1-\mu_I^c(i_3)$$

$$\mu_I(0) \leq \mu_I(i_3). \tag{3.7}$$

So,

$$\mu_I^c(0\star i_3) \geq \min\{\mu_I^c(0\star(i_3\star i_4)), \mu_I^c(0\star i_4)\}$$
$$1-\mu_I^c(0\star i_3) \leq 1-\min\{\mu_I^c(0\star(i_3\star i_4)), \mu_I^c(0\star i_4)\}$$
$$\mu_I(0\star i_3) \leq \max\{1-\mu_I^c(0\star(i_3\star i_4)), 1-\mu_I^c(0\star i_4)\}$$

$$\mu_I(0\star i_3) \leq \max\{\mu_I(0\star(i_3\star i_4)), \mu_I(0\star i_4)\} \tag{3.8}$$

Therefore, μ_I is a $Af\tau BRK\ I$ of a $\tau BRK\ Alg\ I$. □

Theorem 3.2. *Let μ_I be an $f\tau BRKI$ of $\tau BRK\ Alg\ I$. Then $I_{\mu_I} = \{i_1 \in I | \mu_I(0\star i_1) = \mu_I(0)\}$ is a $\tau BRK\ I$.*

Proof. Clearly $0 \in I_{\mu_I}$. Let $i_1, i_2 \in I_{\mu_I}$ be such that $(0\star(i_1\star i_2)) \in I_{\mu_I}$ and $0\star i_2 \in I_{\mu_I}$. Then $\mu_I(0\star(i_1\star i_2)) = \mu_I(0\star i_2) = \mu_I(0)$. It follows that

$$\mu_I(0\star i_1) \geq \min\{\mu_I(0\star(i_1\star i_2)), \mu_I(0\star i_2)\}$$
$$\mu_I(0\star i_1) \geq \min\{\mu_I(0), \mu_I(0)\}$$
$$\mu_I(0\star i_1) \geq \mu_I(0).$$

So, by combining with Definition 3.1, we get that $\mu_I(0\star i_1) = \mu_I(0)$ and hence $0\star i_1 \in I_{\mu_I}$. □

Definition 3.3. *Let* $(I, \star, 0, \tau)$ *and* $(J, \star', 0', \tau)$ *be* $\tau BRK\ Algs$*. A mapping* $h : I \to J$ *is said to be a homomorphism of a* $\tau BRK\ Alg$ *if* $h(i_1 \star i_2) = h(i_1) \star' h(i_2)$*,* $\forall\, i_1, i_2 \in I$*.*

Definition 3.4. *Let a map* $h : I \to J$*. If* ${\mu_I}^*$ *is a fuzzy subset of* J*, then the fuzzy subset defined by* ${\mu_I}^*(h(i_1)) = \mu_I(i_1)\ \forall\, i_1 \in I$ *is said to be the inverse image of* ${\mu_I}^*$ *under* h*.*

Theorem 3.3. *The epimorphic image of an* $f\tau BRKI$ *is also an* $f\tau BRKI$*.*

Proof. Let $h : I \to J$ be an epimorphism of $\tau BRK\ Alg$'s $(I, \star, 0, \tau)$ and $(J, \star', 0', \tau)$. Consider that β is an $f\tau BRKI$ of I and μ_I is the image of β under h. Let $j_1 \in J$. Then $\exists i_1 \in I$ such that $h(i_1) = j_1$. Then

$$\mu_I(j_1) = \mu_I(h(i_1)) = \beta(i_1) \le \beta(0) = \mu_I(h(0)) = \mu_I(0').$$

Let $i_1', j_1' \in J$. Then $\exists\, i_1, j_1 \in I \ni h(i_1) = i_1'\ \&\ h(j_1) = j_1'$. It follows that

$$\begin{aligned}
\mu_I(0' \star' i_1') &= \mu_I(h(0 \star i_1))\\
&= \beta(0 \star i_1) \ge \min\{\beta(0 \star (i_1 \star j_1)), \beta(0 \star j_1)\}\\
&= \min\{\mu_I(h(0 \star (i_1 \star j_1))), \mu_I(h(0 \star j_1))\}\\
&= \min\{\mu_I(h(0) \star' (h(i_1) \star' h(j_1))), \mu_I(h(0) \star' h(j_1))\}\\
&= \min\{\mu_I(0' \star' (i_1' \star' j_1')), \mu_I(0' \star' j_1')\}.
\end{aligned}$$

Hence μ_I is an $f\tau BRKI$ of J. □

Theorem 3.4. *The into homomorphic inverse image of an* $f\tau BRKI$ *is also an* $f\tau BRKI$*.*

Proof. Let $h : I \to J$ be an into homomorphism of $\tau BRK\ Alg$'s $(I, \star, 0, \tau)$, $(J, \star', 0', \tau)$. And ${\mu_I}^*$ is an $f\tau BRKI$ of J and μ_I is the inverse image of ${\mu_I}^*$ under h. By definition 3.4 we find that ${\mu_I}^*(h(i_1)) = \mu_I(i_1)$, for all $i_1 \in I$, since ${\mu_I}^*$ is an $f\tau BRKI$ of J, then ${\mu_I}^*(0') \ge {\mu_I}^*(h(i_1))\ \forall\, i_1 \in I$.

So that (3.7) holds, since $\mu_I(0) = {\mu_I}^*(h(0)) = {\mu_I}^*(0') \ge {\mu_I}^*(h(i_1)) = \mu_I(i_1)$. For all $i_1, i_2 \in I$, we have

$$\begin{aligned}
\mu_I(0 \star i_1) &= {\mu_I}^*(h(0 \star i_1)) = {\mu_I}^*(h(0) \star' h(i_1))\\
&\ge \min\{{\mu_I}^*(h(0) \star' (h(i_1) \star' h(i_2))), {\mu_I}^*(h(0) \star' h(i_2))\}\\
&= \min\{{\mu_I}^*(h(0 \star (i_1 \star i_2))), {\mu_I}^*(h(0 \star i_2))\}\\
&= \min\{\mu_I(0 \star (i_1 \star i_2)), \mu_I(0 \star i_2)\}.
\end{aligned}$$

Hence $\mu_I(0\star i_1) = \mu_I{}^*(h(0\star i_1)) = (\mu_I{}^* \circ h)(0\star i_1)$ is an $f\tau BRKI$ of I. The proof is complete. □

4. Cartesian Product of $f\tau BRK$-Ideal

Definition 4.1. *A μ_I be fuzzy relation on any set I is a fuzzy subset $\mu_I : I \times I \to [0,1]$.*

Definition 4.2. *Let μ_I and $\mu_I{}^*$ be fuzzy subsets of a set I. The Cartesian product of μ_I and $\mu_I{}^*$ is defined by $(\mu_I \times \mu_I{}^*)(i_1, j_1) = \min\{\mu_I(i_1), \mu_I{}^*(j_1)\}\ \forall\, i_1, j_1 \in I$.*

Corollary 4.1. *Let $(I, \star, 0, \tau)$ and $(J, \star, 0', \tau)$ be $\tau BRK\ Alg$'s, we define $\star$ on $I \times J$ by for every $(i_3, i_4), (j_3, j_4) \in I \times J$, $(i_3, i_4) \star (j_3, j_4) = (i_3 \star j_3, i_4 \star j_4)$ then $(I \times J, \star, (0, 0'), \tau)$ is a $\tau BRK\ Alg$.*

Proof. Let $(I, \star, 0, \tau)$ and $(J, \star, 0', \tau)$ be $\tau BRK\ Alg$'s (see Definition 3.1). For all $(i_3, i_4), (j_3, j_4) \in I \times J$, then

$$(i) - (i_3, i_4) \star (0, 0') = (i_3 \star 0, i_4 \star 0') = (i_3, i_4)$$

$$(ii) - ((i_3, i_4) \star (j_3, j_4)) \star (i_3, i_4) = (i_3 \star j_3, i_4 \star j_4) \star (i_3, i_4)$$

$$= ((i_3 \star j_3) \star i_3, (i_4 \star j_4) \star i_4) = (0 \star j_3, 0' \star j_4).$$

So, $(I \times J, \star, (0, 0'), \tau)$ is a $\tau BRK\ Alg$. □

Theorem 4.1. *If μ_I and μ'_I are $f\tau BRKI$'s of $\tau BRK\ Alg$'s I, then $\mu_I \times \mu'_I$ is an $f\tau BRKI$ of $(I \times I, \star, (0, 0'), \tau)$.*

Proof. Let $i_3, i'_3 \in I \times I$. Then

$$(\mu_I \times \mu'_I)(0, 0') = \min\{\mu_I(0), \mu'_I(0')\} \geq \min\{\mu_I(i_3), \mu'_I(i'_3)\} = (\mu_I \times \mu'_I)(i_3, i'_3).$$

For any $(i_3, i'_3), (i_4, i'_4) \in I \times I$ we have

$$(\mu_I \times \mu'_I)(0 \star i_3, 0' \star i'_3) = \min\{\mu_I(0 \star i_3), \mu'_I(0' \star i'_3)\}$$

$$= \min\{\min\{\mu_I(0 \star (i_3 \star i_4)), \mu_I(0 \star i_4)\}, \min\{\mu'_I(0' \star (i'_3 \star i'_4)), \mu'_I(0' \star i'_4)\}\}$$

$$= \min\{\min\{\mu_I(0 \star (i_3 \star i_4)), \mu'_I(0' \star (i'_3 \star i'_4))\}, \min\{\mu_I(0 \star i_4), \beta(0' \star i'_4)\}\}$$

$$= \min\{(\mu_I \times \beta)((0, 0') \star ((i_3, i'_3) \star (i_4, i'_4))), (\mu_I \times \mu'_I)((0, 0') \star (i_4, i'_4))\}.$$

Hence $\mu_I \times \mu'_I$ is a $f\tau BRKI$ of $(I \times I, \star, (0, 0'), \tau)$. □

Definition 4.3. *If ζ is a fuzzy subset of a set I, the strongest fuzzy relation on I that is a fuzzy relation on ζ is μ_{I_ζ} given by $\mu_{I_\zeta}(i_1, i_2) = \min\{\zeta(i_1), \zeta(i_2)\}\ \forall\, i_1, i_2 \in I$.*

Proposition 4.1. *For a fuzzy subset ζ of a $\tau BRK\ Alg\ I$, let μ_{I_ζ} be the strongest fuzzy relation on I. If μ_{I_ζ} is an $f\tau BRKI$ of $(I \times I; \star, (0,0))$, then $\zeta(0) \geq \zeta(i_1)$ for all $i_1 \in I$.*

Proof. Since μ_{I_ζ} is a $f\tau BRKI$ of $I \times I$, it follows from (3.5) that $\mu_{I_\zeta}(0,0) \geq \mu_{I_\zeta}(i_1, i_1)$. So that $\mu_{I_\zeta}(0,0) = \min\{\zeta(0), \zeta(0)\} \geq \max\{\zeta(i_1), \zeta(i_1)\} = \mu_{I_\zeta}(i_1, i_1)$. This implies that $\zeta(0) \geq \zeta(i_1)$. □

Theorem 4.2. *Let ζ be a fuzzy subset of $\tau BRK\ Alg\ I$ and μ_{I_ζ} be the strongest fuzzy relation on I. If ζ is a $f\tau BRKI$ of I then μ_{I_ζ} is a $f\tau BRKI$ of $(I \times I; \star, (0, 0'), \tau)$.*

Proof. Suppose that, ζ is a fuzzy subset of a $f\tau BRKI\ I$ and μ_{I_ζ} is the strongest fuzzy relation on I. Then $\mu_{I_\zeta}(0, 0') = \min\{\zeta(0), \zeta(0')\} \geq \min\{\zeta(i_1), \beta(j_1)\} = \mu_{I_\zeta}(i_1, j_1)\ \forall\ (i_1, j_1) \in I \times I$.

For all $(i_1, i_1'), (j_1, j_2') \in I \times I$, we get that

$$\begin{aligned}
&\mu_{I_\zeta}((0,0') \star (i_1, i_1')) = \mu_{I_\zeta}(0 \star i_1, 0' \star i_1') = \min\{\beta(0 \star i_1), \beta(0' \star i_1')\} \\
&\geq \min\{\min\{\beta(0 \star (i_1 \star j_1)), \beta(0 \star j_1)\}, \min\{\zeta(0' \star (i_1' \star j_1')), \zeta(0' \star j_1')\}\} \\
&= \min\{\min\{\zeta(0 \star (i_1 \star j_1)), \beta(0' \star (i_1' \star j_1'))\}, \min\{\beta(0 \star j_1), \beta(0' \star j_1')\}\} \\
&= \min\{\mu_{I_\zeta}(0 \star (i_1 \star j_1), 0' \star (i_1' \star j_1')), \mu_{I_\zeta}(0 \star j_1, 0' \star j_1')\} \\
&= \min\{\mu_{I_\zeta}((0,0') \star ((i_1, i_1') \star (j_1, j_1'))), \mu_{I_\zeta}((0,0') \star (j_1, j_1'))\}.
\end{aligned}$$

Hence μ_{I_ζ} is a $f\tau BRKI$ of $(I \times I; \star, (0, 0'), \tau)$. □

5. Conclusion

In this paper, the $f\tau BRKI$ concept of $\tau BRK\ Alg$ was introduced and studied their properties. The epimorphic and into homomorphic inverse images of a $f\tau BRKI$ are also discussed and studied well. The $f\tau BRKI$ of a cartesian product was also discussed in this work.

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