We present some properties of the groups with the infinite non-quasicentral periodic nodal subgroup. Our main results are formulated in Theorem 1, 2 and Theorem 3, 4. 2000 Mathematics Subject Classification: 20F22, 20F25

Keywords: A group, a subgroup, a commutator of a group, a locally graded group, p-quasicyclic group, a direct and semi-direct product of groups, an extension of a group.

The description of groups defined by the systems of their subgroups was first described in the papers of Chernikov and Kurosh (RN – groups, [1]). Chernikov dealt with an extension of the direct product of the finite number of the quasicyclic groups by the finite abelian group (ч – groups, [2]). Tomanek. L. studied the IAN and the IANA groups, Definition 1, (IAN groups, [4]). This definition was given to the author by Chernikov. In this paper we describe IAN and IANA groups with the infinite non-quasicentral periodic nodal subgroup.

We use standard designations of terminology where: \( M \times N \) is the direct product of the groups \( M, N \), \( \sum_{i} x_i \) is the sum of the additive groups \( X_i \) for all \( i \in I, M, N \) is the semi-direct product of the groups \( M, N, M \sqcup N = \{mn | m \in M, n \in N \} \) is the product of the groups \( M, N, G/A \) is the factor group of \( G \) by \( A, |G:N| \) is the index of the subgroup \( N \) in a group \( G \), \( \langle a \rangle \) is the cyclic group generated by the element \( a \), \( < a, b, c> \) is the group generated by the elements \( a, b, c \), \( H \sqsupseteq G \) is the subgroup of \( G, H \triangleleft G \), \( H \) is normal in \( G \), \( [a,b] = a^{-1} b^{-1} ab \) is the commutator of the elements \( a, b \in G \), \( G = \langle G, G \rangle \) generated by all commutators of the elements \( a, b \in G \), \( \langle x^\sigma = 1, n = 1, 2, 3, \ldots \rangle \) is the \( p \)-quasicyclic group; \( C_{(A)} \) is the centralizer of the subgroup \( A \) in \( G \); \( C(G) \) is the centre of the group \( G \); \( G \triangleleft H \) where the groups \( G, H \) are isomorphic. The group \( G \) is the \( p \)-group if each of its elements has an order with a power of some fixed prime \( p \) [6].

Definition 1.

An infinite non-abelian \( G \) is said to be the IAN group if there exists a subgroup \( A \) of \( G \) so that every infinite subgroup of \( A \) and every infinite subgroup of \( G \) containing \( A \) is a normal subgroup of \( G \). The group \( G \) is the INH group if \( A \) is the abelian subgroup. The subgroup \( A \) is called the nodal subgroup.

Definition 2.

An infinite non-abelian \( G \) is the INH group if an arbitrary infinite subgroup of \( G \) is the normal subgroup of \( G \).

Definition 3.

The group \( G \) is the Dedekind group if an arbitrary subgroup of \( G \) is the normal subgroup of \( G \). Non-abelian Dedekind group \( G \) is called the Hamiltonian group.

Proposition 1. [2], T. 6.10

The infinite Hamiltonian groups and the non-abelian non-Hamiltonian groups that are the finite extensions of the quasicyclic...
subgroups by the finite abelian and the finite Hamiltonian groups form the class of the solvable INH groups.

**Proposition 2.** ([7], T.12.5.4)

The group $G$ is the Hamiltonian group if and only if the group $G=Q_i \times M \times N$ where $Q_i$ is the quaternion group, $M$ is an elementary abelian 2-group, $N$ is a periodic abelian group with no elements of the order 2.

**Lemma 1.**

Let $G$ be the IAN group with a nodal subgroup $A$. If a nodal subgroup $A$ contains the element of the infinite order, then $A$ is the abelian quasicentral subgroup of group $G$.

**Proof.** If the group $A$ contains the element $x$ of the infinite order, then according to Definition 2, the group $A$ is the INH group. According to Proposition 1 $A$ is the abelian group. Let $B$ be an arbitrary subgroup of the group $A$. We shall show that $B \leq G$. If $B$ is an infinite subgroup of $G$, $B$ is admittedly a normal subgroup of $G$.

Let $B$ be a finite subgroup of $G$. If $A$ is the abelian group containing the element $x$ of the infinite order, then $B \leq B \leq B \leq G$. Pursuant to Definition 1 $(B \leq G)$ which implies $B \leq G$. Thus $A$ is the abelian quasicentral subgroup of the group $G$. $\blacksquare$

**Lemma 2.**

If $G$ is the locally graded IAN group with the nodal subgroup $A$, there exists a subgroup of $A$ that is not a normal subgroup of $G$. Then $A$ is a finite group or $A$ is the extension of the quasicyclic subgroup by the finite Dedekind group.

**Proof.** Let $G$ be the IAN group with a nodal subgroup $A$ and let $A \leq \varphi$ where $A$ is not a normal subgroup of $G$. Admittedly, $A = \varphi$ is a finite subgroup of $G$. In agreement with Lemma 1 $A$ is a periodic group. If $A$ is a finite group, then this lemma is valid. Let $A$ be an infinite periodic subgroup of $G$. We consider two possible cases: $A$ is not a group, or $A$ is a group.

Case 1. Let $A$ not be a group. Then choose the subgroup $A_1$ of $A$, where $A_1 = \varphi \cdot A_1 \cdot A_1 \cdot A_1 = \varphi$, and where $A_1 \cdot A_1$ are the infinite cyclic groups of $G$. By Definition 1, $A \leq G$, $A \leq A \leq G$, $A \leq G$. Evidently $(A \leq A) \leq (A \leq A)$, and furthermore $A \leq G$, so it is a contradiction.

Case 2. Let $A$ be a group. Then put $A=\{R, B\}$ where $R$ is the direct product of the finite number of the quasicyclic groups, $R$ is at the same time a divisible group, and $B$ is a finite group where $B \leq \varphi$. Therefore, $A$ is not a normal subgroup of $G$; there exists a cyclic subgroup $\varphi$ of $A$ that is not normal in $G$ and where $R \leq \varphi$. Since $R$ is a divisible group, there exists a quasicyclic subgroup $R_1$ of $R$ and furthermore $R_1$ contains the subgroup $\varphi$. Let $R_1 = \varphi$, where $R_1$ is an infinite subgroup of $A$ or $R_1 \leq \varphi$. If $R_1$ is an infinite subgroup of $A$, then by Definition 1 $R_1 \leq G$, furthermore $(R_1 \leq \varphi) \leq G$, $(R_1 \leq \varphi) \leq G$. Evidently $(R_1 \leq \varphi) \leq (R_1 \leq \varphi)$ and $\leq \varphi \leq G$. This is a contradiction.

Let $R_1 = \varphi$, then $R_1 = R_1$, is a quasicyclic group and moreover $A/R_1 = B$ where $B$ is a finite Dedekind group. Thus $A$ is the extension of the quasicyclic subgroup by the finite Dedekind group. $\blacksquare$

**Theorem 1.**

If $G$ is a locally graded IAN group with a nodal subgroup $A$, then subgroup $A$ belongs to one of the types:

1. $A$ is a finite subgroup of $G$;
2. $A$ is an extension of the quasicyclic subgroup by a finite Dedekind group where $G$ is an infinite group;
3. $A$ is an infinite quasicentral periodic subgroup of $G$;
4. $A$ is a quasicentral non-periodic abelian subgroup of $G$.

**Proof.** If $A$ is not a quasicentral subgroup of $G$, then, based on Lemma 2, the subgroup $A$ belongs to one of types 1 or 2 of this theorem. If $A$ is a quasicentral subgroup of $G$, then by Lemma 1 the subgroup $A$ belongs to one of the types 3 or 4 of this theorem. $\blacksquare$

By Theorem 1 and according to the definition of IANA groups the next corollary follows.

**Corollary 1.**

If $G$ is a locally graded IAN group with a nodal subgroup $A$, then subgroup $A$ belongs to one of the types:

1. $A$ is a finite abelian subgroup of $G$;
2. $A = \mathbb{Z}(p\infty)$, where $B$ is a finite group;
3. $A$ is an infinite quasicentral periodic abelian subgroup of $G$;
4. $A$ is a quasicentral non-periodic abelian subgroup of $G$.

**Lemma 3.**

If $G$ is the locally graded group with the infinite periodic nodal subgroup $A$, then the subgroup $A$ satisfies one of the following conditions:

1. $A$ is the infinite periodic Dedekind quasicentral subgroup of the group $G$ where $G/A$ is the abelian group;
2. $A$ is the infinite periodic Dedekind quasicentral subgroup of the group $G$ where $G/A$ is the Hamiltonian group and $G$ is a locally finite group;
3. $A$ is not the quasicentral subgroup of $G$, $A$ is an almost quasicyclic subgroup of $G$ where $G/A$ is the Dedekind group.

**Proof.** If $G$ is the locally graded group with an infinite periodic nodal subgroup $A$, then, according to Theorem 1 $A$ is the extension of the quasicyclic subgroup by the finite Dedekind group, or $A$ is the quasicentral subgroup of the group $G$.

Let $A$ be the extension of the quasicyclic subgroup $B$ by the finite Dedekind group. If $B$ is an infinite subgroup of $G$, containing $A$, then $B \leq G$ and furthermore every quotient subgroup
Since $G/A$ is the Dedekind group, $A$ then satisfies the 3rd condition of this lemma.

If $A$ is a quasicyclic subgroup of group $G$, then, analogous to the paragraph above, we can prove that $G/A$ is the Dedekind group. Admittedly, $G/A$ is the abelian or the Hamiltonian group.

Let $G/A$ be the Hamiltonian group. By Proposition 2 $G/A$ is a locally finite group. Thus an extension of a locally finite group by a locally finite group is a locally finite group, which implies that $G$ is a locally finite group and hence $A$ satisfies the 2nd condition of this lemma.

Let $G/A$ be the Hamiltonian group. By Proposition 2 $G/A$ is an almost quasicyclic group which contains the finite non-quasicentral subgroup $A$ of $G$ if and only if it satisfies one of the following conditions:

1. $A$ is a finite non-quasicentral subgroup of $G$ if and only if $A$ is the abelian group.
2. $A$ is an almost quasicyclic group.

Proof. Let $G$ be the locally graded $IAN$ group with the infinite nodal subgroup $A$ non-quasicentral of $G$, then $A$ is the extension of a quasicyclic group by the Dedekind group.

Lemma 4.

If $G$ is the locally graded $IAN$ group with the infinite nodal subgroup $A$ non-quasicentral of $G$, then $A$ is the extension of a quasicyclic group by the Dedekind group.

Proof. Let $G$ be the locally graded $IAN$ group with the infinite nodal subgroup $A$ non-quasicentral of $G$. According to Theorem 1 $A$ is a periodic group, by Lemma 3 $A$ is the extension of a quasicyclic group by the Dedekind group.

Lemma 5.

If $G$ is the group with a finite nodal subgroup $A$, then $G/A$ is the abelian group, or the group.

Proof. If $G/A$ is the abelian group, then this lemma is valid. Let $G/A$ be a non-abelian group and $B/A$ be an arbitrary infinite subgroup of $G$. There evidently exists $B\leq G$ and furthermore $B/A\leq G/A$. Thus $G/A$ is the INH group.

Theorem 2.

Let $G$ be the locally graded $IAN$ group with a nodal subgroup $A$. The nodal subgroup $A$ of $G$ is a non-quasicentral of $G$ if and only if it satisfies one of the following conditions:

1. $A$ is a finite non-quasicentral subgroup of $G$, the quotient group $G/A$ is the INH group with the abelian commutator or $G/A$ is the abelian group.
2. $A$ is an almost quasicyclic group which contains the finite subgroups that are not normal in $G$, $|A:A\cap G|<\infty$, and $G/A$ is the Dedekind group.

Proof. Let $G$ be the locally graded $IAN$ group with the infinite nodal subgroup $A$. According to Lemma 5, $G/A$ is the abelian group or $G/A$ is a solvable INH group. According to Proposition 1 the commutator of a solvable INH group is the abelian group. Thus the subgroup $A$ satisfies the 1st condition of this theorem.

Let $G/A$ be a solvable INH group. By the condition 3 of Lemma 3 $G/A$ is the Dedekind group. Based on this fact $A$ is an almost quasicyclic group and by Definition 1 $A$ is a non-quasicentral of $G$. Suppose there exists a finite subgroup and $A$ is normal in $G$. Therefore $G/A$ is the Dedekind group. $A$ is an almost quasicyclic group, thus $G'$ is a subgroup of that almost quasicyclic subgroup $A, G'$. Let $G'$ be a finite group and put $A=G'$. Hence $A$ satisfies either condition 1 or condition 2 of this theorem.

If $G'$ is an infinite group, then $|A.G':A|<\infty, |A.A.G':A|<\infty$, too. Admittedly, $A$ satisfies the 2nd condition of this theorem.

Conversely. Suppose the nodal subgroup $A$ satisfies either condition 1 or condition 2 of this theorem, then $G$ is the $IAN$ group with the non-quasicentral nodal subgroup $A$.

By Theorem 2 and the definition of IANA groups the next corollary follows.

Corollary 2.

Let $G$ be a locally graded $IANA$ group with a nodal subgroup $A$. The nodal subgroup $A$ of $G$ is a non-quasicentral of $G$ if and only if it satisfies one of the following conditions:

1. $A$ is the finite abelian non-quasicentral subgroup of $G$ if and only if $A$ is the Dedekind group.
2. $A$ is the finite abelian non-quasicentral subgroup of $G$.

Proof. Let $G$ be the locally graded $IANA$ group with the infinite non-quasicentral Dedekind nodal subgroup $A$. Then $A=Z(p^{\infty})\times D$ where $D$ is the finite abelian subgroup of $G$. $A$ contains finite subgroups that are not normal in $G$, and $G/A$ is the Dedekind group.

Lemma 6.

Let $G$ be the $IAN$ group with the infinite non-quasicentral Dedekind nodal subgroup $A$. Then $A=Z(p^{\infty})\times D$ where $D$ is a finite Dedekind group, $p\mid |D|$, and there exists the element $a\in A$ so that the subgroup $\langle a \rangle$ is not normal $p$-subgroup of $G$. For $p=2$ is $D'=\langle e \rangle$.

Proof. Let $G$ be the $IAN$ group with the infinite non-quasicentral Dedekind nodal subgroup $A$. By Lemma 1 $A$ is an almost quasicyclic group. Pursuant to Proposition 2 $A=Z(p^{\infty})\times D$ where $D$ is a finite Dedekind group, $p\mid |D|$, and $D'=\langle e \rangle$. We shall prove that $A$ does not contain a normal $p$-group $\langle a \rangle$ of $G$.

Obviously, if every cyclic subgroup of $A$ is a normal subgroup of $G$, then $A$ is a quasicentral subgroup of $G$. Thus there exists a cyclic subgroup $\langle x \rangle$ of $A$ that is not normal in $G$, which implies that the $\langle x \rangle$ Sylow $q$-subgroup of the group $\langle x \rangle$ is not normal in $G$. This verifies that $q=p$.

Let $q=p$ and $Z(p^{\infty})\langle a \rangle=\langle e \rangle$. Then $Z(p^{\infty})\langle a \rangle=Z(p^{\infty})\langle a \rangle$ where $Z(p^{\infty})\langle a \rangle$ is the normal subgroup of $G$. Evidently, $\langle a \rangle$ is the Sylow $q$-subgroup normal in $Z(p^{\infty})\langle a \rangle$ and $\langle a \rangle$ is normal in $G$. This is a contradiction, thus $q=p$.

If $A=Z(p^{\infty})\times D$ then $Z(p^{\infty})\langle a \rangle=Z(p^{\infty})\langle b \rangle$, $\langle a \rangle=\langle e \rangle$, $\langle b \rangle$ is a normal $p$-subgroup of $G$. Because the subgroup $\langle a \rangle$ is the $p$-subgroup...
normal in $G$ and furthermore $Z(p^\infty) \cap \langle a \rangle < \langle a \rangle \cdot |b| > 1$, it is a $p$-group, therefore $p \mid |D|$.

According to Lemma 6 and the Definition of IANA groups, the next corollary follows.

**Corollary 3.**

Let $G$ be the IANA group with the infinite non-quasicentral nodal subgroup $A$. Then $A = Z(p^\infty) \cdot D$, where $D$ is a finite group, $p \mid |D|$, the subgroup $D$ contains an element $a$ so that the $\langle a \rangle \cdot p$-subgroup is not normal in $G$.

**Theorem 3.**

The group $G$ is the locally graded IAN group with the infinite non-quasicentral nodal subgroup $A$ of $G$ if and only if a quotient group $G/A$ is the Dedekind group, $|A : A \cap G| < a$ and the non-quasicentral nodal subgroup $A$ is an$A$ group. Then $A = Z(p^\infty) \cdot D$, where $D$ is a finite group, the next corollary follows.

1. $A = Z(p^\infty) \cdot D$, where $D$ is the finite Dedekind group, $p \equiv 2$, $D = \langle a \rangle$. The subgroup $A$ contains an element $a$ such that the $\langle a \rangle \cdot p$-subgroup is not normal in $G$, and the quotient group $A/Z(p^\infty)$ is the quasicentral in $G/Z(p^\infty)$.
2. $A = Z(p^\infty) \cdot D$, where $D$ is the finite Dedekind subgroup, the group $A$ does not contain the normal subgroup of $G$, and $A/Z(p^\infty)$ is the quasicentral in $G/Z(p^\infty)$.
3. $A = Z(p^\infty) \cdot D$, where $Z(p^\infty) \cdot B$ is the non-abelian Sylow $p$-subgroup of $G$, $D$ is the infinite Dedekind group, $p \equiv 2$, $D = \langle a \rangle$. The finite group $D$ has a normal series: $Z(p^\infty) \cap B = \langle B' \rangle$, for all $i \geq 1$, $|b_i| = 2$, $|B_i| = 2$ and $A/Z(p^\infty)$ is the quasicentral in $G/Z(p^\infty)$.
4. $A = Z(p^\infty) \cdot B \cdot Q \cdot D$, where $Z(p^\infty) \cdot B \cdot Q$ is the Sylow $2$-subgroup of $G$, $D$ is the finite Dedekind group, $Z(p^\infty) \subseteq C(G)$, the finite group $D$ has a normal series: $Z(p^\infty) \cap B = \langle B' \rangle$, for all $i \geq 1$, $|B_i| = 2$, $|B_i| = 2$ and $A/Z(p^\infty)$ is the quasicentral in $G/Z(p^\infty)$.
5. $A = (Z(p^\infty) \cdot B \cdot Q \cdot D$, where $Z(p^\infty) \cdot B \cdot Q$ is the Sylow $2$-subgroup of $G$, $D$ is the finite Dedekind group, $Z(p^\infty) \subseteq C(Z(p^\infty) \cdot B)$, for each $c \in Z(p^\infty)$, $d \cdot c \cdot d^{-1}$, the finite group $D$ has a normal series: $Z(p^\infty) \cap B = \langle B' \rangle$, $B = \langle B' \rangle$, $B = \langle B' \rangle$, for all $i \geq 1$, $|b_i| = 2$, $|B_i| = 2$ and $A/Z(p^\infty)$ is the quasicentral in $G/Z(p^\infty)$.
6. $A = ((Z(p^\infty) \cdot B \cdot Q \cdot D \cdot A)$, where $Z(p^\infty) \cdot B \cdot Q \cdot D$ is the Sylow $2$-subgroup of $G$, $D$ is the finite Dedekind group, $Z(p^\infty) \subseteq C(Z(p^\infty) \cdot B)$, for each $c \in Z(p^\infty)$, $d \cdot c \cdot d^{-1}$, the finite group $D$ has a normal series: $Z(p^\infty) \cap B = \langle B' \rangle$, $B = \langle B' \rangle$, $B = \langle B' \rangle$, for all $i \geq 1$, $|b_i| = 2$, $|B_i| = 2$ and $A/Z(p^\infty)$ is the quasicentral in $G/Z(p^\infty)$.
7. $A = ((Z(p^\infty) \cdot B \cdot Q \cdot D \cdot A)$, where $Z(p^\infty) \cdot B \cdot Q \cdot D$ is the Sylow $2$-subgroup of $G$, $D$ is the finite Dedekind group, $Z(p^\infty) \subseteq C(Z(p^\infty) \cdot B)$, $Z(p^\infty) \cdot Q \cdot A$ is the quasicentral in $G/Z(p^\infty)$.

**Proof.** Let $G$ be the locally graded IAN group with the infinite non-quasicentral nodal subgroup $A$ of $G$. By Theorem 1 $A$ is an almost quasicyclic group containing the finite subgroups that are not normal in $G$, $A : A'G \leq \langle a \rangle$, and $G/A$ is the Dedekind group. The above mentioned implies that $A$ contains a subgroup $Z(p^\infty)$ which is normal in $G$, $A/Z(p^\infty)$ is the finite Dedekind group and furthermore $Z(p^\infty) \subseteq B \cdot A$ is the infinite subgroup of $B$. Admittedly, $B$ is normal in $G$ and the factor group $A/Z(p^\infty)$ is the quasicentral subgroup of $G/Z(p^\infty)$. According to Theorem 3.1 [8] the subgroup $A$ satisfies the conditions of this theorem. Evidently, $A$ is the group of one of types 1 to 8 of this theorem.

If $A$ is a group of the type 1 of Theorem 3.1 [8], then $A$ is the Dedekind group, $A = Z(p^\infty) \cdot D$ where $D$ is the finite Dedekind group, $p \equiv 2$, and $D = \langle a \rangle$. By Lemma 6 $p \mid |D|$, the subgroup $A$ contains element $a$ so that a subgroup $\langle a \rangle$ is normal in $G$. Thus $A$ is of the type 1 of this theorem.

If $A$ is a group of one of the types 2 - 8 of Theorem 3.1 [8], then $A$ is a subgroup of one of the types 2 - 8 of this theorem. Conversely, if $G$ is a group with the normal subgroup $A$ of one of the types 1 - 8 of this theorem, then $G/A$ is the Dedekind group. $G$ is evidently the locally graded group. Because $G/A$ is the Dedekind group and $A/Z(p^\infty)$ is the quasicentral subgroup of $G/Z(p^\infty)$, then any infinite subgroup contained in $A$ and any subgroup which contains a subgroup $A$ is normal in $G$. Thus $G$ is the IAN group.

Let $A$ be an infinite subgroup of $G$. If the subgroup $A$ is of the type 1 of this theorem, then the subgroup $A$ contains a subgroup $\langle a \rangle$ that is normal in $G$. Thus the subgroup $A$ is non-quasicentral subgroup of $G$

Thus the quasicentral subgroups of the group $G$ are the Dedekind groups, which implies $A$ is a group of one of the types 2 - 8 of this theorem. Thus $A$ is the non-Dedekind group, which implies that the subgroup $A$ of one of the types 2 - 8 is a non-quasicentral subgroup of $G$. ■
Theorem 4.

The group $G$ is the IANA group with an infinite non-quasicentral nodal subgroup $A$, if and only if $A=Z(p^{\infty})\times D$, where $D$ is a finite group, $p \mid |D|$, the subgroup $A$ contains an element $a$ so that $<a>$ $p$-subgroup is not normal in $G$, and $A/Z(p^{\infty})$ is the quasicentral in $G/Z(p^{\infty})$.

Proof. Let $G$ be the locally graded IAN group with the infinite non-quasicentral nodal subgroup $A$ of $G$, and $A'=<e>$. Because $G/A$ is the Dedekind group, $A=Z(p^{\infty})\times D$, where $D$ is the finite abelian group, $A$ contains the finite subgroups that are not normal in $G$, and $G/A$ is the Dedekind group. The group $G$ is evidently the locally graded IAN group with the nodal subgroup $A$ of the type 1 of Theorem 2, $p \mid |D|$, the subgroup $A$ contains an element $a$ so that $<a>$ $p$-subgroup is not normal in $G$, and $A/Z(p^{\infty})$ is the quasicentral in $G/Z(p^{\infty})$.

Conversely. Suppose that $A \trianglelefteq G$ where $A$ is an almost quasicyclic group. Since $A/Z(p^{\infty})$ is a quasicentral in $G/Z(p^{\infty})$, then $B/Z(p^{\infty}) \trianglelefteq G/Z(p^{\infty})$ for all $B/Z(p^{\infty}) < A/Z(p^{\infty})$. Hence $B \trianglelefteq G$, $A$ is the abelian subgroup, every infinite subgroup of $A$ and every infinite subgroup of $G$ containing $A$ is a normal subgroup of $G$. By Definition 1 the group $G$ is the IAN group. Hence the subgroup $A$ contains the subgroup that is not normal in $G$, then $A$ is the non-quasicentral in $G$. □

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