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Generalized Differential Operators Involving Multivariable Hyper geometric Function

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ABSTRACT

In this paper we use differential operators we to derive a formula of multivariable Hyper geometric function. In this generalization Leibnitz's rule for fractional derivative in order to obtain one the aforementioned formulas which involve a product of two multivariable's Hyper geometric function.

Keywords: Fractional differential operator, multivariable H-function, Leibnitz's rule.

1. INTRODUCTION AND DEFINITIONS

The fractional derivative of special function of one and more variables is important such as in the evaluation of series,[10,15] the derivation of generating function[12,chap.5] and the solution of differential equation[4, 14,;chap-3] motivated by these and many other avenues of application. The fractional differential operators $\mathrm{D}^{n}_{k,\alpha,x}$ and ${}_{\alpha}D^{\mu}{}_{x}$ are much used in the theory of special function of one and more variables.
We use the fractional derivative operator defined in the following manner[16]

$$\mathrm{D}^{n}_{k,\alpha,x}(x^{\mu}) = \left[\frac{\sqrt{\mu+rk+1}}{\sqrt{\mu+rk-\alpha+1}}\right]x^{\mu+nk} \tag{1}$$

Where $\alpha \neq \mu+1$ and α and K are not necessarily integers.
We use the binomial expansion in the following manner

$$(ax^{\mu}+b)^{\lambda} = b^{\lambda}\sum_{l=0}^{\infty}\binom{\lambda}{l}\left(\frac{ax^{\mu}}{b}\right)^{l} \quad \text{where } \left[\frac{ax^{\mu}}{b}\right] <1 \tag{2}$$

The familiar differential operator ${}_{\alpha}D^{\mu}{}_{x}$ is defined by[5],

$${}_{\alpha}D^{\mu}{}_{x}\; f(x) = \begin{cases} \frac{1}{\sqrt{-\mu}}\int_{\alpha}^{x}(x-t)^{-\mu-1}f(t)dt, & [\mathrm{Re}(\mu)<0] \\ \frac{d^{m}}{dx^{m}}\;{}_{\alpha}D^{\mu-m}{}_{x}\; f(x), & [0\leq Re(\mu)<m] \end{cases} \tag{3}$$

Where m is a positive integer

For $\alpha = 0$ (3) Defines the classical Riemann- Liouville fractional derivative of order μ (0r- μ) when $\alpha \to\infty$ (3) may be identified with the definition of the well known Weyl fraction derivative of order μ (0r- μ)[1,chap.13);3] the special case of fractional calculus operator ${}_{\alpha}D^{\mu}{}_{x}$ when $\alpha = 0$ is written as D_x^{μ} thus we have

$$D_x^{\mu} = {}_0D^{\mu}{}_x \tag{4}$$

In this paper we drive several fractional derivative formulas involving multivariable H-function which as defined by Srivastav and Panda[8] thus following the various conventions and notations explained fairly and fully in their earlier works[6].

$$H[z_{1,\ldots\ldots,\ldots}z_r] = H^{0,n;m_1,n_1,\ldots,m_r,n_r}_{p,q;p_1q_1\ldots\ldots,p_r,q_r}$$

$$H[z_{1,\ldots\ldots,\ldots}z_r] = H^{0,n;m_1,n_1,\ldots,m_r,n_r}_{p,q;p_1q_1\ldots\ldots,p_r,q_r}\left(\begin{array}{c|c} z_1 & (a_j,\alpha_{j,\ldots,}^{(1)}\alpha_j^{(r)})_{1,p}:(c_j^1,\gamma_j^1)_{1,}p_{1,\ldots}(c_j^r,\gamma_j^r)_{1,}p_r \\ z_r & \left(b_j,\beta_{j,}^{(1)}\ldots,\beta_j^{(r)}\right)_{1,q}:(d_j^1,\delta_j^1)1,q_1,\ldots,(d_j^r\delta_j^r)1,q_r \end{array}\right) \tag{5}$$

Denote the H- function of r-variables $z_1, z_2,\ldots\ldots,z_r$ here for convenience

$(a_1,\alpha_j^1,\ldots\alpha_j^r)_{1,p}$ Abbreviates the P- member array $(,\alpha_j^1,\ldots\alpha_j^r),\ldots\ldots\ldots,(a_p,\alpha_p^1,\ldots\alpha_p^r)$ (6)

While $(c_j^{(i)},\gamma_j^{(i)})_{1,p_2}$ Abbreviates the array of p_i pairs of parameters

$(\alpha_j^{(i)},\gamma_j^{(i)}),\ldots\ldots\ldots\ldots(,\alpha_{p_i}^i,\ldots\alpha_{p_i}^i)$; (i = 1,……..,r) (7)

And so on , suppose , as usual that the parameters

a_j , j = 1,….,p; $c_j^{(i)}$, j = 1,……,P_i

b_j , j = 1,….,q; $d_j^{(i)}$, j = 1,…..,q_i; $\forall i \in (i = 1,\ldots,r)$ (8)

Are complex number and the associated coefficients

α_j , j = 1,….,p; $\gamma_j^{(i)}$, j = 1,……,P_i

β_j , j = 1,….,q; $\delta_j^{(i)}$, j = 1,…..,q_i; $\forall i \in (i = 1,\ldots,r)$ (9)

Are positive real numbers such that

$$\Delta_i = \sum_{j=1}^{r}\alpha_j^{(i)} - \sum_{j=1}^{q}\beta_j^{(i)} + \sum_{j=1}^{Pi}\gamma_j^{(i)} - \sum_{j=1}^{q_i}\delta_j^{(i)} \leq 0 \tag{10}$$

And

$$\Omega_i = -\sum_{j=n+1}^{p}\alpha_j^{(i)} - \sum_{j=1}^{q}\beta_j^{(i)} + \sum_{j=1}^{ni}\gamma_j^{(i)} - \sum_{j=n_i+1}^{P_i}\gamma_j^{(i)} + \sum_{j=1}^{m_i}\delta_j^{(i)} - \sum_{j=m_2+1}^{q_i}\delta_j^{(i)} > 0; \quad \forall i \in (i = 1,\ldots,r) \tag{11}$$

Where the integers n, p, q, m_i, n_i, p_i, q_i are constrained by the inequalities $0\leq n \leq P, q \geq 0$, $1\leq m_i \leq q_i$, $0 \leq n_i \leq P_i$ [i = 1,……,r] and the equality (10) holds true for suitably restricted values of the complex variables $z_1,\ldots\ldots,z_r$

Then it is known that the multiple Mellin-Barnes counter integral[11], representing the multivariable H- function (5) converges absolutely under the condition (11) when

$$|\arg(z_i)| < \frac{1}{2}\Delta\Omega_i, \qquad \forall i \in (i = 1, \ldots, r) \tag{12}$$

$$H[z_{1,\ldots\ldots,}z_r] = \left| \begin{array}{ll} 0(|z_1|^{\xi_1} \ldots |z_r|^{\xi_r}), & (max|z_1| \ldots |z_r| \to 0) \\ 0(|z_1|^{\eta_1} \ldots |z_r|^{\eta_r}), & (\eta = 0; mix|z_1| \ldots |z_r| \to \infty) \end{array} \right| \tag{13}$$

Where with i= 1,…….r min

$$\xi_i = \min\left\{Re({d_j}^{(i)} / {\delta_j}^{(i)}\right\}, \qquad (j=1,\ldots\ldots m_i)$$

$$\eta_i = \max\left\{Re({c_j}^{(i)} - 1 / {\gamma_j}^{(i)}\right\}, \qquad (j=1,\ldots\ldots n_i) \tag{14}$$

Provided that each of the inequalities holds true.

Throughout the present paper we assume that the convergence and existence condition corresponding appropriately to the ones detained above are satisfied by each of the various H-function involved in our results which are presented in the following sections.

2. MAIN RESULT

In this section we shall prove our main formula on fractional differential operator involving multivariable H- function.

Result (1)

$$D^n_{k,\alpha,x}\{x^t (x^{\upsilon_1} + a)^{\lambda} (b - x^{\upsilon_2})^{-\delta}$$
$$H[z_1 x^{\rho_1} (x^{\upsilon_1} + a)^{\sigma_1} (b - x^{\upsilon_2})^{-\delta_1}, \ldots\ldots, z_r x^{\rho_r} (x^{\upsilon_1} + a)^{\sigma_r} (b - x^{\upsilon_2})^{-\delta_r}]\}$$

$$= a^{\lambda} b^{-\delta} x^{t+nk} \sum_{l,m=0}^{\infty} \frac{(x^{\upsilon_1}/a)^l (x^{\upsilon_2}/b)^m}{l!m!} H^{0,\, n+n+2 : m_1, n_1, \ldots\ldots, m_r, n_r}_{p+n+2,\, q+n+2 : p_1, q_1; \ldots; p_r, q_r}$$

$$\left[\begin{array}{c|c} z_1 x^{\rho_1} a^{\sigma_1} b^{-\delta_1} & (-\lambda, \sigma_1, \ldots, \sigma_r), (1-\delta-m, \delta_1, \ldots, \delta_r), (-t-gk-\nu_1 l-\nu_2 m; \rho_1, \ldots, \rho_r)_{g=0,n-1}, (a_j, \alpha_j^{(i)}, \ldots, \alpha_j^{(r)})_{1,p} \\ \cdot & (c_j^{(1)}, \gamma_j^{(1)})_{1,P_1}, \ldots\ldots, (c_j^{(r)}, \gamma_j^{(r)})_{1,P_r} \\ \cdot & (-\lambda+l, \sigma_1, \ldots, \sigma_r), (1-\delta, \delta_1, \ldots, \delta_r), (\alpha-t-gk-\nu_1 l-\nu_2 m; \rho_1, \ldots, \rho_r)_{g=0,n-1}, (bj, \beta_j^{(1)}, \ldots, \beta_j^{(r)})_{1,q} \\ z_r x^{\rho_r} a^{\sigma_r} b^{-\delta_r} & (d_j^{(1)}, \delta_j^{(1)})_{1,q_1}, \ldots\ldots, (d_j^{r}, \delta_j^{(r)})_{1,q_r} \end{array}\right]$$

Provided (in addition to appropriate convergence and existing condition) that

$\min\{\upsilon_1, \upsilon_2, \rho_i, \sigma_i, \delta_i\} > 0 \qquad (i = 1, \ldots, r);$

$\max\{|\arg(x^{\upsilon_1}/a)|, |\arg(x^{\upsilon_2}/b)|\} < \Pi$

$$\mathrm{Re}(k) + \prod_{i=1}^{r} k_i\, \xi_i > -1$$

Where ξ_i = (i = 1,…..,r) .

Proof:

$$D^{n}_{k,\alpha,x}\{x^{t}\,(x^{\upsilon_1}+a)^{\lambda_1}\,(b-x^{\upsilon_2})^{-\delta_1}\,(x^{\upsilon_3}+c)^{\lambda_2}\,(d-x^{\upsilon_4})^{-\delta_2}$$

$$H\,[z_1 x^{\rho_1}(x^{\upsilon_1}+a)^{\sigma_1}(b-x^{\upsilon_2})^{-\delta_1}(x^{\upsilon_3}+c)^{\sigma_2}(d-x^{\upsilon_4})^{-\delta_2},\ldots\ldots,z_r\,x^{\rho_r}(x^{\upsilon_1}+a)^{\sigma_r}(b-x^{\upsilon_2})^{-\delta_r}(x^{\upsilon_3}+c)^{\sigma_r}(d-x^{\upsilon_4})^{-\delta_r}\,]\}$$

$$= a^{\lambda_1} b^{-\delta_1} c^{\lambda_2} d^{-\delta_2}\, x^{t+nk} \sum_{k,l,m,n=0}^{\infty} \frac{(x^{\upsilon_1}/a)^k\,(x^{\upsilon_2}/b)^l\,(x^{\upsilon_3}/c)^m\,(x^{\upsilon_4}/d)^n}{k!\,l!\,m!\,n!}\, H^{0,n+n+4:k_1 l_1 m_1 n_1,\ldots\ldots\ldots,k_r l_r m_r n_r}_{p+n+4,q+n+4:p_1,q_1,\ldots\ldots\ldots\ldots,p_r,q_r}$$

$$\left[\begin{array}{c|c} z_1 x^{\rho_1} a^{\sigma_1} b^{-\delta_1} c^{\sigma_2} b^{-\delta_2} & (-\lambda,\sigma_1,.,\sigma_r),(1-\delta-k-m,\delta_1,\ldots,\delta_r),(-t-gk-\nu_1 k-\nu_2 l-\nu_3 m-\nu_4 n;\rho_1,\ldots,\rho_r)_{g=0,n-1},(a_j,\alpha_j^{(i)},\ldots,\alpha_j^{(r)})_{1,p} \\ . & :(c_j^{(1)},\gamma_j^{(1)})_{1,P_1},\ldots\ldots,(c_j^{(r)},\gamma_j^{(r)})_{1,P_r} \\ . & (-\lambda+l,\sigma_1,.,\sigma_r),(1-\delta,\delta_1,.,\delta_r),(\alpha-t-gk-\nu_1 k-\nu_2 l-\nu_3 m-\nu_4 n;\rho_1,\ldots,\rho_r)_{g=0,n-1},(bj,\beta_j^{(1)},\ldots,\beta_j^{(r)})_{1,q} \\ z_r x^{\rho_r} a^{\sigma_r} b^{-\delta_r} c^{\sigma_r} d^{-\delta_2} & :(d_j^{(1)},\delta_j^{(1)})_{1,q_1},\ldots\ldots,(d_j^{r},\delta_j^{(r)})_{1,q_r} \end{array}\right]$$

Provided (in addition to the appropriate convergence and existing condition) that

min $\{\upsilon_1,\upsilon_2,\upsilon_3,\upsilon_4,\rho_i,\sigma_i,\delta_i\} > 0$ (i = 1,….., r) ;

max $\{|\arg(x^{\upsilon_1}/a)|,\ |\arg(x^{\upsilon_2}/b)|,\ |\arg(x^{\upsilon_3}/c)|,\ |\arg(x^{\upsilon_4}/d)|\} < \Pi$

Re (k) + $\prod_{i=1}^{r} k_i\,\xi_i > -1$ Re (k) + $\prod_{i=1}^{r} k_i\,\xi_i > -1$

Where ξ_i = (i = 1,…..,r) .

Result (2)

$$D^{n}_{k,\alpha,x}\, D^{\mu}_{y}\{x^{t}\, y^{\lambda}\,(x^{\upsilon_1}+a)^{\lambda}\,(b-x^{\upsilon_2})^{-\delta}\,(y^{\upsilon_3}+c)^{h}\,(d-y^{\upsilon_4})^{-g}$$

$$H\,[z_1\, x^{\rho_1} y^{\lambda_1}(x^{\upsilon_1}+a)^{\sigma_1}(b-x^{\upsilon_2})^{-\delta_1}(y^{\upsilon_3}+c)^{h_1}(d-y^{\upsilon_4})^{-g_1},\ldots\ldots,z_r\, x^{\rho_r} y^{\lambda_r}(x^{\upsilon_1}+a)^{\sigma_r}(b-x^{\upsilon_2})^{-\delta_r}(y^{\upsilon_3}+c)^{h_r}(d-y^{\upsilon_4})^{-g_r}\,]\}$$

$$= a^{\lambda} b^{-\delta} c^{h} d^{-g}\, x^{t+nk} y^{\lambda-\mu} \sum_{l,m,r,s=0}^{\infty} \frac{(x^{\upsilon_1}/a)^l\,(x^{\upsilon_2}/b)^m\,(x^{\upsilon_3}/c)^r\,(x^{\upsilon_4}/d)^s}{l!\,m!\,r!\,s!}\, H^{0,n+n+5:m_1 n_1,\ldots\ldots\ldots,\ldots,m_r n_r}_{p+n+5,\ q+n+5:p_1,q_1,\ldots\ldots\ldots\ldots,p_r,q_r}$$

$$\left[\begin{array}{c|c} z_1 x^{\rho_1} y^{\lambda_1} a^{\sigma_1} b^{-\delta_1} c^{h_1} d^{-g_1} & (-\lambda,\sigma_1,..,\sigma_r),(1-\delta-m,\delta_1,\ldots,\delta_r),(-h,h_1,..,h_r),(1-g-t,g_1,..,g_r)(-\lambda-r\nu_3-s\nu_4;\lambda_1,..,\lambda_r) \\ . & (-t-gk-\nu_1 l-\nu_2 m;k_1,\ldots,k_r)_{g=0,n-1,}(a_j,\alpha_j^{(i)},\ldots,\alpha_j^{(r)})_{1,p}:(c_j^{(1)},\gamma_j^{(1)})_{1,P_1},\ldots\ldots,(c_j^{(r)},\gamma_j^{(r)})_{1,P_r} \\ . & (-\lambda+l,\sigma_1,..,\sigma_r),(1-\delta,\delta_1,..,\delta_r),(-h+r,h_1,..,h_r),(1-g,g_1,..,g_r)(-\lambda+\mu-r\nu_3-s\nu_4;\lambda_1,..,\lambda_r) \\ z_r x^{\rho_r} y^{\lambda_r} a^{\sigma_r} b^{-\delta_r} c^{h_r} d^{-g_r} & (\alpha-t-gk-\nu_1 l-\nu_2 m;k_1,\ldots,k_r)_{g=0,n-1},(b_j,\beta_j^{(1)},\ldots,\beta_j^{(r)})_{1,q}:(d_j^{(1)},\delta_j^{(1)})_{1,q_1},\ldots\ldots,(d_j^{r},\delta_j^{(r)})_{1,q_r} \end{array}\right]$$

provided (in addition to the appropriate convergence and existing condition) that

min $\{\upsilon_1,\upsilon_2,\upsilon_3,\upsilon_4,\rho_i,\sigma_i,\delta_i,h_i,g_i\} > 0$ (i = 1,….., r) ;

$$\max \{|\arg(x^{\upsilon_1}/a)|, |\arg(x^{\upsilon_2}/b)|, |\arg(y^{\upsilon_3}/c)|, |\arg(y^{\upsilon_4}/d|\} < \Pi$$

$\text{Re}(k) + \prod_{i=1}^{r} k_i \xi_i > -1 \quad \text{Re}(\lambda) + \prod_{i=1}^{r} \lambda_i \xi_i > -1$

Where $\xi_i = (i = 1, \ldots, r)$ are given in (14)

$$D_{k,\alpha,x}^{n} D_{y}^{\mu} D_{w}^{\eta}\{x^t y^{\lambda} w^{\gamma} (x^{\upsilon_1}+a)^{\lambda} (b - x^{\upsilon_2})^{-\delta} (y^{\upsilon_3}+c)^{h} (d - y^{\upsilon_4})^{-g} (w^{\upsilon_5}+e)^{\theta} (f - w^{\upsilon_6})^{-\varphi} H\, [z_1 x^{\rho_1} y^{\lambda_1} w^{\gamma_1} (x^{\upsilon_1}+a)^{\sigma_1} (b - x^{\upsilon_2})^{-\delta_1} (y^{\upsilon_3}+c)^{h_1} (d - y^{\upsilon_4})^{-g_1} (w^{\upsilon_5}+e)^{\theta_1} (f - w^{\upsilon_6})^{-\varphi_1}, \ldots, z_r x^{\rho_r} y^{\lambda_r} w^{\gamma_r} (x^{\upsilon_1}+a)^{\sigma_r} (b - x^{\upsilon_2})^{-\delta_r} (y^{\upsilon_3}+c)^{h_r} (d - y^{\upsilon_4})^{-g_r} (w^{\upsilon_5}+e)^{\theta_r} (f - w^{\upsilon_6})^{-\varphi_r}]\}$$

$$= a^{\lambda} b^{-\delta} c^{h} d^{-g} e^{\theta} f^{-\varphi} x^{t+nk}\, y^{\lambda-\mu} w^{\gamma-\eta} \sum_{k,l,m,n,r,s=0}^{\infty} \frac{(x^{\upsilon_1}/a)^k (x^{\upsilon_2}/b)^l (y^{\upsilon_3}/c)^m (y^{\upsilon_4}/d)^n (w^{\upsilon_5}/e)^r (w^{\upsilon_6}/f)^s}{k!\, l!\, m!\, n!\, r!\, s!} H^{0,n+n+7:m_1 n_1,\ldots,m_r n_r}_{p+n+7,q+n+7:p_1,q_1,\ldots,p_r,q_r}$$

$$\left[\begin{matrix} z_1 x^{\rho_1} y^{\lambda_1} a^{\sigma_1} b^{-\delta_1} c^{h_1} d^{-g_1} e^{\theta_1} f^{-\varphi_1} \\ \vdots \\ z_r x^{\rho_r} y^{\lambda_r} a^{\sigma_r} b^{-\delta_r} c^{h_r} d^{-g_r} e^{\theta_r} f^{-\varphi_r} \end{matrix} \left| \begin{matrix} (-\sigma,\sigma_1,..,\sigma_r),(1-\delta-m,\delta_1,.,\delta_r),(-h,h_1,.,h_r),(1-g-t,g_1,.,g_r),(-\theta,\theta_1,..,\theta_r)(-\lambda-r\nu_3-s\nu_4-\theta\nu_5-\varphi\nu_6 \\ ;\lambda_1,..,\lambda_r)(-t-gk-\nu_1 l-\nu_2 m;k_1,\ldots,k_r)_{g=0,n-1},(a_j,\alpha_j^{(i)},\ldots,\alpha_j^{(r)})_{1,p}:(c_j^{(1)},\gamma_j^{(1)})_{1,P_1},\ldots,(c_j^{(r)},\gamma_j^{(r)})_{1,P_r} \\ (-\sigma+l,\sigma_1,.,\sigma_r),(1-\delta,\delta_1.,\delta_r),(-h+r,h_1.,h_r),(1-g,g_1,.,g_r)(-\theta+r,,\theta_1,.,\theta_r)(-\lambda+\mu-r\nu_3-s\nu_4-\theta\nu_5-\varphi\nu_6 \\ ;\lambda_1,..,\lambda_r)(\alpha-t-gk-\nu_1 l-\nu_2 m;k_1,\ldots,k_r)_{g=0,n-1},(b_j,\beta_j^{(1)},\ldots,\beta_j^{(r)})_{1,q}:(d_j^{(1)},\delta_j^{(1)})_{1,q_1},\ldots,(d_j^{r},\delta_j^{(r)})_{1,q_r} \end{matrix}\right.\right]$$

Provided (in addition to the appropriate convergence and existing condition) that

$$\min\{\upsilon_1, \upsilon_2, \upsilon_3, \upsilon_4, \upsilon_5, \upsilon_6, \rho_i, \sigma_i, \delta_i, h_i, g_i, \theta_i, \varphi_i\} > 0 \qquad (i = 1, \ldots, r);$$

$$\max \{|\arg(x^{\upsilon_1}/a)|, |\arg(x^{\upsilon_2}/b)|, |\arg(y^{\upsilon_3}/c)|, |\arg(y^{\upsilon_4}/d|, |\arg(w^{\upsilon_5}/e)|, |\arg(w^{\upsilon_6}/f)|\} < \Pi$$

$\text{Re}(k) + \prod_{i=1}^{r} k_i \xi_i > -1 \quad \text{Re}(\lambda) + \prod_{i=1}^{r} \lambda_i \xi_i > -1 \quad \text{Re}(\gamma) + \prod_{i=1}^{r} \gamma_i \xi_i > -1$

Where $\xi_i = (i = 1, \ldots, r)$.

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