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Bi-ideals in Ternary Seminear Rings

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ABSTRACT
In this paper, we introduce the concept of Bi-ideal in ternary seminear rings as a generalization of quasi ideals in ternary seminear rings. We also study the notion of minimal bi-ideal in ternary seminear rings and derive some of their interesting properties.

KEYWORDS: Ternary seminear ring, Regular Ternary seminear ring, Ideals in Ternary seminear ring, Quasi ideal in ternary seminear rings, Bi-ideal
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1 INTRODUCTION

Algebraic structures take a part in very marvellous role in mathematics which classifies in many area such as control engineering, physics, computer coding, IT, control engineering, etc. In 1952, Good.R.A and Hughes.D.R [2] started the concept of bi-ideals for a semigroup. Szasz.F [14][9] generalized bi-ideals of rings in 1970. In 1983, Pilz Gunter [11] came up with an idea of near ring. Krishna.K.V. [6][7][8] brought up with near-semi rings in 2005.

Kar.S.[4] initiated on quasi-ideals and bi-ideals in ternary semi rings. Dheena.P and Elavarasan.B., [1] were studied about the prime bi-ideals in ternary semi ring. Shique Li and Young He [13] floated on semigroups whose bi-ideals are strongly prime. Iampan.A [3] studied a note on bi-ideals in T-Semigroups. Koteswaramma.N and Venkateswara Rao.J.[5] have studied on bi-ideals and Minimal bi-ideals in ternary semi ring. Many authors worked on bi-ideals [10][12].

The notion of ternary seminear rings was initiated in 2020 by us [15]. Later we worked on [16][17][18][19][20].

In this paper, we define the notion of bi-ideal in ternary seminear rings. We also introduce a minimal bi-ideal in ternary seminear rings and obtained their properties.

2 PRELIMINARIES

Definition 2.1 *A ternary seminear ring is a nonempty set T together with a binary operation called addition '+' and a ternary operation called ternary multiplication denoted by juxtaposition, such that*

$(i)(T,+)$ is a semigroup.
(ii)T is a ternary semigroup under ternary multiplication.
$(iii)xy(z+u)=xyz+xyu$ for all $x,y,z,u\in T$.

Definition 2.2 *A ternary seminear ring T is said to have an absorbing zero if there exists an element $0\in T$ such that $i)x+0=0+x=x$ for all $x\in T$. $ii)xy0=x0y=0xy=0$ for all $x,y\in T$.*

Remark 2.3 *Throughout this paper T will always stand for the ternary seminear ring will always mean that ternary seminear ring with an absorbing zero.*

Definition 2.4 *Let T be a ternary seminear ring. A nonempty subset R of T is said to be a ternary subseminear ring of T if R itself is a ternary seminear ring under the same operations of T.*

Definition 2.5 *Let T be a ternary seminear ring $(T,+,.)$. A non empty subset I of T is said to be a left(lateral and right) ideal of T if it holds the following conditions i) $i+j\in I$ for all $i,j\in I$ ii) t_1t_2i(respectively t_1it_2, it_1t_2) $\in I$ for all $t_1,t_2\in T$ and $i\in I$. If I is a left, a lateral and a right ideal of T then I is said to be an ideal of T.*

Definition 2.6 *Let T be a ternary seminear ring. A proper ideal I of T is said to be a prime ideal if whenever $XYZ\subseteq I$ then $X\subseteq I$ or $Y\subseteq I$ or $Z\subseteq I$, for all ideals X,Y,Z of T.*

Definition 2.7 *Let T be a ternary seminear ring. A proper ideal I of T is said to be s semiprime ideal if whenever $X^3\subseteq I$ then $X\subseteq I$, for any ideals X of T.*

Definition 2.8 *Let* $(T,+,.)$ *be a ternary seminear ring. For all* $x,y,u,v \in T$, *T is called*
i) Left cancellative if $u+x=u+y \Rightarrow x=y$ and $uvx = uvy \Rightarrow x=y$
ii) Right cancellative if $x+v=y+v \Rightarrow x=y$ and $xuv = yuv \Rightarrow x=y$
iii) Lateral cancellative if $uxv = uyv \Rightarrow x=y$
iv) Cancellative if T is left, right and laterally cancellative.

Definition 2.9 *A congruence* ρ *on a ternary seminear ring T is said to be a cancellative congruence on T if* T/ρ *is a cancellative ternary seminear ring.*

Remark 2.10 *Multiplicatively cancellative (MC) means it is enough to show that the ternary cancellative operations in the cancellative ternary seminear ring (ie,. we can omit the binary addition).*

Definition 2.11 *Let* T *be a ternary seminear ring. Let* U *be an additive subsemigroup of* T. U *is said to be a quasi-ideal of* T *if* $UTT \cap (TUT + TTUTT) \cap TTU \subseteq U$.

Definition 2.12 *Let* $(B,+,*)$ *be a semiring. A bi-ideal C is a subsemiring of B if* $CBC \subseteq C$

Definition 2.13 *An element x in a ternary seminear ring T is called regular if there exists an element y in T such that xyx=x. A ternary seminear ring T is called regular if all of its elements are regular.*

Theorem 2.14 *Let* T *be a ternary seminear ring. Then the following conditions are equivalent*
i) T is regular.
ii) For any right ideal A, lateral ideal B, left ideal C of T, $ABC = A \cap B \cap C$.
iii) For $x,y,z \in T, <x>_r <y>_m <z>_l = <x>_r \cap <y>_m \cap <z>_l$
iv) For $x \in T, <x>_r <x>_m <x>_l = <x>_r \cap <x>_m \cap <x>_l$

Theorem 2.15 *Let I be a ternary subsemigroup of a ternary seminear ring T. Then I is a left(lateral or right)ideal of T if and only if* $TTI \subseteq I$
(respectively TIT $\subseteq I$ and $ITT \subseteq I$).

3 BI IDEALS IN TERNARY SEMINEAR RINGS

In this section we discussed about the Bi-ideals in ternary seminear rings.

Definition 3.1 *Let* T *be a ternary seminear ring. A ternary subseminear ring* V *of* T *is said to be a bi-ideal of* T *if* $VTVTV \subseteq V$.

Theorem 3.2 *Let* T *be a ternary seminear ring. An intersection of an arbitrary collection of bi-ideals of T is also a bi-ideal of* T.

Proof. Let $\{V_i : i \in I\}$ be an arbitrary collection of bi-ideals of a ternary seminear ring T. Let $a,b \in \bigcap_{i\in I} V_i$. Then $a,b \in V_i$ for all $i \in I$. Since every V_i is a bi-ideal of T, then we have $a+b \in V_i$, $\forall i \in I$ which implies that $a+b \in \bigcap_{i\in I} V_i$

Let $a,b,c \in \bigcap_{i\in I} V_i$. Then $a,b,c \in V_i$ for all $i \in I$. Since every V_i is a bi-ideal of T, we have $a,b,c \in V_i$ for all $i \in I$ implies that $a,b,c \in \bigcap_{i\in I} V_i$. Now $V_iTV_iTV_i \subseteq V_i$ and $\bigcap_{i\in I} V_i \subseteq V_i$ for all $i \in I$ then we have $\left[\bigcap_{i\in I} V_i\right] T \left[\bigcap_{i\in I} V_i\right] T \left[\bigcap_{i\in I} V_i\right] \subseteq V_iTV_iTV_i \subseteq V_i$ for all $i \in I$. Thus which implies that $\left[\bigcap_{i\in I} V_i\right] T \left[\bigcap_{i\in I} V_i\right] T \left[\bigcap_{i\in I} V_i\right] \subseteq \bigcap_{i\in I} V_i$. Hence $\bigcap_{i\in I} V_i$ is a bi-ideal of T.

Theorem 3.3 *Let* T *be a ternary seminear ring. Each quasi-ideal of* T *is a bi-ideal of* T.

Proof. Let T be a ternary seminear ring. U be a quasi-ideal of T. Then
$UTUTU \subseteq U(TTT)T \subseteq UTT$,
$UTUTU \subseteq T(TTT)U \subseteq TTU$, *and*
$UTUTU \subseteq TTUTT$. *And* $\{0\} \subseteq TUT$.
Therefore $\{0\} + UTUTU \subseteq TUT + TTUTT$.
Hence it follows that
$UTUTU \subseteq UTT \cap (TUT + TTUTT) \cap TTU \subseteq U$.
and consequently U is a bi-ideal of T.

Remark 3.4 *Generally* V *be a bi-ideal of* T *and* W *is a bi-ideal of* V, *then* W *is need not a bi-ideal of* T. *Yet, in specific case, we have the succeeding theorem.*

Theorem 3.5 *Let* T *be a ternary seminear ring.* V *be a bi-ideal of* T *and* W *be a bi-ideal of* V *such that* $W^3 = W$. *Then* W *is a bi-ideal of* T.

Proof. As V be a bi-ideal of T, $VTVTV \subseteq V$, and W be a bi-ideal of V, then $WVWVW \subseteq W$. Consequently,

$$\begin{aligned} WTWTW &= (WWW)TWT(WWW) \\ &= WW(WTWTW)WW \\ &\subseteq WW(VTVTV)WW \\ &\subseteq WWVWW \\ &= WWVW(WWW) \\ &= W(WVWVW)W \\ &\subseteq WWW \\ &\subseteq W. \end{aligned}$$

Definition 3.6 *Let* T *be a ternary seminear ring.* $|T| \geq 2$ *is said to be a ternary division seminear ring if any non zero element* x *in* T, *there exists a non zero element* y *of* T *such that* $xyz = yxz = zxy = zyx = z$ *for all* $z \in T$.

Theorem 3.7 *Let* T *be a ternary seminear ring.* T *has no non zero proper bi-ideals if* T *is a ternary division seminear ring.*

Proof. Let T be a ternary division seminear ring and V be a non zero bi-ideal of T.

Let x be a non zero element in V.
Then there exists a non zero element t in T such that $xtz = txz = zxt = ztx = z$, $\forall z \in T$, which implies that $T =$

$VTT = TTV$.

Now

$$\begin{aligned} T &= VTT \\ &= V(TTV)(TTV) \\ &= V(VTT)(TVT)(TTV)V \\ &= V(VTVTV)V \\ &\subseteq VVV \\ &\subseteq V. \end{aligned}$$

Therefore, T ⊂ V and V ⊂ T which implies $V = T$ and thus T has no non zero proper bi-ideals.

Theorem 3.8 *A Multiplicative Cancellative (MC) ternary seminear ring T is zero divisor.*

Proof. Let T be a MC ternary seminear ring and $xyz = 0$ for $x, y, z \in T$. If $y \neq 0$ and $z \neq 0$, then by right cancellativity $xyz = 0yz = x = 0$. Similarly we can show that $y = 0$ if $x \neq 0$ and $z \neq 0$ or $z = 0$ if $x \neq 0$ and $y \neq 0$. Therefore, T is zero divisor.

Theorem 3.9 *Let T be a ternary seminear ring. A, B and C be three ternary subseminear rings of T and $V = ABC$. Then, V is a bi-ideal if atleast one of A, B, C is a right, a lateral or a left ideal of T.*

Proof. Let T be a ternary seminear ring and $V = ABC$. If A be a right ideal of T. Then

$$\begin{aligned} (ABC)T(ABC)T(ABC) &\subseteq A(TTT)(TTT)TTBC \\ &\subseteq A(TTT)TBC \\ &\subseteq (ATT)BC \\ &\subseteq ABC. \quad (By\ \ Theorem\ \ 2.8) \end{aligned}$$

Therefore $V = ABC$ is a bi-ideal of T. Again, B be a right ideal of T. Then

$$\begin{aligned} (ABC)T(ABC)T(ABC) &\subseteq AB(TTT)(TTT)TTC \\ &\subseteq AB(TTT)TC \\ &\subseteq A(BTT)C \\ &\subseteq ABC. \end{aligned}$$

Consequently $V = ABC$ is a bi-ideal of T. Now, if C be a right ideal of T, then

$$\begin{aligned} (ABC)T(ABC)T(ABC) &\subseteq (ABC)(TTT)(TTT)TT \\ &\subseteq (ABC)(TTT)T \\ &\subseteq (ABC)TT \\ &\subseteq AB(CTT) \\ &\subseteq ABC. \end{aligned}$$

Therefore $V = ABC$ is a bi-ideal of T. Similarly, if A be a left ideal of T. The

$$\begin{aligned} (ABC)T(ABC)T(ABC) &\subseteq (TTT)(TTT)TT(ABC) \\ &\subseteq TTTTABC \\ &\subseteq (TTA)BC \\ &\subseteq ABC. \end{aligned}$$

Therefore $V = ABC$ is a bi-ideal of T. Suppose B be a left ideal of T. Then

$$\begin{aligned} (ABC)T(ABC)T(ABC) &\subseteq A(TTT)(TTT)TTBC \\ &\subseteq A(TTT)TBC \\ &\subseteq A(TTB)C \\ &\subseteq ABC \end{aligned}$$

Hence $V = ABC$ is a bi-ideal of T.

If C be a left ideal. Then

$$\begin{aligned} (ABC)T(ABC)T(ABC) &\subseteq AB(TTT)(TTT)TTC \\ &\subseteq AB(TTT)TC \\ &\subseteq AB(TTC) \\ &= ABC \end{aligned}$$

Therefore $V = ABC$ is a bi-ideal of T.

If A be a lateral ideal of T. Then

$$\begin{aligned} (ABC)T(ABC)T(ABC) &\subseteq (TTT)TA(TTT)TBC \\ &\subseteq T(TAT)TBC \\ &\subseteq (TAT)BC \\ &\subseteq ABC. \end{aligned}$$

Therefore A be a lateral ideal of T. $V = ABC$ be a bi-ideal of T.

Again B be a lateral ideal of T. Then

$$\begin{aligned} (ABC)T(ABC)T(ABC) &\subseteq A(TTT)TBT(TTT)C \\ &\subseteq AT(TBT)TC \\ &\subseteq A(TBT)C \\ &\subseteq ABC. \end{aligned}$$

Therefore $V = ABC$ be a bi-ideal of T.

Suppose C be a lateral ideal of T. Then

$$\begin{aligned} (ABC)T(ABC)T(ABC) &\subseteq AB(TTT)TCT(TTT) \\ &\subseteq ABT(TCT)T \\ &\subseteq AB(TCT) \\ &\subseteq ABC. \end{aligned}$$

Therefore $V = ABC$ be a bi-ideal of T.

Theorem 3.10 *A ternary subseminear ring V of T be a bi-ideal of T if $V = ABC$, where A is a right ideal, B is a lateral ideal and C is a left ideal of T.*

Proof. Let V be a ternary subseminear ring of T. Suppose $V = ABC$, where A is a right ideal, B is a lateral ideal and C is a left ideal of T, then

$$\begin{aligned} V &= (ATT)(TBT)(TTC) \forall A, B, C \in V \\ &\subseteq A(TTT)B(TTT)C \\ &\subseteq ATBTC \\ &\subseteq V \\ &= ABC. \end{aligned}$$

Therefore V is a bi-ideal of T.

Theorem 3.11 *Let T be a ternary seminear ring. Let V be a ternary subseminear ring of T. If A be a right ideal, B be a lateral ideal and C be a left ideal of T such that $ABC \subseteq V \subseteq A \cap B \cap C$ then V be a bi-ideal of T.*

Proof.

$$\begin{aligned} VTVTV &\subseteq (A \cap B \cap C)T(A \cap B \cap C)T(A \cap B \cap C) \\ &\subseteq A(TBT)C \\ &\subseteq ABC \\ &\subseteq V. \end{aligned}$$

Therefore V is a bi-ideal of T.

Theorem 3.12 *The following criteria in a ternary seminear ring T are eqivalent.*

i) T be regular.

ii) Each bi-ideal V of T, $VTVTV = V$.

iii) Each quasi-ideal U of T, $UTUTU = U$.

Proof. $(i) \Rightarrow (ii)$ Suppose T is regular. Let V is a bi-ideal of T. Let $x \in V$.Then there exists an element y in T such that $xyx = x$. Thus implies that $x = xyxyx \in VTVTV$.

Therefore $V \subseteq VTVTV$. Since V is a bi-ideal of T, $VTVTV \subseteq V$. Hence $VTVTV = (ii) \Rightarrow (iii)$

Obviously it is true.$(iii) \Rightarrow (i)$

If (iii) holds. Let A be a right ideal B be a lateral ideal and C be a left ideal of T. Then $U = A \cap B \cap C$ is a quasi ideal of T (by theorem 3.3). Hence $UTUTU = U$. Suppose $A \cap B \cap C = U = UTUTU \subseteq ATBTC \subseteq ABC$. Clearly $ABC \subseteq A \cap B \cap C$. Therefore $A \cap B \cap C = ABC$ and thus from (theorem 2.7). T is a regular ternary seminear ring.

Theorem 3.13 *A ternary subseminear ring V of a regular ternary seminear ring T is a bi-ideal of $T \Leftrightarrow V = VTV$.*

Proof. If $V = VTV$, then obviously V is a bi-ideal of T. Conversely, V is a bi-ideal of a regular ternary seminear ring T. Let $x \in V$, then there exists an element y in T such that $x = xyx$. This implies that $x \in VTV$ and consequently $V \subseteq VTV$. Now, $VTV \subseteq VTVTV \subseteq V$. Therefore $V = VTV$.

Theorem 3.14 *A ternary subseminear ring V of a regular ternary seminear ring T is a bi-ideal of $T \Leftrightarrow V$ is a quasi ideal of T.*

Proof. Let T is a regular ternary seminear ring. If V is a quasi-ideal of T, then (by theorem 3.3), V is a bi-ideal of T. Conversely, let V be a bi-ideal of T (by theorem 2.7), we have T be a regular ternary seminear ring then $A \cap B \cap C = ABC$, for any right ideal A, lateral ideal B and left ideal C.

Also,

$$\begin{aligned}
&VTT \cap (TVT + TTVTT) \cap TTV \\
&= VTT(TVT + TTVTT)TTV \\
&= (VTT)(TVT)(TTV) + (VTT)(TTVTT)(TTV) \\
&= V(TTT)V(TTT)V + V(TTT)TV(TTT)TV \\
&\subseteq VTVTV + VTTVTTV \\
&\subseteq V + VTV \quad (by \quad theorem \quad 3.13) \\
&= V + V \\
&\subseteq V.
\end{aligned}$$

Therefore V is a quasi-ideal of T.

Theorem 3.15 *Let T be a ternary seminear ring. R is a ternary subseminear ring of T. If V is a bi-ideal of T then $V \cap R$ is a bi-ideal of R.*

Proof. Let T be a ternary seminear ring R be a ternary subseminear ring of T. Let $A = V \cap R \Rightarrow A \subseteq V$ and $A \subseteq R$.

Consider

$ARARA \subseteq VRVRV \subseteq VTVTV \subseteq V$,

and$ARARA \subseteq RRRRR \subseteq R$.

Consequently, $ARARA \subseteq V \cap R = A$.

Hence $A = V \cap R$ is a bi-ideal of R.

Theorem 3.16 *Let T be a ternary seminear ring. If V_1, V_2 and V_3 are three bi-ideals of T, then $V_1V_2V_3$ is a bi-ideal of T.*

Proof. Let T, be a ternary seminear ring. V_1, V_2 and V_3 are three bi-ideals of T.

$$\begin{aligned}
&\Rightarrow VTVTV \subseteq V. \\
&\Rightarrow (V_1V_2V_3)T(V_1V_2V_3)T(V_1V_2V_3) \\
&\subseteq (V_1TT)T(TV_2T)T(TTV_3) \\
&\subseteq (V_1TT)(TTV_2TT)(TTV_3) \\
&\subseteq V_1V_2V_3.
\end{aligned}$$

Consequently, $V_1V_2V_3$ be a bi-ideal of T.

Theorem 3.17 *Let T be a ternary seminear ring. If I be an ideal and U be a quasi-ideal of T then $I \cap U$ be a bi-ideal of T.*

Proof. Let T be a ternary seminear ring. I be an ideal. U be a quasi ideal of T. Clearly $I \cap U$ be a ternary subseminear ring of T.

$$\begin{aligned}
&\Rightarrow (I \cap U)T(I \cap U)T(I \cap U) \\
&\subseteq (ITITI) \cap (UTUTU) \\
&\subseteq I \cap U.
\end{aligned}$$

Hence $I \cap U$ is a bi-ideal of T.

Theorem 3.18 *Let T be a ternary seminear ring. R, S be ternary subseminear ring of T, then $V = RTS$ be a bi-ideal of T.*

Proof. Let T be a ternary seminear ring. R, S be two ternary subseminear ring of T, then $V = RTS$ is a subseminear ring of T.

$$\begin{aligned}
VTVTV &\subseteq (RTS)T(RTS)T(RTS) \\
&\subseteq R(TTT)(TTT)(TTT)S \\
&\subseteq RTS \\
&\subseteq V.
\end{aligned}$$

Then $V = RTS$ be a bi-ideal of T.

Definition 3.19 *Let T be a ternary seminear ring. A proper bi-ideal V of T is called prime bi-ideal if $XYZ \subseteq V$ which implies that $X \subseteq V$ or $Y \subseteq V$ or $Z \subseteq V$ for bi-ideals X, Y and Z of T.*

Definition 3.20 *Let T be a ternary seminear ring. A proper bi-ideal V of T is called semi prime bi-ideal if $X^3 \subseteq V$ which implies that $X \subseteq V$ for bi-ideal $X \in T$.*

Definition 3.21 *Let T be a ternary seminear ring. A non zero bi-ideal V of T is said to be a minimal bi-ideal of T if V does not properly contain any non zero bi-ideal.*

Theorem 3.22 *Let T be a ternary seminear ring. A is a minimal right ideal, B is a minimal lateral ideal and C is a minimal left ideal of T. Then $ABC = 0$ or ABC be a minimal bi-ideal of T.*

Proof. Let T be a ternary seminear ring. A is a minimal right ideal, B is a minimal lateral ideal and C is a minimal left ideal of T. ABC be an additive subseminear ring of T. Suppose $ABC \neq 0$ and let $V = ABC$. Then (by theorem 3.10), V is a bi-ideal of T.

Let X be any bi-ideal of T, such that $0 \neq X \subseteq V \subseteq A$. Then XTT is a right ideal of T and $XTT \subseteq VTT = (ABC)TT \subseteq ATT \subseteq A$. As A be a minimal right ideal of T. Consequently $XTT = 0$ or $XTT = A$.

If $XTT = 0$ then $X = A$ and $ABC = 0$ this makes a contradiction. Consequently $XTT = A$.

Similarly, we can show $TXT = B$ and $TTX = C$. Consequently $V = ABC = XTTTXTTTX \subseteq XTXTX \subseteq X$. Therefore $V = X$. Thus ABC be a minimal bi-ideal of T.

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