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Recent Advances in Kushare and Soham Transform

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Abstract: Integral transforms are used efficiently for handling diverse problems and have been utilized to convert complicated problems to simple one and obtain exact solution of the problem easily. Now a day's researchers are engaged in developing new integral transforms. Kushare transform and Soham transform are introduced in September and October 2021. In this paper we take review about where these transforms are used since they are introduced.

Key words: Integral transform; Kushare transform; Soham transform

I. INTRODUCTION:

Integral transforms play very important role in solving numerous problems on differential equations, integral equations, difference equations , integro differential equations and systems of such equations. Integral transform converts equation from complicated form to simple form and easily obtain the solution of the problem. Lot of integral transforms have been developed by many researchers by taking various Kernels and on different domains. Recently Kushare transform and Soham transform have been introduced. As researchers are interested in introducing the new integral transforms at the same time they are also interested in applying the transforms to various fields, various equations in different domain. Newton's law of Cooling is solved by using Kushare transform [1], Emad- Falih transform [23], Soham transform [24], HY integral transform [25]. D. P. Patil, et al [1] used Kushare transform, HY integral transform[26], Emad Sara transform [27], Alenzi transform [28], Emad Falih transform[29], Kharrat Toma transform [30], KKAT transform[31], ARA transform[32], Rangaig integral transform[33] and KKA transform [34] for solving the problems on population growth and decay.

D.P. Patil [35] also used Sawi transform in Bessel functions. Further, Patil [36] evaluate improper integrals by using Sawi transform of error functions. Laplace transforms and Shehu transforms are used in chemical sciences by Patil [37]. Dinkar Patil [38] used Sawi transform and its convolution theorem for solving wave equation. Using Mahgoub transform, parabolic boundary value problems are solved by D .P. Patil [39]. D .P. Patil [40] used double Laplace and double Sumudu transforms to obtain the solution of wave equation. Further Dr. Patil [41] also obtained dualities between double integral transforms. The system of differential equations is solved by using Emad Sara transform [42]. D. P. Patil [43] used Aboodh and Mahgoub transforms to solve boundary value problems of the system of ordinary differential equations. Double Mahgoub transformed is used by Patil [44] to solve parabolic boundary value problems. Laplace, Sumudu , Aboodh , Elazki and Mahagoub transforms are compared and used it for solving boundary value problems by Dinkar Patil [45]. D. P. Patil et al obtained solution of Volterra Integral equations of first kind by using, Anuj transform [46] Emad Sara transform[47] and Emad-Falih transform [48] are used for solving telegraph equation. Kandalkar, Zankar and Patil [57] evaluate the improper integrals by using general integral transform of error function. Dinkar Patil, Prerana Thakare and Prajakta Patil [49] obtained the solution of parabolic boundary value problems by using double general integral transform. Raundal and Patil [50] used double general integral transform for solving boundary value problems in partial differential equations. Rahane, et al [51] developed generalized double rangaig integral transform. Patil et al [52] used new general integral transform [53] to solve Abel's integral equations. Thakare and Patil [54] used general integral transform for solving mathematical models from health sciences NE transform is used in mechanics [55]. KAJ transform is used to solve stochastic differential equations [56]. Models in health sciences [59] and environmental sciences [58] are solved by using integral transforms.

In this paper we take survey of where these two transforms have been used.

Paper is organized as follows; Introduction is in first section, Second section is for review of Kushare transform and review of Soham transform is conducted in third section.

II. REVIEW OF KUSHARE TRANSFORM:

Sachin R .Kushare, Dinkar P. Patil, Archana M. Takate[1] introduced the integral transform named as kushare transform in sept.2021. It is defined as follows:

The new integral transform said to be KUSHARE change characterized for capacity of outstanding characterized by, $A = \left\{f(t), \exists M\tau_1\tau_2 > 0, |f(t)| < Me^{\frac{|t|}{w}}, if\ t \in (-1)^j \times (0,\infty)\right\}$

The purpose of this study is to show the applicability of this interesting new transform and operator S(v) defined by the integral equations: $K[f(t)] = S(V) = v\int_0^\infty f(t)e^{-tv^\alpha}dt$

Kushare Transform of some preliminary functions is stated in following table

Table No. :1

Title: Kushare Transform of functions

Sr No.	$f(t)$	$K(f(t))$
1	1	$\frac{1}{v^{\alpha-1}}$
2	t^n	$\frac{(n+1)}{v^{\propto(n+1)-1}}$
3	e^{at}	$\frac{v}{v^\alpha - a}$
4	$\sin(at)$	$\frac{av}{(v^{2\propto}+a^2)}$
5	$\cos(at)$	$\frac{v^{\propto+1}}{(v^{2\propto}+a^2)}$

Further authors obtained derivatives of transform as follows; if S(V) is Kushare transform of function f(t) then,

1.$K[f^n(t)] = v^{n\propto}s(v) - v\sum_{k=0}^{n-1} v^{\propto(n-k-1)}f^k(0)$

2. $K[f'(t)] = v^{\propto}s(v) - vf(0)$

3.$K\left[f''(t)\right] = v^{2\propto}s(v) - v^{\propto+1}f(0) - vf^{'(0)}$

This transform is used by many researchers for various problems.

In January 2022, Rohidas S. Sanap et al [2] used Kushare integral transform for solving the problems on newton's law of cooling. Equation of Newton's law of cooling is stated as follows

$$\frac{dT}{dt} = -c(T - T_e)$$

Further, problems on Growth and decay are solved by P. S. Nikam, S. D. Shirsath, A. T. Aher[3] in April 2022. The exponential growth and decay model is $\frac{dy}{dt} = ky$. Authors solved problems based on this law by using Kushare transform.

In July 2022, Dinkar P. Patil, Divya S. Patil, Kanchan S. Malunjkar[4] introduced New integral transform called as "Double Kushare Integral Transform" , which is defined as follows,

$$K_2[f(x,y)] = v\int_0^\infty\int_0^\infty f(x,y)e^{-(v_1^\propto + v_2^\propto y)}\,dx, dy$$

Sr. No.	f(x,y)	K$_2[f(x,y)]$
1	1	$\frac{v_1v_2}{v_1^\propto v_2^\propto}$
2	$exp(ax+by)$	$\frac{v_1v_2}{(v_1^\propto - a)(v_2^\propto - b)}$
3	$exp\left(i(ax+by)\right)$	$\frac{v_1v_2}{(v_1^\propto - ia)(v_2^\propto - ib)}$
4	$\cosh(ax+by)$	$\frac{1}{2}\left(\frac{v_1v_2}{(v_1^\propto - ia)(v_2^\propto - ib)} + \frac{v_1v_2}{(v_1^\propto + a)(v_2^\propto + b)}\right)$
5	$\sinh(ax+by)$	$\frac{1}{2}\left(\frac{v_1v_2}{(v_1^\propto - ia)(v_2^\propto - ib)} - \frac{v_1v_2}{(v_1^\propto + a)(v_2^\propto + b)}\right)$
6	$\cos(ax+by)$	$\frac{1}{2}\left(\frac{v_1v_2}{(v_1^\propto - ia)(v_2^\propto - ib)} + \frac{v_1v_2}{(v_1^\propto + ia)(v_2^\propto + ib)}\right)$
7	$\sin(ax+by)$	$\frac{1}{2i}\left(\frac{v_1v_2}{(v_1^\propto - ia)(v_2^\propto - ib)} - \frac{v_1v_2}{(v_1^\propto + ia)(v_2^\propto + ib)}\right)$
8	$(xy)^n, n > 0$	$\frac{\left((n+1)\right)^2}{(v_1^\propto v_2^\propto)^{\propto((n+1)-1)}}$
9	$x^m y^n, m > 0, n > 0$	$\frac{(m+1)(n+1)}{v_1^{\propto((n+1)-1)}v_2^{\propto((n+1)-1)}}$

Double Kushare transform of some preliminary functions are stated in following table , Table No.2

Transform of derivatives of function $f(x,y)$ is stated by the authors in following theorem.

Theorem:1 Let $f(x,y)$ be function of two variables. If the partial derivatives of first order $\frac{\partial f}{\partial x}$ and $\frac{\partial f}{\partial y}$ exists and $f(0,y)$, $f(x,0)$ exists then ,

$$K_2\left[\frac{\partial f}{\partial x}(x,y)\right] = -v_1 K\{f(0,y)\} + {v_1}^{\propto} K_2\{f(x,y)\}$$

and

$$K_2\left[\frac{\partial f}{\partial y}(x,y)\right] = -v_2 K\{f(x,0)\} + {v_2}^{\propto} K_2\{f(x,y)\}$$

Further authors used it to solve partial differential equations.

In July 2022, Dinkar P. Patil, Shweta L. Kandalkar and Nikita D. Gatkal[5] used kushare transform for solving the system of first order differential equations.

Further in July 2022, Dinkar P. Patil, Saloni K. Malpani, Prachi N. Shinde[6] developed Convolution theorem for Kushare Transform as follows;

Convolution theorem for Kushare Transform: If $F(v)$ and $G(v)$ are Kushare transform of functions $f(t)$ and $g(t)$ respectively, then

$K[f(t) * g(t)] = \frac{1}{v} K[f(t)].K[g(t)]$ where $*$ denotes convolution product.

Authors used Kushare transform and convolution theorem of Kushare transform for the solution of the Volterra integral equation of first kind. Convolution type Volterra integral equations of first kind as follows;

$$f(t) = \int_0^x k(x-t).h(t)dt$$

In Aug 2022, D. P. Patil [7] obtained Kushare transform of Error Functions in evaluating improper integrals, where Error function is defined as follows:

$$erf\sqrt{t} = \frac{2}{\sqrt{\pi}}\int_0^t e^{x^2}dx = \frac{2}{\sqrt{\pi}}\int_0^t \left[1 - x^2 + \frac{x^4}{4!} - \frac{x^6}{6!} + \cdots\right]dx$$

Kushare transform of this error functions is obtained and it is used to evaluate improper integrals.

In October 2022, Dinkar P. Patil, Poonam S. Nikam, Pragati D. Shinde[8] used Kushare transform for solving Faltung type Volterra-Integro-Differential equation of first kind. Faltung type Volterra integro-differential equation of first kind could be written as:

$\int_0^t (t-u)w(u)du + \int_0^t (t-u)^2 w^{'(v)}du = F(t),$

Where, $K_1(t-u)$ and, $K_2(t-u)$ are the faltung type kernel of integral equation.

Volterra Integro-Differential equations are of the following form:

$$U^n(x) = f(x) + \gamma \int_0^x k(x,t)U(t)dt$$

These equations are solved by using Kushare transform. In solving these problems, Kushare transform of function $tf(t)$ are required. This is proved in following equation.

$$K[tf(t)] = \left(\frac{-1}{\propto v^{\propto-1}}\right)\left[\frac{d}{dv} - \frac{1}{v}\right]s(v)$$

D.P.Patil et al [9] Evaluate the integrals containing Bessel's Function by using Kushare Transform in Nov-Dec.2022. Bessel's Function of order n is defined as follows:

$$J_n(t) = \frac{t^n}{2^n n!}\left[1 - \frac{t^2}{2(2n+2)} + \frac{t^4}{2.4.(2n+2)(2n+4)} - \frac{t^6}{2.4.6.(2n+2)(2n+4)(2n+6)} + \right]$$

D. P. Patil, G. K. Tile, Y. C. Mahajan [10] solved Abel's integral equations by using Kushare transform in January2023. Abel's integral equation is defined as:

$$f(x) = \int_{t=0}^{\infty} \frac{1}{\sqrt{(x-t)}} u(t)dt = \int_{t=0}^{\infty} (x-t)^{\frac{1}{2}} u(t)dt$$

Also, Dinkar P. Patil, Priyanka S. Wagh, Pratiksha Wagh[11] used of Kushare transform in Chemical Sciences in 2023 Author use this transform to solve problems in various branches of chemical sciences. As follows:

In organic chemistry: Saponification to produce ' homemade' soap model and Mixing problem in chemical sciences are solved .

Dinkar P. Patil, Sonal R. Borse, Darshana P. Kapadi[12] Kushare transform for the solution of Models in Health Sciences in January 2023.

Author use this transform to solve following Mathematics models in Health science.

Mathematical model - 1: A two compartment model for drug absorption and circulation through gastrointestinal tract and blood, which is represented by following system of initial value problem.

$$\frac{dc_1(t)}{dt} = -K_1 C_1(t); \quad c_1(0) = c_0$$

$$\frac{dc_2(t)}{dt} = K_1 C_1(t) - K_2 C_2(t); \quad c_2(0) = 0$$

Mathematical model - 2: Model for the intravenous drug and administration. It is represented by following initial value problem

$$\frac{dc_b(t)}{dt} = -(K_b + K_e)C_b + K_t C_t; \qquad c_b(0) = c_0$$

$$\frac{dc_t(t)}{dt} = K_b C_b(t) - K_t C_t; \qquad c_1(0) = c_0$$

D.P.Pantil et al[13] used Kushare integral transform to solve the problems from Mechanics, like simple harmonic motion.

III. REVIEW OF SOHAM TRANSFORM:

In this section we write the advances in Soham transform.

D. P. Patil, Savita Khakale[14] introduced the new integral transform called as "Soham transform" in oct 2021. Soham transform is defined as follows;

The new integral transform called the soham transform defined for function of exponential order we consider functions in the set B, defined by,

$$B = \{f(t): \exists M, k_1 k_2 > 0 |f(t)| < Me^{|t|kj}, if t \in (-1)^j \times [0, \infty)\}$$

For a given function in the set B the constant M must be finite number K_1, K_2 may be finite or infinite. Soham transform denote $\delta(.)$ defined by the integral equation:

$\delta[f(t)] = p(v) = \frac{1}{v}\int_0^\infty f(t)\, e^{-v^{\propto}t} dt$,

Soham transform of some preliminary functions are stated in following table:

Sr. No.	Function $f(t)$	Soham transform $\delta[f(t)]$
1	1	$\frac{1}{v^{2\propto+1}}$
2	t	$\frac{1}{v^{2\propto+1}}$
3	t^n	$\frac{\sqrt{(n+1)}}{v^{an+\propto+1}}$
4	e^{et}	$\frac{1}{v(v^{\propto}+a)}$
5	e^{-at}	$\frac{1}{v(v^{\propto}-a)}$
6	$\sin at$	$\frac{a}{v(v^{\propto}-a^2)}$
7	$\cos at$	$\frac{v^{\propto}}{v(v^{\propto}+a^2)}$
8	$\sinh at$	$\frac{av}{v^{2\propto}-a^2}$
9	$\cosh at$	$\frac{v^{\propto}}{v^{2\propto}-a^2}$

Inverse of the soham transform: Inverse Soham transform is denoted as follows:

If soham transform of function f(t) is p(v) then inverse Soham transform is defined as: $s^{-1}[p(v)] = f(t)$

Soham transform of derivatives of the function is stated by the authors as follows:

Let p(v) be the Soham transform of a function $f(t)$ i.e. $\delta[f(t)] = P(v)$ then,

1. $S[f'(t)] = v^{\propto}P(v) - \frac{1}{v}f(0)$
2. $S[f''(t)] = v^{2\propto}P(v) - v^{\propto-1}f(0) - \frac{1}{v}f'(0)$
3. $S[f^n(t)] = v^{n\propto}P(v) - \frac{1}{v}\sum_{k=0}^{n-1} v^{\propto(n-1-k)} f^k(0)$

Authors used Soham transform for solving ordinary differential equations.

D.P.Patil et al[15] used Soham transform for solving Volterra-Integral Equations of first kind in April 2022. The Convolution theorem for Soham transform is stated as follows:

The convolution of two functions f(t) and g(t) is $(f * g)(t) = \int_0^t (t-\tau)g(\tau)\,d\tau$ then , convolution theorem for Soham transform is $S(f * g)(t) = V\{F(v)G(v)\}$

The Bessel's function $J_n(t)$of order n is defined as,

$$J_n(t) = \sum_{r=0}^{\infty} \frac{(-1)^r}{r!\sqrt{n+r+1}}\left(\frac{t}{2}\right) n + 2r$$

The Bessel's function of zero order as,

J_0 (t): $\sum_{r=0}^{\infty}\frac{(-1)^r}{r!\sqrt{r+1}}\left(\frac{t}{2}\right)^{2r} = \sum_{r=0}^{\infty}\frac{-1^r}{r!^2}\left(\frac{t}{2}\right)^{2r} = 1\frac{t^2}{2^2} + \frac{t^4}{2^2\times4^2} - \frac{t^6}{2^2\times4^2\times6^2} + \cdots$

Soham transform of these Bessel functions is obtained by the authors

D. P. Patil, Shweta D. Rathi, Shrutika D. Rathi[16] used the new integral transform called as soham transform for system of differential equations in May2022.

Soham transform is used for obtaining solution of system of first order and degree differential equations. D. P. Patil, D. S.

Shirsath and V. S. Gangurde [17] used Soham transform for solving problems based on Newton's law of cooling in 2022.
Dinkar P. Patil, Priyanka S. Wagh, Pratiksha Wagh[18] Apllication of soham transform in chemical science 2022. Author use Soham transform in various branches of chemical science.In that paper author solved Saponification problem and concentration problems in his paper.
D. P. Patil, R. K. Godge [19] used soham transform for getting solution of laminar flow between parallel plates in January 2023.
Author solved the equation of motion of a viscous fluid: $\mu \ddot{U}(y) = \frac{dp}{dx}$
Patil Dinkar Pitambar, Wagh Shivali Nanasaheb, Bachhav Tejas Popat[20] obtain the Solution of Abel's integral equation by using Soham transform. Abel's integral equation is:

$$f(x) = \int_{t=0}^{x} \frac{1}{\sqrt{(x-t)}} u(t)\, dt = \int_{t=0}^{x} (x-t)^{\frac{-1}{2}} u(t) dt$$

Exact solution for Abel's integral equation is:

$$u(x) = \frac{1}{\pi}\left[\frac{d}{dx}\int_{t=0}^{x} \frac{1}{\sqrt{x}-t} f(t)\, dt\right]$$

Author used Soham transform for solving exact solution of Abel's integral equation. Dinkar P. Patil, Yashashri S. Suryawanshi, Mohini D. Nehete[21] Applied Soham transform for solving mathematical models occurring in Health science and Biotechnology in January 2023. In this paper authors solved following models,
Logistic Growth Model equation:

$$\frac{du}{dt} = u - f(u), u(0) = u_0$$

and the system of differential equations governing predator prey model,

$$\frac{du}{dt} = \mu - f(u, v)$$

$\frac{dv}{dt} = \beta[g(u, v) - v].$

Dinkar P. Patil, Shrutika D. Rathi, Shweta D. Rathi [22] used Soham transform for analysis of impulsive response of mechanical and electrical oscillators in January 2023.
The differential equation of mechanical oscillator is $\frac{d^2x}{dt^2} + 2a\frac{dx}{dt} + \omega^2 x(t) = g(t)$

The differential equation of electrical oscillator is $\frac{d^2Q}{dt^2} + 2a\frac{dQ}{dt} + \omega^2 Q(t) = g(t)$
Soham transform is used in mechanical (Damped) oscillator and electrical oscillators.

Conclusion: In this paper we collected all advances in Kushare and Soham transform till date.

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