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New Class of αg*p-Continuous Functions in Topological Spaces

Research Article

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Abstract: The aim of this paper is to introduce and study the new class of functions namely αg*p-totally continuous functions and totally αg*p-continuous functions. Further the relationship between this new class with other classes of existing functions are established.Also strongly (αg*p)*-continuous functions in topological spaces are introduced and studied.

MSC: 54C10.

Keywords: αg*p-totally continuous function, totally αg*p-continuous function, strongly (αg*p)*-continuous function, αg*p-co-Hausdorff space.

1. Introduction

In 1980, Jain [2] introduced the concept of totally continuous functions. T. M. Nour [9] introduced the concept of totally semi-continuous functions as a generalization of totally continuous functions and several properties of totally semi-continuous functions were obtained. Benchalli et al. [1] introduced and studied semi-totally continuous and semi-totally open functions. Veerakumar [14] introduced totally pre-continuous and strongly pre-continuous functions as alternative stronger forms of totally continuous functions and strongly continuous functions respectively. In this paper, we introduce a new class of continuous functions called αg*p-totally continuous functions and totally αg*p-continuous functions and investigate some of their fundamental properties. Also we define strongly (αg*p)*-continuous functions in topological spaces.

Throughout this paper, the spaces X ,Y and Z always mean topological spaces (X, τ), (Y, σ) and (Z, η) respectively. For a subset A of X, the closure and the interior of A in X are denoted by cl(A) and int(A) respectively. The union of all preopen sets of X contained in A is called pre-interior of A and it is denoted by pint(A). The intersection of all preclosed sets of X containing A is called pre-closure of A and it is denoted by pcl(A). Also the collection of all αg*p-open subsets of X is denoted by αg*p-O(X).

2. Preliminaries

We recall the following definitions and notations, which are useful in the sequel.

Definition 2.1. *A subset A of a topological space (X, τ) is called*

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(1). preopen [7] if $A \subseteq int\ (cl\ (A))$ and preclosed if $cl\ (int(A)) \subseteq A$.

(2). α-open [8] if $A \subseteq int\ (cl\ (int\ (A)))$ and α-closed if $cl(int(cl(A))) \subseteq A$.

Definition 2.2. *A subset A of a topological space (X, τ) is called*

(1). generalized closed (briefly, g-closed) [4] if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.

(2). α-generalized closed(briefly, αg-closed) [5] if $\alpha\ cl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.

(3). generalized preclosed (briefly, gp-closed) [6] if $pcl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.

(4). generalized star preclosed (briefly, g^*p-closed set) [13] if $pcl\ (A) \subseteq U$ whenever $A \subseteq U$ and U is g-open in X.

(5). generalized pre star closed (briefly gp^*-closed set) [3] if $cl\ (A) \subseteq U$ whenever $A \subseteq U$ and U is gp-open in X.

(6). α-generalized star closed (briefly, αg^*-closed set) if $\alpha cl\ (A) \subseteq U$ whenever $A \subseteq U$ and U is αg-open in X.

Definition 2.3 ([12]). *A subset A of a topological space (X, τ) is called alpha generalized star preclosed set (briefly, αg^*p-closed) if $pcl(A) \subseteq U$ whenever $A \subseteq U$ and U is αg-open in X.*

Definition 2.4 ([10]). *For a subset A of (X, τ), the intersection of all αg^*p-closed sets containing A is called the αg^*p-closure of A and is denoted by αg^*p-$cl(A)$. That is, $\alpha g^*p\text{-}cl(A) = \cap\{F : F$ is αg^*p-closed in X , $A \subseteq F\}$.*

Definition 2.5. *A function $f : (X, \tau) \to (Y, \sigma)$ is called*

(1). totally continuous [2] if $f^{-1}(V)$ is clopen in X for each open set V of Y.

(2). totally pre-continuous [14] at each point of X if for each open subset V in Y containing $f(x)$, there exists a pre-clopen subset U in X containing x such that $f(U) \subset V$.

Definition 2.6 ([10]). *A subset A of a topological space (X, τ) is called*

(1). αg^*p-continuous if $f^{-1}(V)$ is αg^*p-closed in (X, τ) for every closed set V in (Y, σ).

(2). αg^*p-irresolute if $f^{-1}(V)$ is αg^*p-closed in (X, τ) for every αg^*p-closed set V in (Y, σ).

(3). αg^*p-closed if $f(V)$ is αg^*p-closed in (Y, σ) for every αg^*p-closed set V in (X, τ).

(4). αg^*p-open if $f(V)$ is αg^*p-open in (Y, σ) for every αg^*p-open set V in (X, τ).

Definition 2.7 ([11]). *A topological space X is said to be αg^*p-connected if X cannot be written as the disjoint union of two non empty αg^*p-open sets in X.*

Definition 2.8 ([10]). *A space (X, τ) is called*

(1). an αg^*p-space if every αg^*p-closed set is closed.

(2). a $T_{\alpha g*p}$-space if every αg^*p-closed set is preclosed.

Definition 2.9 ([15]). *A space X is said to be*

(1). T_1 if for every pair of distinct points x and y in X there exist open sets U and V such that $x \in U$ but $y \notin U$ and $y \in V$ but $x \notin V$.

(2). T_2 if for each distinct points x, y in X, there exist two disjoint open sets U and V containing x and y respectively.

3. αg*p-totally Continuous Functions

In this section we define αg*p-totally continuous function and investigate their fundamental properties

Definition 3.1. *A function $f : (X, \tau) \to (Y, \sigma)$ is said to be αg*p-totally continuous function if the inverse image of every αg*p-open set of Y is clopen in X.*

Theorem 3.2. *A bijective function $f : (X, \tau) \to (Y, \sigma)$ is αg*p-totally continuous function if and only if the inverse image of every αg*p-closed subset of Y is clopen in X.*

Proof. Let F be any αg*p-closed set in Y. Then Y \ F is a αg*p-open set in Y. By definition, f^{-1}(Y\ F) is clopen in X. That is, X \ $f^{-1}(F)$ is clopen in X. This implies $f^{-1}(F)$ is clopen in X.
Conversely if V is αg*p-open in Y then Y \ V is αg*p-closed in Y. By assumption, f^{-1}(Y \ V) = X \ $f^{-1}(V)$ is clopen in X, which implies $f^{-1}(V)$ is clopen in X. Therefore f is αg*p-totally continuous function. □

Theorem 3.3.

*(1). Every αg*p-totally continuous function is totally continuous.*

*(2). Every totally continuous function is αg*p-continuous.*

Proof.

(1). Let U be any open subset of Y. Since every open set is αg*p-open, U is αg*p-open in Y and $f : (X, \tau) \to (Y, \sigma)$ is αg*p-totally continuous, it follows that $f^{-1}(U)$ is clopen in X.

(2). Obvious.

□

Remark 3.4. *The converse of Theorem 3.3 is not true, which can be verified from the following examples.*

Example 3.5. *Let $X = Y = \{a, b, c, d\}$, $\tau = \{X, \phi, \{a, b\}, \{c, d\}\}$ and $\sigma = \{Y, \phi, \{a, b\}\}$. αg*p-O(Y) = $\{Y, \phi, \{a\}, \{b\}, \{c\}, \{d\}, \{a, c\}, \{a, d\}, \{b, c\}, \{b, d\}, \{c, d\}, \{a, c, d\}, \{b, c, d\}\}$. Define a function $f : X \to Y$ by $f(a) = c$, $f(b) = d$, $f(c) = a$, $f(d) = b$. Then f is totally continuous but f is not αg*p-totally continuous , since $f^{-1}(\{a, c\}) = \{a, c\}$ is not clopen in X .*

Example 3.6. *Let $X = Y = \{a, b, c, d\}$, $\tau = \{X, \phi, \{a\}, \{b\}, \{a, b\}\}$ and $\sigma = \{Y, \phi, \{d\}, \{c, d\}, \{a, c, d\}, \{b, c, d\}\}$. αg*p-C(X) = $\{X, \phi, \{c\}, \{d\}, \{c, d\}, \{a, c, d\}, \{b, c, d\}\}$. Define $f : X \to Y$ by $f(a) = c$, $f(b) = d$, $f(c) = a$, $f(d) = b$. Then f is αg*p-continuous but f is not totally continuous , since $f^{-1}(\{d\}) = \{b\}$ is not clopen in X.*

Theorem 3.7. *Let $f : (X, \tau) \to (Y, \sigma)$ be a function, where X and Y are topological spaces. Then the following are equivalent:*

*(1). f is αg*p-totally continuous.*

*(2). For each $x \in X$ and each αg*p-open set V in Y with $f(x) \in V$, there is a clopen set U in X such that $x \in U$ and $f(U) \subset V$.*

Proof. (1)⇒(2) Suppose f is αg*p-totally continuous and let V be any αg*p-open set in Y containing $f(x)$ such that $x \in f^{-1}(V)$. Since f is αg*p-totally continuous, $f^{-1}(V)$ is clopen in X. Let $U = f^{-1}(V)$ then U is a clopen set in X and $x \in U$. Also $f(U) = f(f^{-1}(V)) \subset V$. This implies $f(U) \subset V$.

(2)⇒(1) Let V be a αg*p-open set in Y. Let $x \in f^{-1}(V)$ be any arbitrary point. This implies $f(x) \in V$. Therefore by (2) there is a clopen set G_x containing x such that $f(G_x) \subset V$, which implies $G_x \subset f^{-1}(V)$ is a clopen neighbourhood of x. Since x is arbitrary, it implies $f^{-1}(V)$ is a clopen neighbourhood of each of its points. Hence it is a clopen set in X. Therefore f is αg*p-totally continuous. □

Definition 3.8. *For a function $f : (X,\tau) \to (Y,\sigma)$, the subset $\{(x, f(x)) : x \in X\} \subset X \times Y$ is called the graph of f and is denoted by G(f).*

Theorem 3.9. *A function $f : (X,\tau) \to (Y,\sigma)$ is αg*p-totally continuous, if its graph function is αg*p-totally continuous.*

Proof. Let $g : X \to X \times Y$ be a graph function of $f : X \to Y$. Suppose g is αg*p-totally continuous and F be αg*p-open in Y, then $X \times F$ is a αg*p-open set of $X \times Y$. Since f is αg*p-totally continuous, $g^{-1}(X \times F) = f^{-1}(F)$ is clopen in X. Thus the inverse image of every αg*p-open set in Y is clopen in X. Therefore g is αg*p-totally continuous. □

Theorem 3.10. *If $f : (X,\tau) \to (Y,\sigma)$ is αg*p-totally continuous surjection and X is connected then Y is αg*p-connected.*

Proof. Suppose Y is not αg*p-connected, let A and B form a disconnection of Y. Then A and B are αg*p-open sets in Y and $Y = A \cup B$ where $A \cap B = \phi$. Also $f^{-1}(Y) = X = f^{-1}(A) \cup f^{-1}(B)$, where $f^{-1}(A)$ and $f^{-1}(B)$ are non empty clopen sets in X, because f is αg*p-totally continuous. Further, $f^{-1}(A) \cap f^{-1}(B) = f^{-1}(\phi) = \phi$. This implies X is not connected, which is a contradiction. Hence Y is αg*p-connected. □

Theorem 3.11. *If a function $f : (X,\tau) \to (Y,\sigma)$ is totally continuous and Y is a αg*p-space then f is αg*p-totally continuous.*

Proof. Let V be αg*p-open in Y. Since Y is a αg*p-space, V is open in Y. Also as f is totally continuous, $f^{-1}(V)$ is open and closed in X. Hence $f^{-1}(V)$ is clopen in X. Therefore f is αg*p-totally continuous. □

Theorem 3.12.

*(1). If $f : X \to Y$ and $g : Y \to Z$ are αg*p-totally continuous, then $g \circ f : X \to Z$ is also αg*p-totally continuous.*

*(2). If $f : X \to Y$ is αg*p-totally continuous and $g : Y \to Z$ is αg*p-continuous, then $g \circ f : X \to Z$ is totally continuous.*

Theorem 3.13. *Let $f : X \to Y$ be a αg*p-open map and $g : Y \to Z$ be any function. If $g \circ f : X \to Z$ is αg*p-totally continuous, then g is αg*p-irresolute.*

Proof. Let $g \circ f : X \to Z$ be αg*p-totally continuous. Let V be αg*p-open set in Z. Since $g \circ f$ is αg*p-totally continuous, $(g \circ f)^{-1}(V) = f^{-1}(g^{-1}(V))$ is clopen in X. Since f is αg*p-open, $f(f^{-1}(g^{-1}(V)))$ is αg*p-open in Y. Then $g^{-1}(V)$ is αg*p-open in Y. Hence g is αg*p-irresolute. □

Theorem 3.14. *Let $f : X \to Y$ be αg*p-totally continuous and $g : Y \to Z$ be any function, then $g \circ f : X \to Z$ is αg*p-totally continuous if and only if g is αg*p-irresolute.*

Proof. Let V be a αg*p-open subset of Z. Then $g^{-1}(V)$ is αg*p-open in Y as g is αg*p-irresolute. Then $f^{-1}(g^{-1}(V)) = (g \circ f)^{-1}(V)$ is clopen in X. Hence $g \circ f : X \to Z$ is αg*p-totally continuous. Conversely, let $g \circ f : X \to Z$ be αg*p-totally continuous. Let V be a αg*p-open set in Z, then $(g \circ f)^{-1}(V) = f^{-1}(g^{-1}(V))$ is clopen in X. Since f is αg*p-totally continuous, $g^{-1}(V)$ is αg*p-open in Y. Hence g is αg*p-irresolute. □

4. Totally αg*p-continuous Functions

In this section we define the totally αg*p-continuous and strongly (αg*p)*-continuous functions and investigate their fundamental properties

Definition 4.1. *A function $f:(X,\tau)\rightarrow(Y,\sigma)$ is called*

*(1). totally αg*p-continuous at a point $x\in X$ if for each open subset V in Y containing f(x), there exists a αg*p-clopen subset U in X containing x such that $f(U)\subset V$.*

*(2). totally αg*p-continuous if it has this property at each point of X.*

Theorem 4.2. *The following statements are equivalent for a function $f:(X,\tau)\rightarrow(Y,\sigma)$, whenever the class of αg*p-closed sets in (X,τ) are closed under finite union:*

*(1). f is totally αg*p-continuous.*

*(2). For every open set V of Y, $f^{-1}(V)$ is αg*p-clopen in X.*

Proof. (1)⇒(2) Let V be an open subset of Y and let $x\in f^{-1}(V)$. Since $f(x)\in V$, by (1), there exists a αg*p-clopen set U_x in X containing x such that $U_x\subset f^{-1}(V)$. We obtain $f^{-1}(V)=\cup\{U_x : x\in f^{-1}(V)\}$. Thus $f^{-1}(V)$ is αg*p-clopen in X.
(2)⇒(1) Straightforward. □

Definition 4.3. *A function $f:(X,\tau)\rightarrow(Y,\sigma)$ is said to be strongly (αg*p)*-continuous if the inverse image of every αg*p-open set of (Y,σ) is αg*p-clopen in (X,τ).*

Theorem 4.4.

*(1). Every strongly (αg*p)*-continuous function is totally αg*p-continuous.*

*(2). Every totally αg*p-continuous function is αg*p-continuous.*

*(3). Every totally continuous function is totally αg*p-continuous.*

*(4). Every αg*p-totally continuous function is totally αg*p-continuous.*

Proof. (1) Let V be an open set in Y. Then V is αg*p-open in Y. Then $f^{-1}(V)$ is αg*p-clopen in X as f is a strongly (αg*p)*-continuous function. Hence f is totally αg*p-continuous.
Proof is obvious for (2) to (4). □

Remark 4.5. *The converse of Theorem 4.4 is not true, which can be verified from the following examples.*

Example 4.6. *Let $X=Y=\{a,b,c,d\}$, $\tau=\{X,\phi,\{a,b\}\}$ and $\sigma=\{Y,\phi,\{a,b\},\{c,d\}\}$. Define $f:X\rightarrow Y$ by $f(a)=d$, $f(b)=a$, $f(c)=c$, $f(d)=b$. Then f is totally αg*p-continuous but f is not strongly (αg*p)*-continuous, totally continuous and αg*p-totally continuous.*

Example 4.7. *Let $X=Y=\{a,b,c,d\}$, $\tau=\{X,\phi,\{a\},\{b,c\},\{a,b,c\}\}$, and $\sigma=\{Y,\phi,\{a\},\{b\},\{a,b\},\{b,c\},\{a,b,c\}\}$. αg*p-C(X) $=\{X,\phi,\{b\},\{c\},\{d\},\{a,d\},\{b,d\},\{c,d\},\{a,b,d\},\{a,c,d\},\{b,c,d\}\}$. Define $f:X\rightarrow Y$ by $f(a)=b$, $f(b)=c$, $f(c)=a$, $f(d)=d$. Then f is αg*p-continuous but f is not totally αg*p-continuous.*

Theorem 4.8. *If $f:(X,\tau)\rightarrow(Y,\sigma)$ is a totally αg*p-continuous map from a αg*p-connected space (X,τ) onto a space (Y,σ), then (Y,σ) is an indiscrete space.*

Proof. On the contrary, suppose that (Y, σ) is not an indiscrete space. Let A be a proper non-empty open subset of (Y, σ) . Since f is totally αg*p-continuous map , then $f^{-1}(A)$ is a proper non-empty αg*p-clopen subset of X. Then $X = f^{-1}(A)\cup$(X $\setminus f^{-1}(A)$) which is a contradiction to the fact that X is αg*p-connected. Therefore Y must be an indiscrete space. □

Theorem 4.9. *Let $f : (X, \tau) \to (Y, \sigma)$ be a totally αg*p-continuous map and Y be a T_1-space. If A is a non-empty subset of a αg*p-connected space X, then f(A) is singleton.*

Proof. Suppose if possible f(A) is not singleton, let $f(x_1) = y_1 \in A$ and $f(x_2) = y_2 \in A$. Since y_1, $y_2 \in Y$ and Y is a T_1 space, then there exists an open set G in (Y, σ) containing y_1 but not y_2. Since f is totally αg*p-continuous, $f^{-1}(G)$ is a αg*p-clopen set containing x_1 but not x_2. Now $X = f^{-1}(G)\cup$ (X $\setminus$ $f^{-1}(G)$). Thus X is a union of two non-empty αg*p-open sets which is a contradiction. □

Definition 4.10. *A space (X, τ) is said to be*

*(1). αg*p-co-T_1 if for each pair of disjoint points x and y of X, there exists αg*p-clopen sets U and V containing x and y, respectively such that $x \in U$, $y \notin U$ and $x \notin V$, $y \in V$.*

*(2). αg*p-co-T_2 if for each pair of disjoint points x and y of X, there exists αg*p-clopen sets U and V in X, respectively such that $x \in U$ and $y \in V$.*

*(3). αg*p-co-Hausdorff if every two distinct points of X can be separated by disjoint αg*p-clopen sets.*

Theorem 4.11. *If $f : (X, \tau) \to (Y, \sigma)$ is totally αg*p-continuous injective function and Y is a T_1 space, then X is αg*p-co-T_1.*

Proof. Since Y is T_1, for any distinct points x and y in X, there exists open sets V, W in Y such that $f(x) \in V$, $f(y) \notin V$, $f(x) \notin W$ and $f(y) \in W$. Since f is totally αg*p-continuous, $f^{-1}(V)$ and $f^{-1}(W)$ are αg*p-clopen subsets of (X, τ) such that $x \in f^{-1}(V)$, $y \notin f^{-1}(V)$, $x \notin f^{-1}(W)$ and $y \in f^{-1}(W)$. This shows that X is αg*p-co-T_1. □

Theorem 4.12. *If $f : (X, \tau) \to (Y, \sigma)$ is totally αg*p-continuous injective function and Y is a T_2-space, then X is αg*p-co-T_2.*

Proof. For any distinct points x and y in X, there exists disjoint open sets U and V in Y such that $f(x) \in U$ and $f(y) \in V$ and $U \cap V = \phi$. Since f is totally αg*p-continuous, $f^{-1}(U)$ and $f^{-1}(V)$ are αg*p-clopen in X containing x and y respectively. Therefore $f^{-1}(U) \cap f^{-1}(V) = \phi$ because $U \cap V = \phi$. This shows that X is αg*p-co-T_2. □

Theorem 4.13. *Let $f : (X, \tau) \to (Y, \sigma)$ be a totally αg*p-continuous injective function. If Y is hausdorff, then X is αg*p-co-Hausdorff.*

Proof. Let x_1 and x_2 be two distinct points of X. Since f is injective and Y is Hausdorff, there exists open sets V_1 and V_2 in Y such that $f(x_1) \in V_1$, $f(x_2) \in V_2$ and $V_1 \cap V_2 = \phi$. By previous theorem, $x_i \in f^{-1}(Vi) \in$ αg*p-clopen (X) for i=1, 2 and $f^{-1}(V_1) \cap f^{-1}(V_2) = \phi$. Thus X is αg*p-co-Hausdorff. □

Definition 4.14. *A space X is said to be*

*(1). αg*p-co-compact if every αg*p-clopen cover of X has a finite subcover.*

*(2). αg*p-co-compact relative to X if every cover of a αg*p-clopen set of X has a finite subcover.*

*(3). countably αg*p-co-compact if every countable cover of X by αg*p-clopen sets has a finite subcover.*

*(4). αg*p-co-Lindelof if every αg*p-clopen cover of X has a countable subcover.*

Theorem 4.15. *Let $f : (X, \tau) \to (Y, \sigma)$ be a totally αg*p-continuous surjective function. Then the following statements hold.*

*(1). If X is αg*p-co-Lindelof then Y is Lindelof.*

*(2). If X is countably αg*p-co-compact then Y is countably compact.*

*(3). If X is αg*p-co-compact then Y is compact.*

*(4). If X is countably αg*p-co-compact then Y is countably compact.*

Proof. Let $\{V_\alpha : \alpha \in I\}$ be an open cover of Y. Since f is totally αg*p-continuous, $\{f^{-1}(V_\alpha) : \alpha \in I\}$ is a αg*p-clopen cover of X. Since X is αg*p-co-Lindelof, there exists a countable subset I_0 of I such that $X = \cup\{V_\alpha : \alpha \in I\}$ and hence Y is Lindelof. Proof of 2 to 4 is similar. □

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