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On Special Spaces of $h(hv)$ −Torsion Tensor C_{jkh} in Generalized Recurrent Finsler Space

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ABSTRACT

The purpose of the present paper is to use the properties of $C2$ −like space, C −reducible space, semi−C −reducible space and $C3$ −like space in the generalized $\mathcal{BP}$ −recurrent space to get new spaces related to generalized recurrent. Further, we find certain identities belong to these spaces.

KEYWORDS: $C2$ −like space, C −reducible space, semi−C −reducible space, $C3$ −like space.
MSC 2010: 47A45, 53C60.

1. INTRODUCTION

Various special forms of the $h(hv)$ −torsion tensor C_{jkh} called as *$C2$ −like space*, *C −reducible space*, *semi−C −reducible space* and *$C3$ −like space* have been studied by the Finslerian geometers. Matsumoto and Numata [14] and Aveesh et al. [19] introduced definition for $C2$ −like space, Singh and Gupta [21] discussed some properties for $C2$ −like space

Saxena [16] studied C −reducible Finsler space with Douglas tensor and gave the condition for Finsler space to be C −reducible Finsler space. Matsumoto [12] defined C −reducible Finsler space, Dwivedi [15] obtained every C −reducible Finsler space is P −reducible and converse is not necessarily true.

Tiwari et al. [9] and Heydari [6] introduced definition for semi−C −reducible space and studied some properties for it. Also, Chethana and Narasimhamurthy [7] proved that every semi−C −reducible manifold with C −reducible metric reduces to Landsberg manifold.

Tayebi and Peyghan [5], Pandey and Tripathi [20] and Beizavi [18] introduced definition for $C3$ −like space and discussed its relationship with other spaces in Finsler space. In addition, Gangopadhyay and Tiwari [17] obtained that $C3$ −like Finsler metric may be consider as a generalization of C −reducible, semi−C − reducible and $C2$ −like Finsler metrics. The aim of this paper is to merge the generalized $\mathcal{BP}$ −recurrent space with various special forms of the $h(hv)$ −torsion tensor C_{jkh} to get new spaces in Finsler space.

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2. PRELIMINARIES

In this section, some definitions will be given for the purpose of this paper. An n −dimensional space X_n equipped with a function $F(x,y)$ which denoted by $F_n = (X_n\ ,\ F(x,y))$ called *a Finsler space* if the function $F(x,y)$ satisfying the request conditions [10].

The tensor C_{ijk} that is known as $(h)hv$ *−torsion tensor* defined as [13]

$$C_{ijk} = \frac{1}{2}\dot{\partial}_i\, g_{jk} = \frac{1}{4}\dot{\partial}_i\dot{\partial}_j\dot{\partial}_k\, F^2.$$

It is positively homogeneous of degree -1 in y^i and symmetric in all its indices. The above tensor C_{ijk} satisfies

(2.1) $\quad C^h_{ik} = g^{hj}C_{ijk}\ ,$

where C^i_{jk} is called *associate tensor of the tensor* C_{ijk}.

Berwald's covariant derivative $\mathfrak{B}_k T^i_j$ of an arbitrary tensor field T^i_j with respect to x^k is given by [10]

$$\mathfrak{B}_k T^i_j = \partial_k T^i_j - \left(\dot{\partial}_r T^i_j\right)G^r_k + T^r_j G^i_{rk} - T^i_r G^r_{jk}\ .$$

Let Berwald's covariant derivative of first order for the tensors C^i_{kh} and C_{jkh} which are satisfy [3]

(2.2) $\quad \mathfrak{B}_m C^i_{kh} = \lambda_m C^i_{kh} + \mu_m(\delta^i_k y_h - \delta^i_h y_k)$

and

(2.3) $\quad \mathfrak{B}_m C_{jkh} = \lambda_m C_{jkh} + \mu_m(g_{jk} y_h - g_{jh} y_k)\ .$

Definition 2.1. A Finsler space $F_n (n \geq 2)$ with $C^2 = C_j C^j \neq 0$, it is called a $C2-$ *like space* if the $(h)hv$ −torsion tensor C_{jkh} can be written in the form [11, 14]

(2.4) $\quad C_{jkh} = C_j C_k C_h / C^2,$

where $C_j = g^{kh}C_{jkh}$.

Definition 2.2. A Finsler space F_n is called a C *−reducible space* if the $(h)hv$ −torsion tensor C_{jkh} is characterized by the condition [12, 15, 16]

(2.5) $\quad C_{jkh} = \dfrac{1}{(n+1)}\left(h_{jk}C_h + h_{kh}C_j + h_{hj}C_k\right)\ ,$

where $h_{jk} = g_{jk} - l_j l_k$ is an angular metric tensor.

Definition 2.3. A Finsler metric F_n is called *a semi−C −reducible* if the $(h)hv$ −torsion tensor C_{jkh} is given by [6, 7, 9]

(2.6) $\quad C_{jkh} = \left[\dfrac{p}{1+n}\left(h_{jk}I_h + h_{kh}I_j + h_{hj}I_k\right) + \dfrac{q}{\|\mathbf{I}\|^2} I_j I_k I_h\right]\ ,$

where $p = p(x,y)$ and $q = q(x,y)$ are scalar function on F_n and $\|\mathbf{I}\|^2 = I^i I_i$.

Definition 2.4. A Finsler metric F_n is called a $C3$ *−like space* if the $(h)hv$ −torsion tensor C_{jkh} is given by [5, 8, 17, 19]

(2.7) $\quad C_{jkh} = \left[\left(A_j h_{kh} + A_k h_{hj} + A_h h_{jk}\right) + \left(B_j I_k I_h + I_j B_k I_h + I_j I_k B_h\right)\right]\ ,$

where $A_i = A_i(x,y)$ and $B_i(x,y)$ are y −homogeneous scalar functions on F_n of degree -1 and 1, respectively.

The generalized $\mathfrak{B}P-$recurrent space has been introduced by Alaa et al. [1, 2, 4]. This space is characterized by the condition

(2.8) $\quad \mathfrak{B}_m P^i_{jkh} = \lambda_m P^i_{jkh} + \mu_m(\delta^i_j g_{kh} - \delta^i_k g_{jh})\ , \quad P^i_{jkh} \neq 0\ .$

The above space is denoted by $G(\mathfrak{B}P) - RF_n$.

3. A $C2$ −LIKE−GENERALIZED $\mathfrak{B}P$ −RECURRENT SPACE

In this section, we will merge the generalized $\mathfrak{B}P-$recurrent space (main space) i.e. [it is characterized by the condition (2.8)] with $C2$ −like space in Finser space to get new space contain the same properties of the main space.

Definition 3.1. The generalized $\mathfrak{B}P-$recurrent space which is $C2$ −like space i.e. satisfies the condition (2.4), will be called *a $C2-$like generalized $\mathfrak{B}P-$recurrent space* and will be denoted briefly by $C2-\text{like}-G(\mathfrak{B}P)-RF_n$.

Let us consider a $C2-\text{like}-G(\mathfrak{B}P)-RF_n$.

Taking $\mathfrak{B}-$covariant derivative for the condition (2.4) with respect to x^m and using (2.3), we get

$$\mathfrak{B}_m\left(C_jC_kC_h/C^2\right)=\lambda_m C_{jkh}+\mu_m\left(g_{jk}y_h-g_{jh}y_k\right).$$

Using the condition (2.4) in above equation, we get

$$\mathfrak{B}_m\left(C_jC_kC_h/C^2\right)=\lambda_m\left(C_jC_kC_h/C^2\right)+\mu_m\left(g_{jk}y_h-g_{jh}y_k\right). \tag{3.1}$$

Transvecting the condition (2.4) by g^{ij} using (2.1), we get

$$C^i_{kh}=C^iC_jC_k/C^2, \tag{3.2}$$

where $C^i=g^{ij}C_j$.

Taking $\mathfrak{B}-$covariant derivative for eq. (3.2) with respect to x^m and using (2.2), we get

$$\mathfrak{B}_m\left(C^iC_jC_k/C^2\right)=\lambda_m C^i_{kh}+\mu_m\left(\delta^i_ky_h-\delta^i_hy_k\right).$$

Using eq. (3.2) in above equation, we get

$$\mathfrak{B}_m\left(C^iC_jC_k/C^2\right)=\lambda_m\left(C^iC_jC_k/C^2\right)+\mu_m\left(\delta^i_ky_h-\delta^i_hy_k\right). \tag{3.3}$$

From eqs. (3.1) and (3.3), we conclude the following theorem.

Theorem 3.1. *In $C2-\text{like}-G(\mathfrak{B}P)-RF_n$, Berwald's covariant derivative of first order for the tensors $\left(C_jC_kC_h/C^2\right)$ and $\left(C^iC_jC_k/C^2\right)$ are given by eqs. (3.1) and (3.3), respectively.*

4. A C −REDUCIBLE−GENERALIZED $\mathfrak{B}P$ − RECURRENT SPACE

In this section, we will merge the generalized $\mathfrak{B}P-$recurrent space (main space) i.e. [it is characterized by the condition (2.8)] with C −reducible space in Finser space to get new space contain the same properties of the main space.

Definition 4.1. The generalized $\mathfrak{B}P-$recurrent space which is C −reducible space i.e. satisfies the condition (2.5), will be called *a C −reducible generalized $\mathfrak{B}P-$recurrent space* and will be denoted briefly by $C-\text{reducible}-G(\mathfrak{B}P)-RF_n$.

Let us consider a $C-\text{reducible}-G(\mathfrak{B}P)-RF_n$.

Taking $\mathfrak{B}-$covariant derivative for the condition (2.5) with respect to x^m and using (2.3), we get

$$\mathfrak{B}_m\left[\frac{1}{n+1}\left(h_{jk}C_h+h_{kh}C_j+h_{hj}C_k\right)\right]=\lambda_m C_{jkh}+\mu_m\left(g_{jk}y_h-g_{jh}y_k\right).$$

Using the condition (2.5) in above equation, we get

(4.1) $$\mathfrak{B}_m\left[\frac{1}{n+1}\left(h_{jk}C_h + h_{kh}C_j + h_{hj}C_k\right)\right] = \lambda_m\left[\frac{1}{n+1}\left(h_{jk}C_h + h_{kh}C_j + h_{hj}C_k\right)\right] + \mu_m\left(g_{jk}y_h - g_{jh}y_k\right).$$

Transvecting the condition (2.5) by g^{ij}, using (2.1), we get

(4.2) $$C^i_{kh} = \frac{1}{n+1}\left(h^i_k C_h + h_{kh}C^i + h^i_h C_k\right),$$

where $C^i = g^{ij}C_j$ and $h^i_k = g^{ij}h_{jk}$.

Taking $\mathfrak{B}-$covariant derivative for eq. (4.2) with respect to x^m and using eq. (2.2), we get

$$\mathfrak{B}_m\left[\frac{1}{n+1}\left(h^i_k C_h + h_{kh}C^i + h^i_h C_k\right)\right] = \lambda_m C^i_{kh} + \mu_m\left(\delta^i_k y_h - \delta^i_h y_k\right).$$

Using eq. (4.2) in above equation, we get

(4.3) $$\mathfrak{B}_m\left[\frac{1}{n+1}\left(h^i_k C_h + h_{kh}C^i + h^i_h C_k\right)\right] = \lambda_m\left[\frac{1}{n+1}\left(h^i_k C_h + h_{kh}C^i + h^i_h C_k\right)\right] + \mu_m\left(\delta^i_k y_h - \delta^i_h y_k\right).$$

From eqs. (4.1) and (4.3), we conclude the following theorem.

Theorem 4.1. *In $C-\text{reducible}-G(\mathfrak{B}P)-RF_n$, Berwald's covariant derivative of first order for the tensors $\left[\frac{1}{n+1}\left(h_{jk}C_h + h_{kh}C_j + h_{hj}C_k\right)\right]$ and $\left[\frac{1}{n+1}\left(h^i_k C_h + h_{kh}C^i + h^i_h C_k\right)\right]$ are given by eqs. . (4.1) and (4.3), respectively.*

5. A SEMI−C −REDUCIBLE−GENERALIZED $\mathcal{BP}$ −RECURRENT SPACE

In this section, we will merge the generalized $\mathfrak{B}P-$recurrent space (main space) i.e. [it is characterized by the condition (2.8)] with semi−C −reducible space in Finser space to get new space contain the same properties of the main space.

Definition 5.1. The generalized $\mathfrak{B}P-$recurrent space which is semi−C −reducible space i.e. satisfies the condition (2.6), will be called *a semi−C −reducible generalized $\mathfrak{B}P-$recurrent space* and will be denoted briefly by $semi-C-\text{reducible}-G(\mathfrak{B}P)-RF_n$.

Let us consider a $semi-C-\text{reducible}-G(\mathfrak{B}P)-RF_n$.

Taking $\mathfrak{B}-$covariant derivative for the condition (2.6) with respect to x^m and using eq. (2.3), we get

$$\mathfrak{B}_m\left[\frac{p}{1+n}\left(h_{jk}I_h + h_{kh}I_j + h_{hj}I_k\right) + \frac{q}{\|\mathbf{I}\|^2}I_jI_kI_h\right] = \lambda_m C_{jkh} + \mu_m\left(g_{jk}y_h - g_{jh}y_k\right).$$

Using the condition (2.6) in above equation, we get

(5.1) $$\mathfrak{B}_m\left[\frac{p}{1+n}\left(h_{jk}I_h + h_{kh}I_j + h_{hj}I_k\right) + \frac{q}{\|\mathbf{I}\|^2}I_jI_kI_h\right]$$

$$= \lambda_m\left[\frac{p}{1+n}\left(h_{jk}I_h + h_{kh}I_j + h_{hj}I_k\right) + \frac{q}{\|\mathbf{I}\|^2}I_kI_h\right] + \mu_m\left(g_{jk}y_h - g_{jh}y_k\right).$$

Transvecting the condition (2.6) by g^{ij}, using (2.1), we get

(5.2) $C^i_{kh} = g^{ij}[\frac{p}{1+n}\left(h_{jk}I_h + h_{kh}I_j + h_{hj}I_k\right) + \frac{q}{\|\mathbf{I}\|^2} I_j I_k I_h].$

Taking $\mathfrak{B}-$ covariant derivative for eq. (5.2) with respect to x^m and using (2.2), we get

$$\mathfrak{B}_m\left(g^{ij}[\frac{p}{1+n}\left(h_{jk}I_h + h_{kh}I_j + h_{hj}I_k\right) + \frac{q}{\|\mathbf{I}\|^2} I_k I_h]\right) = \lambda_m C^i_{kh} + \mu_m\left(\delta^i_k y_h - \delta^i_h y_k\right).$$

Using eq. (5.2) in above equation, we get

(5.3) $$\mathfrak{B}_m\left(g^{ij}[\frac{p}{1+n}\left(h_{jk}I_h + h_{kh}I_j + h_{hj}I_k\right) + \frac{q}{\|\mathbf{I}\|^2} I_j I_k I_h]\right)$$
$$= \lambda_m\left(g^{ij}[\frac{p}{1+n}\left(h_{jk}I_h + h_{kh}I_j + h_{hj}I_k\right) + \frac{q}{\|\mathbf{I}\|^2} I_j I_k I_h]\right) + \mu_m\left(\delta^i_k y_h - \delta^i_h y_k\right).$$

From eqs. (5.1) and (5.3), we conclude the following theorem.

Theorem 5.1. *In* $semi-C-\text{reducible}-G(\mathfrak{B}P)-RF_n$*, Berwald's covariant derivative of first order for the tensors* $\left[\frac{p}{1+n}\left(h_{jk}I_h + h_{kh}I_j + h_{hj}I_k\right) + \frac{q}{\|\text{I}\|^2} I_j I_k I_h\right]$ *and* $\left(g^{ij}\left[\frac{p}{1+n}\left(h_{jk}I_h + h_{kh}I_j + h_{hj}I_k\right) + \frac{q}{\|\text{I}\|^2} I_j I_k I_h\right]\right)$ *are given by eqs. (5.1) and (5.3), respectively.*

6. A $C3$ −LIKE−GENERALIZED $\mathcal{BP}$ −RECURRENT SPACE

In this section, we will merge the generalized $\mathfrak{B}P-$recurrent space (main space) i.e. [it is characterized by the condition (2.8)] with $C3$ −like space in Finser space to get new space contain the same properties of the main space.

Definition 6.1. The generalized $\mathfrak{B}P-$recurrent space which is $C3$ −like space i.e. satisfies the condition (2.7), will be called *a* $C3$ *−like generalized* $\mathfrak{B}P-$*recurrent space* and will be denoted briefly by $C3-\text{like}-G(\mathfrak{B}P)-RF_n$.

Let us consider a $C3-\text{like}-G(\mathfrak{B}P)-RF_n$.

Taking $\mathfrak{B}-$ covariant derivative for the condition (2.7) with respect to x^m and using eq. (2.3), we get

$$\mathfrak{B}_m\left[\left(A_j h_{kh} + A_k h_{hj} + A_h h_{jk}\right) + \left(B_j I_k I_h + I_j B_k I_h + I_j I_k B_h\right)\right]$$
$$= \lambda_m C_{jkh} + \mu_m\left(g_{jk} y_h - g_{jh} y_k\right).$$

Using the condition (2.7) in above equation, we get

(6.1) $$\mathfrak{B}_m\left[\left(A_j h_{kh} + A_k h_{hj} + A_h h_{jk}\right) + \left(B_j I_k I_h + I_j B_k I_h + I_j I_k B_h\right)\right]$$
$$= \lambda_m\left[\left(A_j h_{kh} + A_k h_{hj} + A_h h_{jk}\right) + \left(B_j I_k I_h + I_j B_k I_h + I_j I_k B_h\right)\right] + \mu_m\left(g_{jk} y_h - g_{jh} y_k\right).$$

Transvecting the condition (2.7) by g^{ij}, using (2.1), we get

(6.2) $C^i_{kh} = \left(g^{ij}\left[\left(A_j h_{kh} + A_k h_{hj} + A_h h_{jk}\right) + \left(B_j I_k I_h + I_j B_k I_h + I_j I_k B_h\right)\right]\right).$

Taking $\mathfrak{B}-$ covariant derivative for eq. (6.2) with respect to x^m and using (2.2), we get

$$\mathfrak{B}_m\left(g^{ij}\left[\left(A_j h_{kh} + A_k h_{hj} + A_h h_{jk}\right) + \left(B_j I_k I_h + I_j B_k I_h + I_j I_k B_h\right)\right]\right)$$
$$= \lambda_m C^i_{kh} + \mu_m\left(\delta^i_k y_h - \delta^i_h y_k\right).$$

Using eq. (6.2) in above equation, we get

(6.3) $$\mathfrak{B}_m\left(g^{ij}\left[\left(A_j h_{kh} + A_k h_{hj} + A_h h_{jk}\right) + \left(B_j I_k I_h + I_j B_k I_h + I_j I_k B_h\right)\right]\right)$$
$$= \lambda_m\left(g^{ij}\left[\left(A_j h_{kh} + A_k h_{hj} + A_h h_{jk}\right) + \left(B_j I_k I_h + I_j B_k I_h + I_j I_k B_h\right)\right]\right) + \mu_m\left(\delta^i_k y_h - \delta^i_h y_k\right).$$

From eqs. (6.1) and (6.3), we conclude the following theorem.

Theorem 6.1. *In* $C3-\text{like}-G(\mathfrak{B}P)-RF_n$, *Berwald's covariant derivative of first order for the tensors* $\left[\left(A_j h_{kh} + A_k h_{hj} + A_h h_{jk}\right) + \left(B_j I_k I_h + I_j B_k I_h + I_j I_k B_h\right)\right]$ *and* $\left(g^{ij}\left[\left(A_j h_{kh} + A_k h_{hj} + A_h h_{jk}\right) + \left(B_j I_k I_h + I_j B_k I_h + I_j I_k B_h\right)\right]\right)$ *are given by eqs. (6.1) and (6.3), respectively.*

7. CONCLUSION

We used some special Finsler spaces in the generalized $\mathfrak{B}P-$recurrent space to get new spaces which are called *$C2-$like generalized $\mathfrak{B}P-$recurrent space*, *$C-$reducible generalized $\mathfrak{B}P-$recurrent space*, *semi$-C-$reducible generalized $\mathfrak{B}P-$recurrent space* and *$C3-$like generalized $\mathfrak{B}P-$recurrent space*.

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