Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

ISSN NO. 2320-5407

Article DOI: 10.21474/IJAR01/3318
DOI URL: http://dx.doi.org/10.21474/IJAR01/3318

RESEARCH ARTICLE

WEYL FRACTIONAL DERIVATIVE OF THE PRODUCT MULTIVARIABLES POLYNOMIALS AND I –FUNCTION.

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Manuscript Info

Manuscript History

Received: 20 December 2016
Final Accepted: 28 January 2017
Published: February 2017

Key words:-
Weyl fractional derivative operator, multivariable polynomials and I-function

Abstract

In this research work , we establish a theorem on Weyl fractional derivative of the product multivariable polynomials and I –function . Certain special cases of our theorem have been discussed .
Mathematics Subject classification - 26A33,33C 60 , 44A15.

Introduction:-

The I- function of the one variable is defined by Saxena (1982) and we will represent here in the following manner:

(1.1) $$I[z] = I^{m,n}_{p_i,q_i;r}[z] = I^{m,n}_{p_i,q_i;r}\left[z\left|\begin{matrix}\ldots,\ldots\\ \ldots,\ldots\end{matrix}\right.\right] = I^{m,n}_{p_i,q_i;r}\left[z\left|\begin{matrix}(a_j,e_j)_{1,n}; & (a_{ji},e_{ji})_{n+1,pi}\\ (b_j,f_j)_{1,m}; & (b_{ji},f_{ji})_{m+1,qi}\end{matrix}\right.\right]$$

(1.2) $$= \frac{1}{2\pi i}\int_L \theta(s)\, z^s ds,$$

where $i=\sqrt{(-1)}, z(\neq 0)$ is a complex variable and (1.2) $z^s = \exp[s\{\log|z| + i\arg z\}]$.In which log |z| represent the natural logarithm of |z| and arg |z| is not necessarily the principle value. An empty product is interpreted as unity. Also,

(1.3) $$\theta(s) = \frac{\prod_{j=1}^{m}\Gamma(b_j - f_j s)\prod_{j=1}^{n}\Gamma(1-a_j+e_j s)}{\sum_{i=1}^{r}\left[\prod_{j=m+1}^{q_i}\Gamma(1-b_{ji}+f_{ji}s)\prod_{j=n+1}^{p_i}\Gamma(a_{ji}-e_{ji}s)\right]},$$ m,n,p_i and $q_i \forall i \in (1,\ldots r)$ are non-negative integers satisfying $0\le n\le p_i,\ 0\le m\le q_i; \forall i\in\{1,\ldots,r\}, e_{ji},(j=1,\ldots,p_i;i=1,\ldots r)$ and $f_{ji},(j=1,\ldots,q_i;i=1,\ldots r)$ are assumed to be positive quantities for standardization purpose. Also $a_{ji},(j=1,\ldots,p_i;\ i=1,\ldots r)$ and $b_{ji},(j=1,\ldots,q_i;\ i=1,\ldots,r)$ are complex numbers such that none of the points.

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(1.4) $S = \left\{ (b_n + v) \middle| f_h \right\}, h = 1,\ldots,m; v = 0,1,2,\ldots,$

which are the poles of $\Gamma(b_h - f_h s), h = 1,\ldots,m$ and the points

(1.5) $S = \left\{ (a_l - n - 1) \middle| e_l \right\} l = 1,\ldots,n; \eta = 0,1,2,\ldots,$

Which poles are of $\Gamma(1 - a_l + e_l s)$ coincide with one another, i.e. with

(1.6) $e_l(b_n + v) \neq b_n(a_l - \eta - 1)$,

for $v, \eta = 0,1,2,\ldots;\ h = 1,\ldots,m; l = 1,\ldots,n$.

Further, the contour L runs from $-i_\infty$ to $+i_\infty$. Such that the poles of $\Gamma(b_n - s)$,$h = 1,\ldots,m$; lie to the right of L and the poles $\Gamma(1 - a_l + e_l s),\ l = 1,\ldots,n$ lie to the left of L. The integral converges, if |argz| $< \frac{1}{2} B\pi, B > 0, A \leq 0$, where

(1.7) $A = \sum_{j=1}^{p_i} e_{ji} - \sum_{j=1}^{q_i} f_{ji}$ and

(1.8) $B = \sum_{j=1}^{n} e_j - \sum_{j=n+1}^{p_i} e_{ji} + \sum_{j=1}^{m} f_j - \sum_{j=m+1}^{q_i} f_{ji} \quad \forall i \in (1,\ldots,r)$,

Let A denote a class of good functions. By good function f, we mean Miller [1975, p.82] a function which is everywhere differentiable any number of times and if it is all of its derivatives are $0(x^{-\upsilon})$, for all υ as x in increases without limit. We define the Weyl fractional derivatives of a function g(z) as follows:-

Let $g \in A$, then for $q < 0$,

(1.9) $${}_zW_\infty^q g(z) = \frac{(-1)^q}{\Gamma(-q)} \int_z^\infty (u - z)^{-q-1} g(u) du.$$

For $q \geq 0$

(1.10) $${}_zW_\infty^q g(z) = \frac{d^n}{dz^n} ({}_zW_\infty^{q-n} g(z)),$$

n being positive integer, such that $n > q$.

The general class of multivariable polynomials is defined by Srivastava and Garg [1987]:

(1.11) $$S_{\mathrm{L}}^{h_1,\ldots,h_r}[x_1,\ldots,x_r] = \sum_{k_1,\ldots,k_r=0}^{h_1k_1+\ldots+h_rk_r \leq \mathrm{L}} (-\mathrm{L})_{h_1k_1+\ldots+h_rk_r} A(\mathrm{L}; k_1,\ldots,k_r) \frac{x_1^{k_1}}{k_1!} \cdots \frac{x_r^{k_r}}{k_r!},$$

where $h_1,\ldots,h_r$ are positive integers and the co-efficient $A(\mathrm{L}; k_1,\ldots,k_r)$, ($\mathrm{L}$; $h_1 \in \mathrm{N}$; $i = 1,\ldots,r$) are arbitrary constant, real or complex.

Evidently the case $r = 1$ of the polynomials (1.11).

Would correspond the polynomials given by Shrivastava [1972]

(3.1.2) $$S_{\mathrm{L}}^{h}[x] = \sum_{k=0}^{[L,h]} \frac{(-\mathrm{L})_{hk}}{k!} A_{\mathrm{L},k}\, x^k \left\{ \mathrm{L} \in N = (0,1,2,\ldots) \right\},$$

where h is arbitrary positive integers and the co-efficient $A_{\mathrm{L},k} (\mathrm{L}, k \geq 0)$ are arbitrary constant, real or complex.

Mathematical pre-requisites:-

To establish the main result, we need the following integral of the H-function by SaigÖ[1992]:

(2.1) $$\int_x^\infty t^{\rho-1}(t-x)^{\sigma-1} \mathrm{I}_{p_i,q_i;r}^{m,n}\left[zt^{\mu}\left(t-x\right)^{\upsilon}\left|\begin{matrix}(a_j,e_j)_{1,n};(a_{ji},e_{ji})_{n+1,p_i}\\(b_j,f_j)_{1,m};(b_{ji},f_{ji})_{m+1,q_i}\end{matrix}\right.\right]dt$$

$$= x^{\rho+\sigma-1}\mathrm{I}_{p_i+2,q_i+1;r}^{m+1,n+1}\left[zx^{\mu+\upsilon}\left|\begin{matrix}(1-\sigma,\upsilon),(a_j,e_j)_{1,n};(a_{ji},e_{ji})_{n+1,p_i},(1-\rho,\mu)\\(1-\rho-\sigma,\mu+\upsilon),(b_j,f_j)_{1,m};(b_{ji},f_{ji})_{m+1,q_i}\end{matrix}\right.\right],$$

where

(i) ρ,σ are complex numbers and μ, υ are positive real numbers,

(ii) $|\arg z| < \frac{1}{2}A\pi$, A defined as

$$A=\sum_{j=1}^{p_i} e_{ji} - \sum_{j=1}^{q_i} f_{ji},$$

(iii) $$\min\left[\mathrm{Re}\left(\frac{1-\rho-\sigma}{\mu-\nu}\right),\min 1\le j\le m\left[\mathrm{Re}\left(\frac{b_j}{f_j}\right)\right]\right]>$$

$$\max\left[-\mathrm{Re}\left(\frac{\sigma}{\nu}\right),\max 1\le j\le N\left[\mathrm{Re}\left(\frac{a_j-1}{e_j}\right)\right]\right].$$

Weyl Fractional Derivatives Of The Product Of Multivariable Polynomials And I-Function.
Theorem.

Let m,n,p_i and q_i be non-negative integers such that $0\le n\le p_i, 0\le m\le q_i$ and $\sum_{j=1}^{n}e_j - \sum_{j=n+1}^{p_i}e_{ji} + \sum_{j=1}^{m}f_j - \sum_{j=m+1}^{q_i}f_{ji} > 0$ together with the set of conditions (i) – (iii) given with equation (2.1). Then, for all value of q,

(3.1) $${}_zW_\infty^q\left\{x^{\rho-1}(z-x)^{\sigma-1}S_L^{h_1,\ldots,h_r}\left[c_1x^{\delta_1},\ldots,c_rx^{\delta_r}\right]\right.$$

$$\left.\times\mathrm{I}_{p_i,q_i;r}^{m,n}\left[yx^{\mu}(x-z)^{\upsilon}\left|\begin{matrix}(a_j,e_j)_{1,n};(a_{ji},e_{ji})_{n+1,p_i}\\(b_j,f_j)_{1,m};(b_{ji},f_{ji})_{m+1,q_i}\end{matrix}\right.\right]\right\}$$

$$=\frac{(-1)^{q+\sigma-1}}{\Gamma(-q)}z^{\rho+\sigma-q-\sum_{i=1}^{r}k_i\delta_i-2}\sum_{k_1,\ldots,k_r=0}^{h_1k_1+\ldots+h_rk_r\le L}(-L)_{h_1k_1+\ldots+h_rk_r}A(L;k_1,\ldots,k_r)\frac{c_1^{k_1}}{k_1!}\cdots\frac{c_r^{k_r}}{k_r!}$$

$$\times\mathrm{I}_{p_{i+2}.q_{i+1};r}^{m+1,n+1}\left[yz^{\mu+\upsilon}\left|\begin{matrix}(2-\sigma+q,\upsilon),(a_j,e_j)_{1,n};(a_{ji},e_{ji})_{n+1,p_i},(1-\rho-\sum_{i=1}^{r}k_i\delta_i,\mu)\\(2+q-\rho-\sigma-\sum_{i=1}^{r}k_i\delta_i,\mu+\upsilon),(b_j,f_j)_{1,m};(b_{ji},f_{ji})_{m+1,q_i}\end{matrix}\right.\right].$$

Proof : Taking left hand side of equation (3.1)and using equation (1.11), we get

(3.2) $${}_zW_\infty^q\left\{x^{\rho+\sum_{i=1}^{r}k_i\delta_i-1}(z-x)^{\sigma-1}\sum_{k_1,\ldots,k_r=0}^{h_1k_1+\ldots+h_rk_r\le L}(-L)_{h_1k_1+\ldots+h_rk_r}A(L;k_1,\ldots,k_r)\frac{c_1^{k_1}}{k_1!}\cdots\frac{c_r^{k_r}}{k_r!}\right.$$

$$\left.\times\mathrm{I}_{p_i,q_i;r}^{m,n}\left[yx^{\mu}(x-z)^{\upsilon}\left|\begin{matrix}(a_j,e_j)_{1,n};(a_{ji},e_{ji})_{n+1,p_i}\\(b_j,f_j)_{1,m};(b_{ji},f_{ji})_{m+1,q_i}\end{matrix}\right.\right]\right\},$$

Now using equation (1.9) and definition of I – function, easily we can find the proof of equation (3.1).

For q ≥ 0 invoking the definition (1.10) the relation (3.2) further reduces to

$$= \sum_{k_1,\ldots,k_r=0}^{h_1k_1+\ldots+h_rk_r\le L} (-L)_{h_1k_1+\ldots+h_rk_r} A(L;k_1,\ldots,k_r)\frac{c_1^{k_1}}{k_1!}\cdots\frac{c_r^{k_r}}{k_r!}\frac{(-1)^{q+r+\sigma-1}}{\Gamma(r-q)}\frac{d^r}{dz^r}\left\{ z^{\rho+\sigma-q+r-\sum_{i=1}^{r}k_i\delta_i-2}\right.$$

$$\left.\times I^{m+1,n+1}_{p_{i+2}.q_{i+1};r}\left[yz^{\mu+\upsilon}\left| \begin{matrix}(2-\sigma-r+q,\upsilon),(a_j,e_j)_{1,n};(a_{ji},e_{ji})_{n+1,p_i},(1-\rho-\sum_{i=1}^{r}k_i\delta_i,\mu)\\ (2+q-\rho-\sigma-\sum_{i=1}^{r}k_i\delta_i,\mu+\upsilon),(b_j,f_j)_{1,m};(b_{ji},f_{ji})_{m+1,q_i}\end{matrix}\right.\right]\right\}$$

In replacing of (q - r) by q , we may obtain again

$$= \frac{(-1)^{q+\sigma-1}}{\Gamma(-q)} z^{\rho+\sigma-q-\sum_{i=1}^{r}k_i\delta_i-2} \sum_{k_1,\ldots,k_r=0}^{h_1k_1+\ldots+h_rk_r\le L} (-L)_{h_1k_1+\ldots+h_rk_r} A(L;k_1,\ldots,k_r)\frac{c_1^{k_1}}{k_1!}\cdots\frac{c_r^{k_r}}{k_r!}$$

$$\times I^{m+1,n+1}_{p_{i+2}.q_{i+1};r}\left[yz^{\mu+\upsilon}\left| \begin{matrix}(2-\sigma+q,\upsilon),(a_j,e_j)_{1,n};(a_{ji},e_{ji})_{n+1,p_i},(1-\rho-\sum_{i=1}^{r}k_i\delta_i,\mu)\\ (2+q-\rho-\sigma-\sum_{i=1}^{r}k_i\delta_i,\mu+\upsilon),(b_j,f_j)_{1,m};(b_{ji},f_{ji})_{m+1,q_i}\end{matrix}\right.\right].$$

Special Case : If we put r=1 in the general call of multivariable polynomials given by Srivastava and Garg [1987] reduces to the polynomials given by Srivastava [1972] and I- function reduces into Fax's H – function as follows :

(4.1)
$$ {}_zW_\infty^q\left\{ {}_zW_\infty^q\left\{x^{\rho-1}(z-x)^{\sigma-1}S_{\mathrm{L}}^h\left[x^k\right]\times H^{m,n}_{p,q}\left[yx^{\mu}(x-z)^{\upsilon}\left| \begin{matrix}(a_1,e_1)_{1,p}\\ (b_1,f_1)_{1,q}\end{matrix}\right.\right]\right\}\right\}$$

$$= \frac{(-1)^{q+\sigma-1}}{\Gamma(-q)} z^{\rho+\sigma-q-k-2}\sum_{k=0}^{[L,k]}\frac{(-\mathrm{L})_{hk}}{k!}A_{\mathrm{L},k}\times H^{m+1,n+1}_{p+2,.q+1}\left[yz^{\mu+\upsilon}\left| \begin{matrix}(2-\sigma+q,\upsilon),(a_j,e_j)_{1,p},(1-\rho-k,\mu)\\ (2+q-\rho-\sigma-k,\mu+\upsilon),(b_j,f_j)_{1,q}\end{matrix}\right.\right].$$

Replacing υ by –υ equation (3.3) correspond to the following result according as μ > υ, μ < υ and μ = υ, i.e. for μ > υ

(4.2)
$$ {}_zW_\infty^q\left\{ {}_zW_\infty^q\left\{x^{\rho-1}(z-x)^{\sigma-1}S_{\mathrm{L}}^h\left[x^k\right]\times H^{m,n}_{p,q}\left[yx^{\mu}(x-z)^{-\upsilon}\left| \begin{matrix}(a_1,e_1)_{1,p}\\ (b_1,f_1)_{1,q}\end{matrix}\right.\right]\right\}\right\}$$

$$= \frac{(-1)^{q+\sigma-1}}{\Gamma(-q)} z^{\rho+\sigma-q-k-2}\sum_{k=0}^{[L,h]}\frac{(-\mathrm{L})_{hk}}{k!}A_{\mathrm{L},k}$$

$$\times H^{m+2,n}_{p+1,.q+2}\left[yz^{\mu-\upsilon}\left| \begin{matrix}(a_j,e_j)_{1,p},(1-\rho-k,\mu)\\ (2+q-\rho-\sigma-k,\mu-\upsilon),(\sigma-q-1,\upsilon),(b_j,f_j)_{1,q}\end{matrix}\right.\right]$$

For $\mu < \upsilon$

(4.3)
$$ {}_zW_\infty^q\left\{ {}_zW_\infty^q\left\{x^{\rho-1}(z-x)^{\sigma-1}S_{\mathrm{L}}^h\left[x^k\right]\times H^{m,n}_{p,q}\left[yx^{\mu}(x-z)^{-\upsilon}\left| \begin{matrix}(a_1,e_1)_{1,p}\\ (b_1,f_1)_{1,q}\end{matrix}\right.\right]\right\}\right\}$$

$$= \frac{(-1)^{q+\sigma-1}}{\Gamma(-q)} z^{\rho+\sigma-q-k-2}\sum_{k=0}^{[L,h]}\frac{(-\mathrm{L})_{hk}}{k!}A_{\mathrm{L},k}$$

$$\times H^{m+1,n+1}_{p+2,.q+1}\left[yz^{\mu-\upsilon}\left| \begin{matrix}(\rho+\sigma-q+k-1,\upsilon-\mu),(a_j,e_j)_{1,p},(1-\rho-k,\mu)\\ (\sigma-q-1,\upsilon),(b_j,f_j)_{1,q}\end{matrix}\right.\right]$$

and $\mu = \upsilon$

(4.5)
$$ {}_zW_\infty^q\left\{ {}_zW_\infty^q\left\{x^{\rho-1}(z-x)^{\sigma-1}S_{\mathrm{L}}^h\left[x^k\right]\times H\begin{matrix}m,n\\p,q\end{matrix}\left[yx^{\mu}(x-z)^{-\upsilon}\left|\begin{matrix}(a_1,e_1)_{1,p}\\(b_1,f_1)_{1,q}\end{matrix}\right.\right]\right\}\right. $$

$$ =\frac{(-1)^{q+\sigma-1}\Gamma(2-q-\rho-k)}{\Gamma(-q)}z^{\rho+\sigma-q-k-2}\sum_{k=0}^{[L,h]}\frac{(-\mathrm{L})_{hk}}{k!}A_{\mathrm{L},k} $$

$$ \times H_{p+1,.q+1}^{m+1,n}\left[y\left|\begin{matrix}(a_j,e_j)_{1,p},(1-\rho-k,\mu)\\(\sigma-q-1,\upsilon),(b_j,f_j)_{1,q}\end{matrix}\right.\right]. $$

Finally writing $-\mu$ instead of μ, equation (3.3) yields the following results according as $\mu>\upsilon$, $\mu<\upsilon$ and $\mu=\upsilon$ respectively.

For $\mu>\upsilon$

(4.6)
$$ {}_zW_\infty^q\left\{x^{\rho-1}(z-x)^{\sigma-1}S_{\mathrm{L}}^h\left[x^k\right]\times H\begin{matrix}m,n\\p,q\end{matrix}\left[yx^{-\mu}(x-z)^{\upsilon}\left|\begin{matrix}(a_1,e_1)_{1,p}\\(b_1,f_1)_{1,q}\end{matrix}\right.\right]\right\} $$

$$ =\frac{(-1)^{q+\sigma-1}}{\Gamma(-q)}z^{\rho+\sigma-q-k-2}\sum_{k=0}^{[L,h]}\frac{(-\mathrm{L})_{hk}}{k!}A_{\mathrm{L},k} $$

$$ \times H_{p+2,.q+1}^{m,n+2}\left[yz^{-\mu+\upsilon}\left|\begin{matrix}(q-\rho-\sigma-k+1,\mu-\upsilon),(2+q-\sigma,\upsilon),\ (a_j,e_j)_{1,p}\\(b_j,f_j)_{1,q},(\rho+k,\mu)\end{matrix}\right.\right] $$

for $\mu<\upsilon$

(4.7)
$$ {}_zW_\infty^q\left\{ {}_zW_\infty^q\left\{x^{\rho-1}(z-x)^{\sigma-1}S_{\mathrm{L}}^h\left[x^k\right]\times H\begin{matrix}m,n\\p,q\end{matrix}\left[yx^{-\mu}(x-z)^{\upsilon}\left|\begin{matrix}(a_1,e_1)_{1,p}\\(b_1,f_1)_{1,q}\end{matrix}\right.\right]\right\}\right. $$

$$ =\frac{(-1)^{q+\sigma-1}}{\Gamma(-q)}z^{\rho+\sigma-q-k-2}\sum_{k=0}^{[L,h]}\frac{(-\mathrm{L})_{hk}}{k!}A_{\mathrm{L},k} $$

$$ \times H_{p++,.q+1}^{m+1,n+1}\left[yz^{-\mu+\upsilon}\left|\begin{matrix}(2-\sigma+q,\upsilon),(a_j,e_j)_{1,p}\\(2+q-\rho-\sigma-k,\upsilon-\mu),(b_j,f_j)_{1,q},(\rho+k,\mu)\end{matrix}\right.\right] $$

and for $\mu=\upsilon$

(4.8)
$$ {}_zW_\infty^q\left\{ {}_zW_\infty^q\left\{x^{\rho-1}(z-x)^{\sigma-1}S_{\mathrm{L}}^h\left[x^k\right]\times H\begin{matrix}m,n\\p,q\end{matrix}\left[yx^{-\mu}(x-z)^{\upsilon}\left|\begin{matrix}(a_1,e_1)_{1,p}\\(b_1,f_1)_{1,q}\end{matrix}\right.\right]\right\}\right. $$

$$ =\frac{\Gamma(2-\rho-k-\sigma+q)\ \ (-1)^{q+\sigma-1}}{\Gamma(-q)}z^{\rho+\sigma-q-k-2}\sum_{k=0}^{[L,h]}\frac{(-\mathrm{L})_{hk}}{k!}A_{\mathrm{L},k} $$

$$ \times H_{p+2,.q+1}^{m+1,n+1}\left[yz^{\mu+\upsilon}\left|\begin{matrix}(2-\sigma+q,\upsilon),(a_j,e_j)_{1,p},(1-\rho-k,\mu)\\(2+q-\rho-\sigma-k,\mu+\upsilon),(b_j,f_j)_{1,q}\end{matrix}\right.\right]. $$

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