INFINTESIMAL C-CONFORMAL MOTIONS OF FINSLRIRAN HYPERSURFACES

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ABSTRACT

Let \( F^{n-1} \) be an hypersurface of a Finsler space \( F^n \). In this paper we obtain condition for an infinitesimal C-Conformal motion for hypersurface of Finsler space and prove some results relating to the infinitesimal C-Conformal motion. Further a condition is obtained to preserve \(*P\)-Finsler hypersurface and an infinitesimal C-Conformal motion preserves \( C^h\)-recurrent Finsler hypersurface.

Key Words: Finsler Space, \(*P\)-Finsler space, \( P\)-reducible, \( C\)-reducible, \( C^h\)-recurrent Finsler spaces.

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1. INTRODUCTION

The theory of conformal changes of Finsler metrics has been initiated by M. S. Knebelman in 1929. H. Izumi ([1], [2]) gave the condition for a Finsler space to be \( h\)-conformally flat and he has also studied \(*P\)-Finsler space. Later S. Kikuchi [3] gave the condition for a Finsler space to be conformally flat. M. Hashiguchi introduced a special change called C-conformal change which satisfies C-conditions. C. Shibata and M. Azuma have studied C-conformal invariants of Finsler metric. The authors S. K. Narasimhamurthy and C. S. Bagewadi have published a paper on infinitesimal C-conformal motions of Special Finsler spaces [6]. In this we study infinitesimal C-conformal motions on some special Finsler hypersurfaces and obtain some results on \(*P\)-Finsler hypersurfaces, \( C\)-reducible, \( P\)-reducible, \( C^h\)-recurrent Finsler hypersurfaces.

2. PRELIMINARY

Let \( M^n \) be an n-dimensional smooth manifold and \( F^n = (M^n, L) \) be an n-dimensional Finsler space equipped with fundamental function \( L(x, y) \) on \( M^n \). The metric tensor \( g_{ij}(x, y) \), angular metric tensor \( h_{ij} \) and Cartan’s C-tensor \( C_{ijk} \) are given by

\[
\begin{align*}
g_{ij} &= \frac{1}{2} \partial_i \partial_j L^2, \quad g^{ij} = g_{ij}^{-1} \\
h_{ij} &= g_{ij} - l_i l_j \\
C_{ijk} &= \frac{1}{2} \partial_k g_{ij} \\
C^{k}_{ij} &= \frac{1}{2} g^{km}(\partial_m g_{ij}), \quad \text{where} \quad \partial_i = \frac{\partial}{\partial x^i}.
\end{align*}
\]

The conformal change of a Finsler metric \( L = \tilde{L} = e^{\sigma(x)}L \) then \( \sigma \) is called the conformal factor and depends on point \( x \) only. By this change, we have another Finsler space \( \tilde{F}^n = (M^n, \tilde{L}) \) on the same underlying manifold \( M^n \). M. Hashiguchi introduced the special change called C-conformal which is non-homothetic conformal change satisfying

\[
\begin{align*}
C^\gamma_{a\beta} \sigma^a &= 0, \quad \sigma^a = g^{a\beta} \sigma_a, \quad \sigma_a = \partial \sigma / \partial x^a, \\
C^\gamma_{a\beta} \sigma^\gamma &= 0, \quad \sigma^a = C^\gamma_{a\beta} \sigma^\gamma g_{\gamma \beta} = C^\gamma_{a\beta} \sigma^\gamma = 0, \quad \text{also}
\end{align*}
\]
\[ C_{\alpha\beta\gamma}^{\sigma} = C_{\alpha\gamma}^{\beta\sigma} = C_{\beta\alpha}^{\gamma\sigma} = C_{\alpha\beta\gamma}^{\sigma} = 0. \] (2.1)

The Berwald connection and the Cartan connection of \( F^n \) are given

\[ B = (G_{jk}, N_{jk}, 0), \quad C = (F_{jk}, N_{jk}, C_{jk}) \]

respectively.

A hypersurface \( F^{n-1} \) of the underlying smooth manifold \( F^n \) may be parametrically represented by the equation

\[ x^i = x^i(u^\alpha), \]

where \( u^\alpha \) are Gaussian coordinates on \( F^{n-1} \) and Greek indices run from 1 to \( (n-1) \). Here we shall assume that the matrix consisting of the projection factors \( B_{\alpha}^i = \partial x^i / \partial u^\alpha \) is of rank \( (n-1) \). The following notations are also employed

\[ B_{\alpha\beta}^i = \frac{\partial x^i}{\partial u^\alpha \partial u^\beta}, \quad B_{\alpha\beta} = v^\alpha B_{\alpha\beta}^i, \quad B_{\alpha\beta}^i = B_{\alpha}^i, \quad B_{\beta\alpha}^i = B_{\beta}^i. \]

If the supporting element \( y^i \) at a point \( (u^\alpha) \) of \( M^{n-1} \) is assumed to be tangential to \( M^{n-1} \), we may then write \( y^i = B_{\alpha}^i (u) v^\alpha \); i.e. \( F^{n-1} \) is thought of as the supporting element of \( M^{n-1} \) at a point \( (u^\alpha) \). Since the function \( L(u, v) = L(x(u), y(u, v)) \) gives rise to a Finsler matrix of \( M^{n-1} \), we get a \( (n-1) \) dimension Finsler space \( F^{n-1} = (M^{n-1}, L(u, v)) \).

At each point \( (u^\alpha) \) of \( F^{n-1} \), the unit normal vector \( N^i(u, v) \) is defined by

\[ g_{ij} B_{\alpha}^i N^j = 0, \quad g_{ij} N^i N^j = 1. \]

If \( (B_{\alpha}^i, N_i) \), is the inverse matrix of \( (B_{\alpha}^i, N^i) \), we have

\[ B_{\alpha}^i B_{\alpha}^i = \delta_{\alpha\beta}, \quad B_{\alpha}^i N_i = 0, \quad N^i N_i = 1 \]

and further \( B_{\alpha}^i B_{\beta}^i N_i N_j = \delta_{ij} \).

Making use of the inverse \( g^{\alpha\beta} \) of \( (g_{\alpha\beta}) \), we get

\[ B_{\alpha}^i = g^{\alpha\beta} g_{ij} B_{\beta}^j, \quad N_i = g_{ij} N^j. \]

3. LEI DERIVATIVE ON FINSLER HYPERSURFACE

Consider an infinitesimal extended point transformation in a Finsler space generated by the vector \( X = v^i(x) \partial_i \); i.e.

\[ \vec{x}^i = x^i + v^i dt, \quad \vec{y}^i = y^i + (\partial_j v^i) y^j dt. \] (3.1)

The condition for the above transformation to be infinitesimal conformal motion is that there exists a function \( \sigma \) of \( x \) such that

\[ L_X g_{\alpha\beta} = 2 \sigma(X) g_{\alpha\beta}, \quad L_X g^{\alpha\beta} = -2 \sigma(X) g^{\alpha\beta}. \] (3.2)

It is well known that on i.c.m (3.1) satisfies

\[ L_X C_{\beta\gamma}^{\alpha} = 0, \quad \text{and} \quad L_X y^i = B_{\alpha}^i (u) v^\alpha = 0. \] (3.3)

From this we can easily see that

(a) \( L_X C_{\beta\gamma}^{\alpha} = L_X C_{\beta\gamma} = 0, \quad C_{\alpha} = C_{\beta\gamma}^{\alpha} \)

(b) \( L_X L = \sigma L \)

(c) \( L_X t^\alpha = -\sigma t^\alpha \), \( L_X t_{\alpha} = \sigma t_{\alpha} \)

(d) \( L_X h_{\beta\gamma}^{\alpha} = 0, \quad L_X \left( g^{\alpha\beta} g_{\beta\gamma} \right) = 0 \)

The commutative formulae involving Lie and Covariant derivatives are given by

(i) \( L_X T_{\beta\gamma}^{\alpha\gamma} = (L_X T_{\beta\gamma}^{\alpha\gamma})_{||Y} = T_{\beta\gamma}^{\alpha\gamma} A_{\gamma\delta}^{\alpha\beta} - T_{\gamma\delta}^{\alpha\gamma} A_{\alpha\beta}^{\gamma\delta} - A_{\alpha\beta}^{\gamma\delta} \partial_{\delta} T_{\gamma\delta}^{\alpha\gamma} \)

(ii) \( L_X H_{\beta\gamma\delta} = A_{\beta\gamma\delta}^{\alpha\gamma} + A_{\gamma\delta}^{\alpha\beta} G_{\beta\gamma\delta} - A_{\alpha\beta}^{\gamma\delta} G_{\beta\gamma\delta} - A_{\beta\gamma}^{\alpha\delta} G_{\beta\gamma\delta} \). \] (3.4)
Where \( A^\alpha_{\rho\mu} = L_X G^\alpha_{\mu\nu} \), \( A^\alpha_{\rho\nu} = L_X G^\alpha_{\rho\nu} = \nu^\alpha_{\mu\nu} + H^\alpha_{\rho\nu} e^\delta + G^\alpha_{\rho\nu} v^\rho_0 \).

where \( \frac{\partial}{\partial y} \) means the interchange of indices \( \beta \) and \( y \) in the foregoing terms and symbol ‘\( \ll \)’ denotes the covariant derivative in Finsler hypersurface.

Since the Lie derivative is commutative with \( \partial_y \), \( \dot{\partial_y} \) and from (3.1)

\[
L_X y^\rho_{\beta\nu} = \sigma_\beta \delta^\rho_{\beta\nu} + \sigma_\nu \delta^\rho_{\beta\nu} - \sigma^\rho g_{\beta\nu}, \quad \sigma_\beta = \partial_\beta \sigma.
\]

(3.5)

4. AN INFINITESIMAL C-CONFORMAL MOTION ON \( F^{n-1} \)

If we impose the C-condition on the vector \( \sigma_\beta \), i.e.

\[
C^\delta_{\alpha\beta} = 0,
\]

(4.1)

then the transformation is called an infinitesimal C-conformal motion (denoted by an i. C. c. m). We have

(i) \( L_k \dot{h}_{k}^{j} = -h_{jk}^{l} l^j - h_{j}^{l} l_{j} \)

(ii) \( L^2 \left( \dot{\partial_k} C_{jk}^{\alpha} \right) = L \dot{\partial_k} \left( L C_{jk}^{\alpha} \right) - L C_{jk}^{\alpha} L \dot{\partial_k} L = 0, \quad \text{or} \quad \left( \dot{\partial_k} C_{jk}^{\alpha} \right) \alpha_k = 0. \) (4.2)

Transvecting (4.2) (i) by \( B^{e_{\rho\gamma}}_{\beta\nu} \) we get

\[
L_k \partial_{i} h_{j}^{\gamma} B^{e_{\rho\gamma}}_{\beta\nu} = \left( -h_{jk}^{l} l^j - h_{j}^{l} l_{j} \right) B^{e_{\rho\gamma}}_{\beta\nu}
\]

\[
L_k \partial_{i} h_{k}^{\alpha} = -h_{\beta\gamma} l^\alpha - h_{i}^{\alpha} l_{i}. \]

Transvecting (4.2) (ii) by \( B^{a_{\rho\gamma}}_{i\gamma} B^{b_{\rho\gamma}}_{\gamma\delta} \)

\[
L^2 \left( \dot{\partial_k} C_{jk}^{\alpha} \right) B^{a_{\rho\gamma}}_{i\gamma} B^{b_{\rho\gamma}}_{\gamma\delta} = \left( \dot{\partial_k} \left( L C_{jk}^{\alpha} \right) - L C_{jk}^{\alpha} \dot{\partial_k} L \right) B^{a_{\rho\gamma}}_{i\gamma} B^{b_{\rho\gamma}}_{\gamma\delta} = 0
\]

\[
L^2 \left( \dot{\partial_k} C_{\beta\gamma}^{\delta} \right) = L \dot{\partial_k} \left( L C_{\beta\gamma}^{\delta} \right) - L C_{\beta\gamma}^{\delta} \dot{\partial_k} L = 0.
\]

Using the above calculation, we obtain

(a) \( A^\alpha_{\rho\nu} = L_X G^\alpha_{\rho\nu} = \sigma_\gamma \delta^\rho_{\beta\nu} + \sigma_\beta \delta^\rho_{\gamma\nu} - \sigma^\rho g_{\beta\nu} \)

(b) \( A^\gamma_{\beta\rho} = A^\gamma_{\beta\rho} = L_X G^\gamma_{\beta\rho} = \sigma_\gamma y^\alpha + \sigma_\alpha \delta^\gamma_{\beta\rho} - \sigma^\gamma y_\beta. \) (4.3)

Hence we have

**Theorem 4.1:** An infinitesimal C-conformal motion on \( F^{n-1} \) satisfies \( L_X G^\alpha_{\rho\nu} = \sigma_\gamma \delta^\rho_{\beta\nu} + \sigma_\beta \delta^\rho_{\gamma\nu} - \sigma^\rho g_{\beta\nu} \)

\[
L_X G^\rho_{\gamma\nu} = \sigma_\gamma y^\gamma + \sigma_\nu \delta^\gamma_{\beta\rho} - \sigma^\gamma y_\beta.
\]

From (3.4) (i), we have

\[
L_X C^\alpha_{\beta\gamma} = A^\alpha_{\beta\gamma} C^\alpha_{\beta\gamma} - A^\beta_{\beta\gamma} C^\alpha_{\beta\gamma} - A^\alpha_{\beta\gamma} C^\alpha_{\beta\gamma} - A^\alpha_{\beta\gamma} C^\alpha_{\beta\gamma} - A^\alpha_{\beta\gamma} C^\alpha_{\beta\gamma}
\]

(4.4)

From (3.2), (3.3) and (4.4), we have

\[
L_X C^\alpha_{\beta\gamma} = \left( \sigma_\gamma \delta^\alpha_{\gamma\nu} - \sigma^\alpha g_{\nu\gamma} \right) C^\alpha_{\beta\gamma} - \left( \sigma_\nu \delta^\alpha_{\beta\nu} - \sigma^\alpha g_{\beta\nu} \right) C^\alpha_{\beta\gamma} - \left( \sigma_\gamma \delta^\alpha_{\beta\gamma} - \sigma^\alpha g_{\gamma\nu} \right) C^\alpha_{\beta\gamma} - \left( \sigma_\nu \delta^\alpha_{\gamma\nu} - \sigma^\alpha g_{\nu\gamma} \right) C^\alpha_{\beta\gamma}.
\]

(4.5)

Transvecting above by \( y^\gamma \), we have

\[
L_X C^\alpha_{\beta\gamma} = -\sigma^\alpha C^\alpha_{\gamma\nu} - \sigma_\nu C^\alpha_{\beta\nu} - \sigma_\nu C^\alpha_{\beta\nu} - \sigma_\nu C^\alpha_{\beta\nu} - \sigma_\nu C^\alpha_{\beta\nu} - \sigma_\nu C^\alpha_{\beta\nu} + \sigma^\nu y^\nu \left( \dot{\partial_k} C^\alpha_{\beta\gamma} \right) + \sigma^\nu y^\gamma \left( \dot{\partial_k} C^\alpha_{\beta\gamma} \right).
\]
\( L_x C_{\alpha \beta \gamma}^a y^\alpha = -\sigma \bar{C}_{\gamma \beta \gamma} y^\gamma - \sigma_{\beta} C_{\alpha \gamma}^a y^\gamma - \sigma_{\gamma} C_{\beta \alpha}^a y^\gamma - \sigma_{\alpha}(\bar{\delta}_1 C_{\beta \gamma}^a) y^\Gamma. \) \\
\( L_x C_{\beta \gamma \gamma}^a |a = \sigma_0 C_{\beta \gamma}^a. \) 

Thus we have

**Theorem 4.2:** An infinitesimal C-conformal motion satisfies \( L_x C_{\alpha \beta \gamma}^a |a = \sigma_0 C_{\beta \gamma}^a \)

**Definition [4.1]:** If the tensor * \( P_{i j k} = p_{i j k} - \alpha_0(x) C_{j k}^i \)

Transvecting above equation by \( B^a TB^j_{\beta \gamma} \) we get

\[ * p_{j k} B^a TB^j_{\beta \gamma} = \bar{p}_{j k} B^a TB^j_{\beta \gamma} - \alpha_0(x) C_{j k}^i B^a TB^j_{\beta \gamma}, \]

\[ * p_{\beta \gamma} = \bar{p}_{\beta \gamma} - \sigma_0(x) C_{\beta \gamma}^a. \] 

Vanishes, then the space is called a * P -Finsler hypersurface, \( \sigma_0(x) \) is a scalar function. Taking Lie derivative on (4.7)

\[ L_x * P_{\beta \gamma} = L_x P_{\beta \gamma} - L_x \sigma_0(x) C_{\beta \gamma}^a \]

By * P -condition is given by \( P_{\alpha \beta \gamma} = \sigma_0 C_{\beta \gamma}^a \) and using (4.6) we get

\[ L_x * p_{\beta \gamma} = \sigma_0 C_{\beta \gamma}^a - L_x (\sigma_0) C_{\beta \gamma}^a - \sigma_0 L_x C_{\beta \gamma}^a, \]

\[ L_x * p_{\beta \gamma} = \sigma_0 C_{\beta \gamma}^a - \sigma_0 C_{\beta \gamma}^a, \]

\[ L_x * p_{\beta \gamma} = 0, \text{ where } L_x (\sigma_0) = \sigma_0. \]

Hence we state that

**Theorem 4.3:** An infinitesimal C-conformal motion preserves * P -Finsler hypersurface.

**Definition [4.2]:** If the tensor * \( P_{i j k} = p_{i j k} - (P_x h_{ij} + P_j h_{jk} + P_j h_{ki}) \)

Transvecting on both side of the above equation by \( B^a TB^j_{\beta \gamma} \)

\[ * p_{i j k} B^a TB^j_{\beta \gamma} = \bar{p}_{i j k} B^a TB^j_{\beta \gamma} - (P_x h_{ij} + P_j h_{jk} + P_j h_{ki}) B^a TB^j_{\beta \gamma}, \]

\[ * P_{\alpha \beta \gamma} = P_{\alpha \beta \gamma} - (P_x h_{\alpha \beta} + P_{\alpha} h_{\beta \gamma} + P_{\beta} h_{\gamma \alpha}). \] 

Vanishes, then the Finsler space \( F^n \) is called a P-reducible Finsler hypersurface.

Taking Lie derivative on both side of the above equation, we have

\[ L_x * P_{\alpha \beta \gamma} = L_x P_{\alpha \beta \gamma} - L_x (P_{\alpha} h_{\beta \gamma} + P_{\alpha} h_{\beta \gamma} + P_{\beta} h_{\gamma \alpha}). \]

using \( L_x P_{\alpha \beta \gamma} = \sigma P_{\alpha \beta \gamma}, \quad L_x P_{\gamma} = -\sigma P_{\gamma}, \)

\[ L_x * P_{\alpha \beta \gamma} = L_x P_{\alpha \beta \gamma} - (L_x P_{\alpha} h_{\beta \gamma} + P_{\alpha} L_x h_{\beta \gamma} + L_x P_{\alpha} h_{\beta \gamma} + L_x P_{\alpha} h_{\beta \gamma} + L_x h_{\beta \gamma} + P_{\beta} h_{\gamma \alpha}). \]

\[ L_x * P_{\alpha \beta \gamma} = \sigma P_{\alpha \beta \gamma} - [(\sigma P_{\alpha} h_{\beta \gamma} + (\sigma P_{\beta} h_{\gamma \alpha}) + (\sigma P_{\gamma} h_{\alpha \beta}) + 2\sigma (P_{\alpha} h_{\beta \gamma} + P_{\beta} h_{\gamma \alpha}) + P_{\alpha} h_{\beta \gamma}). \]

\[ L_x * P_{\alpha \beta \gamma} = \sigma P_{\alpha \beta \gamma} - [\sigma P_{\alpha} h_{\beta \gamma} + \alpha P_{\alpha} h_{\gamma \alpha}] + 2\sigma (P_{\alpha} h_{\beta \gamma} + P_{\alpha} h_{\gamma \alpha}). \]

\[ L_x * P_{\alpha \beta \gamma} = 0. \]

Thus we state

**Theorem 4.4:** An infinitesimal C-conformal motion preserves P-reducible Finsler hypersurface.
Definition [4.3]: If the tensor

\[ C_{ijkl} = (C_{ijkl} - \alpha_i C_{jk}) \]

Transvecting above equation by \( B^a_i B^{jkl}_{py} \) we get

\[ C_{ijkl} B^a_i B^{jkl}_{py} = (C_{ijkl} - \alpha_i C_{jk}) B^a_i B^{jkl}_{py} \]

\[ C_{py} \alpha - \sigma_i C_{py} \]

(4.9)

vanishes, then the space \( F^n \) is called \( C^h \)-recurrent Finsler hypersurface here \( \sigma_i = \sigma_i (x, y) \) is a covariant vector field. Transvecting (4.5) by \( \sigma^T \) and using (2.1) we get

\[ (L_x C^a_{py} \sigma^T) = -\sigma C_{py} \sigma^T - \sigma C_{py} \sigma^T - \sigma C_{py} \sigma^T - \sigma_0 (\delta_i C^a_{py}) \sigma^T \]

\[ (L_x C^a_{py} \sigma^T) = -\sigma C_{py} \sigma^T - \sigma C_{py} \sigma^T - \sigma C_{py} \sigma^T - \sigma_0 (\delta_i C^a_{py}) \sigma^T \]

\[ (L_x C^a_{py} \sigma^T) = 0 \]

(4.10)

Taking Lie-derivative on (4.9), we obtain

\[ L_x C^a_{py} = (L_x C^a_{py} |_{T} - L_x \sigma C^a_{py}) \]

\[ L_x C^a_{py} = L_x C^a_{py} - \sigma L_x C^a_{py} - L_x \sigma C^a_{py} \]

\[ L_x C^a_{py} = L_x C^a_{py} - L_x \sigma C^a_{py} \]

(4.11)

Transvecting (4.11) by \( \sigma^T \) and using (4.10), we have

\[ L_x C^a_{py} = (L_x C^a_{py} |_{T} - L_x \sigma C^a_{py} \sigma^T) \]

\[ L_x C^a_{py} = L_x C^a_{py} - L_x \sigma C^a_{py} \sigma^T \]

\[ L_x C^a_{py} = -\sigma C^a_{py} \sigma^T \]

(4.12)

Thus we obtain in view of Deicke’s theorem

**Theorem 4.5:** An infinitesimal \( C \)-conformal motion preserves \( C^h \)-recurrent Finsler hypersurface if and only if it is Riemannian.

**Definition [4.4]:** If the tensor

\[ C_{ijk} = C_{ijk} - \frac{1}{(n+1)} (h_{ij} C_k + h_{jk} C_i + h_{ki} C_j) \]

Contracting on both side of the above equation by \( B^a_i B^{jk}_{py} \) we get

\[ C_{ijk} B^a_i B^{jk}_{py} = C_{ijk} B^a_i B^{jk}_{py} - \frac{1}{n} (h_{ij} C_k + h_{jk} C_i + h_{ki} C_j) B^a_i B^{jk}_{py} \]

\[ C_{a}^{\alpha \beta} = C_{a}^{\alpha \beta} - \frac{1}{n} (h_{a \alpha} C_{\gamma} + h_{\beta \gamma} C_\alpha + h_{\gamma a} C_{\beta}) \]

(4.13)

vanishes, then the Finsler space is called a \( C \)-reducible Finsler hypersurface.

Taking Lie derivative of (4.13) and using

\[ L_x C_{a}^{\alpha \beta} = 2a C_{a}^{\alpha \beta}, \quad L_x h_{ij} = 2a h_{ij}, \quad L_x C_a = 0 \]

we get

\[ L_x C_{a}^{\alpha \beta} = L_x C_{a}^{\alpha \beta} - \frac{1}{n} (L_x h_{a \alpha} C_{\gamma} + L_x h_{\beta \gamma} C_\alpha + L_x h_{\gamma a} C_{\beta}) \]
Thus, we have

**Theorem 4.6:** An infinitesimal C-conformal motion preserves C-reducible Finsler hypersurface.

**CONCLUSION:**

In this paper, we have applied the Lie derivatives on Finsler hypersurface to obtain the condition for the transformation (3.1) to be infinitesimal Conformal motion and ensures (3.5) as Lie derivative is commutative with $\partial_r, \partial_r$. Further we proved that an infinitesimal C-conformal motion preserves $P$-Finsler hypersurface, P-reducible Finsler hypersurface and C-reducible Finsler hypersuface. Also by the view of Deicks’s theorem, on the condition of Riemannian we proved that infinitesimal C-conformal motion preserves $C^h$-recurrent Finsler hypersurface.

**REFERENCES**


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