Results On Generalized Regular And Strongly Regular Near-Rings

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Abstract: Some results on r-regular (r-RN) and also in s-weakly regular **(s-**WRN**)**near-rings were established in this article. It is proved that for a near-ring $\mathscr{H} \in \eta_0$ is **s**-WRN, then $\mathscr{H}$ is simple iff $\mathscr{H}$ is integral. And also proved that for an r-RN $\mathscr{H}$ with unity and satisfies IFP, then $\mathscr{H}$ has the strong IFP iff $\mathscr{H}$ is a PSN.

Keywords: s-weakly regular, r-regular, strong IFP, IFP.

1. INTRODUCTION

Near-rings, an advanced concept, was highly influenced by the Ring-theory. Von-Neumann regular rings give vital information in the structure theory of rings which was first named by VON-NEUMANN. “Generalization of rings “which are familiar with “Near-rings” plays a major part in the development of Mathematics. Several mathematicians studied and developed various concepts in this area, namely, DheenaP [3], B Elavarasan [4] developed the regularity concept by introducing near-rings *s*-weakly regular and strong IFP. This regularity concept was researched by Mason [7], [8], ReddyYV, and MurthyCVLN [10], Groenewald, and Argac [2].Recently, Wendt Gerhard [13], T Manikantan, and S Ram Kumar [6] researched and established several results.

2. PRELIMINARIES

Definition 2.1.1. [9] Let ($\mathscr{H}$, +, .), a non-empty set is designated as R-NR (Right Near-ring) if

(i) $\mathscr{H}$ holds the “Group” axioms under addition

(ii) $\mathscr{H}$ holds the “Semigroup” axioms under multiplication

(iii) $(l+t)\cdot p = l\cdot p + t\cdot p$ for all, l, t, p $\in \mathscr{H}$ (Right distributive law)

Moreover, we assume that an R-NR is ($\mathscr{H}$, +, .) and we designate it as $\mathscr{H}$ except and otherwise mentioned. We write ‘lp’ to denote ‘l.p’ for any two elements ‘l’ and ‘h’ in $\mathscr{H}$. For basic definitions and other related theories, we refer the reader to [9]. We recall the following.

Definition 2.1.2. A near-ring $\mathscr{H}$ is demonstrated as “ZSN (Zero-Symmetric Near-ring)” provided $go = 0\ for\ all\ g$ is in $\mathscr{H}$.i.e., $\mathscr{H} = \mathscr{H}_0$.

Example 2.1.3. Let ($\mathscr{H}$, +) where $\mathscr{H}$ = {*l, t, p, s*} be the Klein’s four group. Then ($\mathscr{H}$, +, .) represents an example for ZSN and expressed it as $\mathscr{H} \in \eta_0$.[9, p408, (13) (0, 7, 13, 9)]

Table 1 Addition table

+	*l*	*t*	*p*	*s*
l	*l*	*t*	*p*	*s*
t	*t*	*l*	*s*	*p*
p	*p*	*s*	*l*	*t*
s	*s*	*p*	*t*	*l*

Table 2 Product table

.	*l*	*t*	*p*	*s*
l	*l*	*l*	*l*	*l*
t	*l*	*t*	*p*	*s*
p	*l*	*l*	*l*	*l*
s	*l*	*t*	*p*	*s*

Definition 2.1.4. A subgroup $\wp$ of $\mathscr{H}$ is known as $\mathscr{H}$**-subgroup,** if $\mathscr{H}\wp \subseteq \wp$.

Definition 2.1.5. An element ‘*l*’ of $\mathscr{H}$ is known as ***the left identity*** of $\mathscr{H}$ if $lx = x$ for all $x \in \mathscr{H}$.

Definition 2.1.6. An element 'p' of $\mathscr{H}$ is known as ***the right identity*** of $\mathscr{H}$ if $yp = y$ for all $y \in \mathscr{H}$.
Definition 2.1.7. An element 't' of $\mathscr{H}$ is known as ***a two-sided identity or an identity element*** of $\mathscr{H}$ if 't' holds both left and right identities in $\mathscr{H}$.
Definition 2.1.8. An element 'q' of $\mathscr{H}$ is designated as ***left invertible*** of $\mathscr{H}$, if there exists an element $b \in \mathscr{H}$ such that $bq = 1$. The element 'b' is referred to as the ***left inverse*** of q.
Definition 2.1.9. An element 's' of $\mathscr{H}$ is designated as ***right invertible*** of $\mathscr{H}$, if there exists an element $c \in \mathscr{H}$ such that $sc = 1$. The element 'c' is referred to as the ***left inverse*** of s.
Definition 2.1.10. An element 'a' of $\mathscr{H}$ is said to be ***invertible(unity)*** of $\mathscr{H}$, if 'a' satisfies both the definitions 2.1.8 and 2.1.9.
Notation 2.1.11. If $\mathscr{B}$, $\mathfrak{C} \subseteq \mathscr{H}$ then we can define $\mathscr{B}\,\mathfrak{C}$= {bc / $b \in \mathscr{B}$, $c \in \mathscr{H}$}
Further, we fix the word $\mathscr{H}$SG to refer to "Normal subgroup ".
Definition 2.1.12. Suppose that$\mathfrak{S}$ be a $\mathscr{H}$SG of ($\mathscr{H}$, +) and is termed as the"Left ideal" of $\mathscr{H}$, provided that $\forall l, p\in \mathscr{H}$, $\forall s\in \mathfrak{S}$, $l(p + s) - lp\in\mathfrak{S}$.
Definition 2.1.13. Suppose that$\mathfrak{S}$ be a $\mathscr{H}$SG of ($\mathscr{H}$, +) termed as the"Right ideal" of $\mathscr{H}$ provided that, $\mathfrak{S}\,\mathscr{H} \subseteq\mathfrak{S}$.
Definition 2.1.14. Suppose that$\mathfrak{S}$ be a $\mathscr{H}$SG of ($\mathscr{H}$, +) is denoted as an ideal (two-sided ideal)provided that if it follows the conditions both left (right) of $\mathscr{H}$.
Theorem 2.1.15. For a near-ring $\mathscr{H} \in\eta_0$, every ideal is a **$\mathscr{H}$-subgroup** of $\mathscr{H}$.
Definition 2.1.16. Consider a family of left ideals which contains a non-empty subset $\mathscr{F}$in $\mathscr{H}$. Then the smallest left ideal which is obtained by the intersection of all left ideals containing $\mathscr{F}$ is termed as "left ideal generated by $\mathscr{F}$"
Definition 2.1.17. The term" Principal ideal"is referred to as an ideal that is generated by a single element say 'j' denoted by $<j>$.
If $\mathfrak{J}$ be a left ideal and is generated by a single element 'j', then $\mathfrak{J}$ is symbolized by $<j|$.
Definition 2.1.18. An element 'k' is termed as an idempotent of $\mathscr{H}$ if $k^2 = k, for\ k\in \mathscr{H}$.
Definition 2.1.19. A ***zero divisor*** of $\mathscr{H}$ is a component $f \neq 0$ of $\mathscr{H}$ which satisfies $ft = 0$ for some nonzero 't' in $\mathscr{H}$.
Definition 2.1.20. Let $\mathscr{H}$ is termed to an **integral** near-ring if it has no non-zero divisors.
Definition 2.1.21. Let $\mathscr{H}$ is termed to a **simple** near-ring if $\mathscr{H}$ is not having non-trivial ideals.
Definition 2.1.22. Let Δ be a subset of a $\mathscr{H}$. Then the set $(\mathbf{0}\colon \Delta) = \{\boldsymbol{h\in N \,/\, hx = 0, for\ all\ x\in}\Delta\}$ is called the **annihilator of** Δ.
Note 2.1.23. If Δ = { δ }, then (0: Δ) is denoted by (0: δ).
Theorem 2.1.24. For any $\delta \in\mathscr{H}$, (0: δ) is a left ideal of $\mathscr{H}$.
Definition 2.1.25. Let $\mathscr{H}$ is referredto as" ***Insertion of Factors Property (in short, IFP)***", assuming that jb= 0 ⇒ jpb = 0, ∀j, b, p ∈ $\mathscr{H}$.
Theorem 2.1.26. The following conditions are equivalent:
(i) **$\mathscr{H}$ has the IFP - property.**
(ii) **(0 : h) is an ideal of $\mathscr{H}$, ∀h∈$\mathscr{H}$.**
(iii) **(0: $\mathfrak{H}$) is an ideal of $\mathscr{H}$, for all subsets $\mathfrak{H}$ of $\mathscr{H}$.**
Definition 2.1.27. For each element d∈ $\mathscr{H}$, if $d^2 = 0$ ⇒d = 0, then $\mathscr{H}$ is referred as ***reduced*** near-ring.
Theorem 2.1.28. For each element k, l in reduced near-ring, $\mathscr{H}\in\eta_0$, then klh = khl where $h^2 = h$, h is in $\mathscr{H}$
Definition 2.1.29. For each elementl∈ $\mathscr{H}$, if $\mathcal{H}\ l = \mathscr{H}l^2$ then $\mathscr{H}$ is termed as" ***left bi potent***".
Definition 2.1.30. For each elementc∈ $\mathscr{H}$, there is anelement l in $\mathscr{H}$ such that c = clc, then $\mathscr{H}$ is called as "***regular near-ring (RN)***".
Example 2.1.31. Let $\mathscr{H}$ = {0, a, b, c} be Klein's four group under addition and multiplication tables 3 & 4 as follows.

Table 3 Addition table

+	0	a	b	c
0	0	a	b	c
a	a	0	c	b
b	b	c	0	a
c	c	b	a	0

Table 4 Product table

.	0	a	b	c
0	0	0	0	0

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

Then ($\mathscr{H}$, +, .) is an example for RN.

Definition 2.1.32. For each r∈ $\mathscr{H}$, there is component l in $\mathscr{H}$ such that r = lr^2, then $\mathscr{H}$ is demonstrated as" ***left strongly regular near-ring (left SRN)***".

Note2.1.33. [9, p288]. Let $\mathscr{H}$ has the strong IFP provided every homomorphic image of $\mathscr{H}$ has IFP.

Note 2.1.34 [10]. $\mathscr{H}$ has strong IFP if and only if for every ideal $\mathscr{L}$ in $\mathscr{H}$ and $ft \in \mathscr{L}$ implies $fpt \in \mathscr{L}$ for every $f, p, t \in \mathscr{H}$.

2.2. r-REGULAR NEAR-RINGS

Definition 2.2.1. [11][12] For each element $p \in \mathscr{H}$, there is anelement 'h' such that $p = ph, h \in <p|$,where h is an idempotent in $\mathscr{H}$ then $\mathscr{H}$ is demonstrated as" r -Regular Near-ring(r-RN)".

Example 2.2.2. Any RN is an r - RN but the converse need not be true.

(i) Let a near-ring $\mathscr{H}$ defined on Z_6 = {0, 1, 2, 3, 4, 5} with operations '+'and '.' given below Tables 5 & 6 as follows.

Table 5 Addition table

+	0	1	2	3	4	5
0	0	1	2	3	4	5
1	1	2	3	4	5	0
2	2	3	4	5	0	1
3	3	4	5	0	1	2
4	4	5	0	1	2	3
5	5	0	1	2	3	4

Table 6 Product table

.	0	1	2	3	4	5
0	0	0	0	0	0	0
1	3	5	5	3	1	1
2	0	4	4	0	2	2
3	3	3	3	3	3	3
4	0	2	2	0	4	4
5	3	1	1	3	5	5

This near-ring is RN and also r - RN.

(ii) Let a near-ring $\mathscr{H}$ defined on Z_8 = {0, 1, 2, 3, 4, 5,6,7} with addition is modulo 8 and product table is given below Tables 7.

Table 7 Product table

.	0	7	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	1	3	3	0	1	1	3
2	0	2	6	6	0	2	2	6
3	0	3	1	1	0	3	3	1
4	0	4	4	4	0	4	4	4
5	0	5	7	7	0	5	5	7
6	0	6	2	2	0	6	6	2
7	0	7	5	5	0	7	7	5

The ideals of this near-ring are {0} and $\mathscr{H}$ itself.

This near-ring is r-RN but not RN (For all x, 4 ≠ 4.x.4).

Theorem 2.2.3. [11] If 𝒳 is r-RN with unity and has IFP then q = ql implies q = lq where 'l' is idempotent.
Theorem 2.2.4.[11] If 𝒳 is r - regular near-ring with 1 and has IFP then 𝒳 is reduced.

Theorem 2.2.5.If 𝒳∈ η_0 is r - regular near-ring with 1 and has IFP then 𝒳 has strong IFP.

Proof: Suppose 𝒳∈ η_0 , r-RN with 1and has IFP.

Let $\psi: N \longrightarrow N^1$ be an epimorphism of r-regular near-ring onto near-ring N^1.
By the definition of r-regular near-ring, $l = ld,\ d^2 = d, d \in< l|$
Now, $l = ld,\ d^2 = d, d \in< l| \subset \langle l\rangle\ so\ that\ d \in \langle l\rangle$.
Consider $\psi(l) = \psi(ld) = \psi(l)\psi(d)$,

$$\psi(d) = \psi(dd) = \psi(d)\psi(d)$$

$\psi(d) \in \psi$<l> ⊆ <ψ<l>> which implies $\psi(d) \in$ <ψ<l>>.
Thus, we can conclude that the homomorphic image of r-RN is r-RN.
By the supposition, and by using the theorem 2.2.4, 𝒳 is reduced.
Let qb =0 then $(bq)^2 = b(qb)q = boq = 0$
Since 𝒳 is reduced, we get that $bq = 0$
So, we have that, if qb =0 then bq =0----(1)
Now, if $\psi(q)\psi(b) = 0$ implies $\psi(qb) = 0$ which implies $\psi(0) = 0$ (using (1))
Then $\psi(b)\psi(q) = \psi(bq) = 0$
Therefore, if $\psi(q)\psi(b) = 0$ then we get $\psi(b)\psi(q) = 0$---(2)
Consider, $\psi(q)\psi(b) = 0$
Take $\psi(nb)\psi(q) = \psi(nbq) = \psi(no) = \psi(0) = 0$
Using (2), we get that $\psi(q)\psi(nb) = 0$ implies $\psi(qnb) = 0$ which implies $\psi(q)\psi(n)\psi(b) = 0$ for all n in 𝒳.
Thus, the homomorphic image of r-RN satisfies IFP.
Hence, 𝒳 has a strong IFP.
Definition 2.2.6. A subset ℒ ≠ ϕ of 𝒳 is called a 'Pseudo Symmetric Subset '(briefly, PSS) of 𝒳 if ∀ p, l ∈ 𝒳, pl ∈ ℒ implies prl ∈ ℒ ∀ r ∈ 𝒳.
Definition 2.2.7. Let ℒ ≠ ϕ of 𝒳 is a subset which is indicated as a 'Pseudo Symmetric Ideal' (briefly, PSI) of 𝒳 if ℒ is both a pseudo symmetric subset and an ideal of 𝒳.
Definition 2.2.8. A 'Pseudo Symmetric Near-ring' (briefly, PSN) is a near-ring 𝒳 in which each ideal of 𝒳 is pseudo symmetric.
Theorem 2.2.9. For an r-RN 𝒳 with IFP and holds unity 1 then 𝒳 has the strong IFP iff 𝒳 is a PSN.
Proof. By theorem 2.2.5, 𝒳 has a strong IFP.
⇔ By Proposition 9.2 of [9], for every ideal ℒ of 𝒳, ∀ p, k ∈ 𝒳, and pk ∈ ℒ implies prk ∈ ℒ ∀ r ∈ 𝒳
⇔ Every ideal of 𝒳 is a PSI of 𝒳
⇔ 𝒳 is a PSN.

2.3. s- WEAKLY REGULAR NEAR-RINGS

The notion of the s-weakly regular ring was first originated by V. Gupta [5] in 1984. Later, Dheena [3] introduced the concept of s-weakly regular near-rings. Recently, Abdullah M. Abdul-Jabbar [1] researched and developed some characteristics in s-weakly regular rings, by studying the above theories, we developed some results on s-weakly regular near-rings.
Definition 2.3.1. Let 𝒳 be designated as ***s - weakly regular*** **(s-WRN)** if for each *a* ∈ 𝒳, *a* = *xa*, for some *x* ∈ $< a^2 >$.
Example 2.3.2. Assume 𝒳 as a near-ring in Klein four group {0, a, b, c} with the operations '+'and '.' shown in table 8 & 9 mentioned below:

Table 8 Addition table

+	0	a	b	c
0	0	a	b	c
a	a	0	c	b
b	b	c	0	a
c	c	b	a	0

Table 9 Product table

.	0	a	b	c
0	0	0	0	0

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

The ideals and $\mathscr{H}$-subgroups of $\mathscr{H}$ are {0} and $\mathscr{H}$ itself. Then ($\mathscr{H}$, +, .) is an example for s-WRN.

Theorem 2.3.3: If a near-ring $\mathscr{H} \in \eta_0$ is an s-WRN, then $\mathscr{H}$ is reduced near-ring.

Proof: Suppose $q \in \mathscr{H}$ such that $q^2 = 0$.
Since $\mathscr{H}$ is s - weakly regular near-ring, then $q = xq$ for some $x \in < q^2 > = 0$.
So that $q = 0$.
Thus $q^2 = 0$ implies $q = 0$ for every q in $\mathscr{H}$.
Hence $\mathscr{H}$ is reduced.

THEOREM2.3.4: If a near-ring $\mathscr{H} \in \eta_0$ is s-WRN, then $\mathscr{H}$ has IFP.

Proof: Suppose $qb = 0$, $(bq)^2 = bqbq = b(qb)q = b0q = b0 = 0$.
By theorem 2.3.3, $\mathscr{H}$ is reduced so that $bq = 0$.
There fore if $qb = 0$ then $bq = 0$.
For all $n \in \mathscr{H}$, $(nb)q = n(bq) = n0 = 0 \Rightarrow qnb = q(nb) = 0$.
Therefore, $\mathscr{H}$ has IFP.

THEOREM 2.3.5: For a near-ring $\mathscr{H} \in \eta_0$ is s-WRN, $\mathscr{H}$ is simple iff $\mathscr{H}$ is integral.

Proof: Suppose $\mathscr{H}$ is simple.
Let $q, b \in \mathscr{H}$ and $qb = 0$ and $q \neq 0 \Rightarrow q \in (0{:}\ b)$.
By using theorems 2.3.3 and 2.3.4, we have $\mathscr{H}$ is reduced and has IFP. Therefore $(0{:}b)$ is a two-sided ideal.
Since by our supposition, $\mathscr{H}$ is simple, $(0{:}\ b) = \mathscr{H}$.
$b \in \mathscr{H} = (0{:}\ b) \Rightarrow b^2 = 0 \Rightarrow b = 0$.
Therefore, $\mathscr{H}$ is integral.
Conversely, suppose that $\mathscr{H}$ is integral.
Let $0 \neq I \trianglelefteq \mathscr{H}$, $q \neq 0$, $q \in I$.
$q = xq$, $x \in < q^2 > \subseteq < q > \subseteq I$.
$(1 - x)\, q = 0 \Rightarrow 1 - x = 0 \Rightarrow 1 = x \in I$.
Therefore $\mathscr{H} = I$.
Therefore, $\mathscr{H}$ is simple.

DEFINITION 2.3.6.[2]Let $\mathscr{H}$ is denoted as ***left quasi duo near-ring*** (in short, LQD) of $\mathscr{H}$ if every maximal left ideal(M-L-I) of $\mathscr{H}$ is a two-sided ideal.

THEOREM 2.3.7. If a near-ring $\mathscr{H}$ is a LQD having left unity, then $\mathscr{H}$ is s-WRN if and only if $\mathscr{H} = < q^2 >$ + (0: q) for every q $\in \mathscr{H}$.

Proof: Suppose $\mathscr{H}$ is **s-WRN**.
Then $q = xq$, $x \in < q^2 > \Rightarrow q \in < q^2 > q$.
$\mathscr{H}q \subseteq \mathscr{H} < q^2 > q \subseteq < q^2 > q$ and $< q^2 > q \subseteq < q > q \subseteq \mathscr{H}q$.
Therefore, $\mathscr{H}q = < q^2 > q$.
Assume that $\mathscr{H} \neq < q^2 > + (0{:}\ q)$.
Then there is a M-L-I $\mathscr{B}$ such that $< q^2 > + (0{:}\ q) \subseteq \mathscr{B}$.
By the definition of LQD, $\mathscr{B}$ is a two-sided ideal.
Since $q^2 \in \mathscr{B}$, $< q^2 > q \subseteq \mathscr{B}q \subseteq \mathscr{H}q = < q^2 > q$
There exists $f \in < q^2 >$ such that $(1 - f)\, q = 0$.
$\Rightarrow (1 - f) \in (0{:}\ q)$.
$1 = f + (1 - f) \in \mathscr{B}$. It is a contradiction.
Therefore $\mathscr{H} = < q^2 > + (0{:}\ q)$.
Conversely suppose that $\mathscr{H} = < q^2 > + (0{:}\ q)$.
Now, $1 \in \mathscr{H} = < q^2 > + (0{:}\ q) \Rightarrow 1 = t + l$, $t \in < q^2 >$, $l \in (0{:}\ q) \Rightarrow lq = 0$.
$q = 1q = (t + l)\, q = tq + lq \Rightarrow q = tq$, $t \in < q^2 >$.
Therefore, $\mathscr{H}$ is **s-WRN**.

Definition 2.3.8. Let $\mathscr{H}$ is designated to ***strongly reduced*** if $l \in \mathscr{H}$, $l^2 \in \mathscr{H}_c$ implies $l \in \mathscr{H}_c$.

Note 2.3.9. A near-ring $\mathscr{H}$ is ***strongly reduced near-ring*** if and only if for each element $a \in \mathscr{H}$ and any positive integer n, $a^n \in \mathscr{H}_c$ implies $a \in \mathscr{H}_c$

Theorem 2.3.10. For a near-ring $\mathscr{H} \in \eta_0$ be an s-WRN, then $\mathscr{H}$ is strongly reduced near-ring.

Proof: By definition of s-WRN, $l = xl$, $x \in < l^2 >$.
If $l^2 \in \mathscr{H}_c$ implies $< l^2 > \subseteq \mathscr{H}_c$.

$l = xl$, $x \in < l^2 > \subseteq \mathscr{H}_c$.
$l \in \mathscr{H}_c \mathscr{H} \subseteq \mathscr{H}_c \Rightarrow l \in \mathscr{H}_c$.
Therefore, $\mathscr{H}$ is strongly reduced near-ring.

3. CONCLUSIONS

In this article, we developed some characteristics on r-RN and in generalized strongly regular near-rings

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