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Optimization and Estimation of Transfer Function Model of Milk Evaporation Process

Vijaya N. Aher, Ganesh S. Sable, Minakshi R. Rajput

Abstract*: Development of Mathematical model has significant role in many applications such as estimation of relations between input and output variables. The relations can be deterministic or behavioral. From the point of view of control actions to be estimated for a particular application, behavioral model is considered to be of utmost importance. This also amounts the prediction of process behavior in time, frequency and complex domains. Here in this paper, attempts have been made to develop behavioral model of milk evaporation used in dairy industry which is of prominent importance in India because of its agriculture based economy. Besides India, there are also many milk producing countries in the world and their economy is dependent on milk producing animals. It is also imperative that excess milk production to be converted in its preservable form and evaporated milk has special significance in this context. The Milk evaporation is a complex process and its output control variables depend on many of its input manipulation variables. Because of its complex nature and many variables involved in it poses a challenge real life MIMO problem. In this paper, MIMO model of Milk evaporation model is estimated and described.

***Keywords:* Milk Evaporation, Mathematical Modeling, Deterministic Modeling, Behavioral Modeling, Transfer function, Process Dynamics, Material Balance, Energy Balance, Process Behavior.**

I. INTRODUCTION

Evaporation process is one of the important process [3] of dairy industry from the point of view of preservation of milk as the concentrated milk is less prone to spoilage. Further, the concentrated milk can be used as a raw material for many traditional Indian milk products. In dairy industry, falling film milk evaporation along with vacuum evaporation (also called as vacuum separators) is normally used for concentrating the milk. The main elements of milk processing equipment are as follows.

A. Falling Film Heat Exchanger

The milk to be concentrated is supplied to the top of the heating tubes and distributed in such a way as to flow down the inside of the tube walls as a thin film. The liquid film starts to boil due to the external heating of the tubes and is partially evaporated as a result. The downward flow, caused initially by gravity, is enhanced by the parallel, downward flow of the vapor formed.

A. Vapor Separator

It separates out liquid from the vapor which is subsequently used for the next evaporation stage while concentrated milk of first stage is again concentrated in next Stage.

B. Condenser

At the final stage of evaporation, vapors are sucked and condensed using cold water spray to create vacuum to achieve boiling at lower temperature. The process of milk evaporation is carried out in vacuum evaporators.

C. Milk Evaporation Process And Characterization

It has been observed milk evaporation is a complex process having many outputs and inputs and hence its characterization is much more complex. In this work, based on the process studies, process variables have been identified those are being used for characterizing the process of milk evaporation. Variables responsible for characterization of the process of milk evaporation are milk concentration (Percentage of solids with respect to total mass of the milk - ^{0}Bx), fat purity of milk (mass of fat component with respect to total solids in the milk-FPM) and pressure (vacuum used for lowering the boiling point of milk - P).

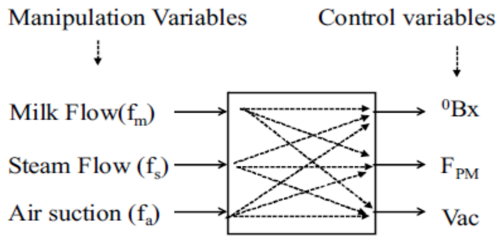

Fig. 1. Generic Milk Evaporation Process Model.

The milk evaporation is then controlled using three manipulation variables called as milk flow rate (f_m), steam flow rate (f_s) and air suction rate (f_a). As evident from the figure and process studies, output variables are dependant on many of input manipulation variables shows that the particular output variable under consideration cannot be controlled by its corresponding major manipulation variable. and variations in milk flow rate (fm), steam flow rate (f_s) and air suction rate (f_a) are reflected in milk concentration

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* Correspondence Author
Vijaya N. Aher*, Department of Electronics and Telecommunication, Maharashtra Institute of Technology, Aurangabad (MH), India. Email: vnaher@rediffmail.com
Ganesh S. Sable, Department of Electronics and Telecommunication, Maharashtra Institute of Technology, Aurangabad (MH), India. Email: sable.eesa@gmail.com
Minakshi R. Rajput, Department of Electronics and Telecommunication, P.E.S. College of Engineering, Aurangabad (MH), India. Email: meenakshiutsav@gmail.com

The changes in air suction rate are reflected in change of pressure in the Vessel which intern changes the boiling temperature of the milk. The complex nature of process is shown in Figure 1.

II. RELATED WORK

The model described in above section gives the dependence of output variables with input manipulation variables. It is now important to estimate of cross-links of the model.

A. Process Transfer Function Model

The model has been written down from the angle of estimation of process behavior and its use in control action to be provided for such process. The cross links are the transfer functions between respective input and output variables such as G^P_{11}, G^P_{12} , G^P_{13}; G^P_{21} , G^P_{22} , G^P_{23} ; G^P_{31}, G^P_{32} and G^P_{33}. The transfer function relations are per equations 1, 2 and 3.

$$G^P_{11} = B_x(s) \div f_m(s), G^P_{12} = B_x(s) \div f_s(s), G^P_{13} = B_x(s) \div f_a(s) \quad (1)$$

$$G^P_{2} = F_{PM}(s) \div f_m(s), G^P_{2} = F_{PM}(s) \div f_s(s), G^P_{2} = F_{PM}(s) \div f_a(s) \quad (2)$$

$$G^P_{31} = P(s) \div f_m(s), G^P_{32} = P(s) \div f_s(s), G^P_{33} = P(s) \div f_a(s) \quad (3)$$

The process transfer function matrix is then written as follows.

$$G^P = \begin{pmatrix} G^P_{11} & G^P_{12} & G^P_{13} \\ G^P_{21} & G^P_{22} & G^P_{23} \\ G^P_{31} & G^P_{32} & G^P_{33} \end{pmatrix} \quad (4)$$

Where G^P_{11}, G^P_{12} , $G^P_{13,}$ G^P_{21} , G^P_{22} , G^P_{23} , G^P_{31}, G^P_{32} and G^P_{33} are as shown in equations 1, 2 and 3.

Many authors have attempted to get the transfer function elements of process transfer function matrix based on various practical and theoretical methods. Different authors have adopted different techniques. For example Wang [15] used step response while Chih has attempted to get transfer function [16] based using partial pulse response data. For our problem, The elements Gij , (i = 1 to 3, j = 1 to 3) of the process transfer function matrix GP can be determined using both theoretical as well as practical methods involving experimental observation in the form of response of a variable with respect to time that forms the basis of computation individual transfer function elements Gij. Application of a typical method depends on how complex is the process from the understanding point of view. Many times the theoretical methods are impracticable and hence practical methods are adopted.

B. Theoretical Methods of Transfer Function Estimation

The theoretical methods make use of mass and energy balance equations to arrive at the results. In mass balance to total mass of material in the process is equivalent to a sum total of various input components received by the process. The processes always require energy for its operation in various forms of energy. In milk evaporation, the heat energy is used for concentrating milk. The energy input to the process is always equivalent to the sum total of energy used by process, heat retained by the process and heat output in terms of heat wasted or dissipated. Using mass and energy balance equations, differential equations related to the process are obtained which intern is used for deriving transfer function elements Gij. Major problem that exists in such calculations are the constants and its numerical values those pose major problems in finalizing the equations and under such circumstances, hence practical approaches are preferred.

C. Practical Methods of Transfer Function Estimation

Practical methods rely on experimental observations in which step input is applied to the process and response is obtained. Under such circumstances, graphical techniques are extensively applied to obtain the transfer elements of the process. For example, the step flow of milk is applied as an input to a milk evaporation process and milk concentration in terms of ^{0}Bx is observed to get transfer function element $G^P_{11}(s)$ (where i = 1 and j = 1) which is a member of overall process transfer function matrix and so on. The plotted transfer function response is then used for estimating the transfer element using one of the graphical methods[17] called Nichol's and Ziegler methods[18][19]. The other approach is to get transfer functions by curve fitting exercises based on experimental data.

III. ESTIMATION OF TRANSFER FUNCTION

The transfer function matrix consists of various transfer function elements those can be estimated using step response characteristics. Here in the case we have considered three output variables called concentration (Bx), Fat purity (FP) and pressure (P). The milk has various components such as fat (f), solid non fat (snf) and water (w), thus concentration of milk is written in the form of their individual masses such as Mf , Msnf and Mw as shown in equation 5.

$$B_x = (M_f + M_{snf}) \div (M_f + M_{snf} + M_w) \quad (5)$$

Similarly we define yet another term called as Fat Purity (FP) as a ratio of fat component (Mf) to the sum total of fat and solid non fat components (Mf +Msnf) as shown in equation 6.

$$F_P = (M_f) \div (M_f + M_{snf}) \quad (6)$$

The milk is boiled in a closed vessel at reduced pressure (Vacuum) in order to lower down its boiling temperature and normally the boiling is done at 600C by keeping a vacuum of 25 inches of Hg. Since boiling is affected by pressure (P), it is considered as third control variable.

A. Transfer functions between milk concentration (Bx) and Fat Purity (FP) with respect to milk flow rate (fm)

The response of milk concentration is obtained by writing mass balance equations where in Mass of milk in evaporator(M_m) is equal to the sum total of initial mass of milk in the vessel (M_{mi}) and milk added (M_{ma}) as time passes.

Masses of components in initial mass of milk in vessel are given by,

$$M_m = M_{mi} + M_{ma} \quad (7)$$

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$$M_{fi} = (FP_{mi} \div 100) * (Bx_{mi} \div 100) * (M_{mi}) \quad (8)$$

$$M_{snfi} = \langle (1-(FP_{mi} \div 100)\rangle * (Bx_{mi} \div 100) * (M_{mi}) \quad (9)$$

$$M_{wi} = \langle 1-(Bx_{mi} \div 100)\rangle * (M_{mi}) \quad (10)$$

Mass of milk added every time in a time interval ΔT is equivalent to ($f_m \Delta T$). Hence components of milk added in time interval ΔT is,

$$M_{fa} = (FP_m \div 100) * (Bx_m \div 100) * (f_m \Delta T) \quad (11)$$

$$M_{snfa} = \langle 1-(FP_m \div 100)\rangle * (Bx_m \div 100) * (f_m \Delta T) \quad (12)$$

$$M_{wa} = \langle 1-(Bx_m \div 100)\rangle * (f_m \Delta T) \quad (13)$$

The cumulative masses of individual components are computed as a mass at current instant which is a sum total of mass at pervious instance and the mass added as follows.

$$M_{snf} = M_{snfp} + M_{snfa} \quad (15)$$

$$M_w = M_{wp} + M_{wa} \quad (16)$$

The C programs have been written and response characteristics are obtained with respect to time. Every time, the masses are added in time interval ΔT, to the individual components, the current values of Bx and FP values in the vessel/evaporator are recursively computed.

The response of milk concentration has been obtained; the same is shown in figure 2. From the figure 2, it is evident that the process time constants are different for different values of initial masses, that is $\tau_{Bxfm} = f(M_{mi})$ and hence a table of τ_{Bxfm} and M_{mi} from above mentioned graphs is formed to derive the mathematical relation between τ_{Bxfm} and M_{mi} deterministically[20][21].

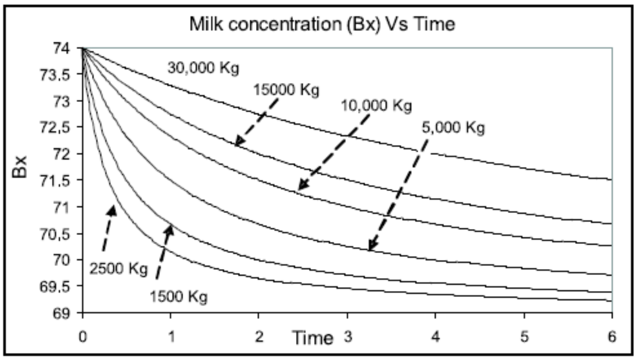

Fig.2. Response of milk concentration (Bx) with respect to time when step of milk flow rate (fm=10000 kg/h) is applied.

For computations of Fat Purity (FP) values, we have considered the values of concentration of input milk (Bx_m) to the evaporator as constant and hence Fat Purity (FP) values remain constant (as it is a ratio of mass of fat component with respect to total solid component in the milk). However, the fat component will change instantaneously if Bri_x of input milk (Bx_m) goes on changing due to fact that the milk received will have different fat contents. Sample experimental readings are shown in Table I.

B. Dependence of time constant (τbxfm) on initial mass of milk

The table of initial mass of milk (M_{mi}), process time constant (τ_{Bxfm}) and transfer function (T_{Bxfm}) shows that process time constant (τ_{Bxfm}) and transfer function (T_{Bxfm}) have dependence on initial mass of milk(M_{mi}) (Refer Table II). The plot of time constant with respect initial to mass of milk is shown in figure 3. The data shown in the Table II and figure 3 can then be fitted in the form of an equation using curve fitting techniques and tools[22][23].

Table- I: Experimental Results

T	Bx1500	Bx 2500	Bx 5000	Bx10000	Bx15000	Bx30000
0	74	74	74	74	74	74
0.02	73.6875	73.80769	73.901962	73.950493	73.966888	73.983391
0.04	73.41177	73.62963	73.807693	73.901962	73.934212	73.966888
0.06	73.16666	73.46429	73.71698	73.85437	73.901962	73.950493
0.08	72.94737	73.31035	73.629631	73.807693	73.870132	73.934212
0.1	72.75	73.16666	73.545456	73.761902	73.838707	73.91803
0.12	72.57143	73.03226	73.464287	73.71698	73.807693	73.901962
0.14	72.40909	72.90625	73.385963	73.672897	73.777069	73.885994
0.16	72.26087	72.78788	73.310349	73.629631	73.746834	73.870132
0.18	72.125	72.67647	73.237289	73.587158	73.71698	73.85437
0.2	72	72.57143	73.166664	73.545456	73.6875	73.838707
0.22	71.88461	72.47222	73.098358	73.504501	73.658386	73.823151
0.24	71.77778	72.37838	73.032257	73.464287	73.629631	73.807693
0.26	71.67857	72.28947	72.968254	73.424782	73.601227	73.792336
0.28	71.58621	72.20513	72.90625	73.385963	73.573174	73.777069
0.3	71.5	72.125	72.846153	73.347824	73.545456	73.761902
0.32	71.41936	72.04878	72.78788	73.310349	73.518074	73.746834

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0.34	71.34375	71.97619	72.731346	73.273506	73.49102	73.731865
0.36	71.27273	71.90698	72.676468	73.237289	73.464287	73.71698
0.38	71.20588	71.84091	72.623192	73.201683	73.437866	73.702194
0.4	71.14286	71.77778	72.571426	73.166664	73.411766	73.6875
0.42	71.08334	71.71739	72.521126	73.132233	73.385963	73.672897
0.44	71.02702	71.65958	72.472221	73.098358	73.360466	73.658386
0.46	70.97369	71.60416	72.42466	73.065041	73.335258	73.643967
0.48	70.92308	71.55102	72.37838	73.032257	73.310349	73.629631
0.5	70.875	71.5	72.333336	73	73.285713	73.615387
0.52	70.82927	71.45098	72.289474	72.968254	73.26136	73.601227
0.54	70.78571	71.40385	72.24675	72.937004	73.237289	73.587158

Table- II: Time constant (τ_{Bxfm}) dependency on initial mass ($_{Mmi}$) when step flow of milk (fm = 10000Kg/h) is applied

Sr. No.	Mass of milk (Fm) in kg	Time constant T	Transfer function
1	1500	0.45	$G_{11(s)}$ = 2.142 s / (1+ 0.45 s)
2	2500	0.72	$G_{11(s)}$ = 3.312 s / (1+ 0.72 s)
3	5000	1.17	$G_{11(s)}$ = 5.031 s / (1+ 1.17 s)
4	10000	1.8	$G_{11(s)}$ = 6.75 s / (1+ 1.8 s)
5	15000	2.25	$G_{11(s)}$ = 7.48 s / (1+ 2.25 s)
6	30000	2.76	G_{11}(s) = 6.90 s / (1+ 2.76 s)

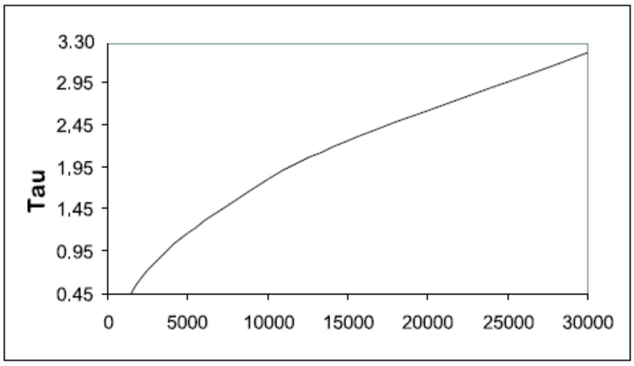

Fig.3: Dependence of time constant (τ_{Bxfm}) with different initial masses of milk (M_{mi}) is taken in the vessel and when step flow of 10000 Kg/h is applied.

Applying curve fitting methods to various parameters to above mentioned table, deterministic relations can be established to replace τ_{Bxfm} as a function of M_{mi}. The equation thus can be written as follows.

$$\tau_{Bxfm} = (-2.4)\times10^{-9} * M_{mi}^{2} + (1.1717)\times10^{-4} * M_{mi} + 0.248 \qquad (17)$$

C. Transfer functions between milk concentration (B_x) and Fat Purity (FP) with respect to steam flow rate (f_s)

The response of milk concentration is obtained by writing mass balance equations where in Mass of milk in evaporator (M_m) is equal to the sum total of initial mass of milk in the vessel (M_{mi}) and water evaporated (Mw_{ev}) as time passes.

$$M_m = M_{mi} - Mw_{ev} \qquad (18)$$

Masses of components in initial mass of milk in vessel are given by equations 8, 9 and 10. The mass of water evaporated is now calculated using energy balance equation in which heat energy input (H_{in}) is sum total of heat content of milk (H_c) and Heat going out of the system in the form vapors (H_v)

$$H_{in} = H_c + H_{out} \qquad (19)$$

$$f_s * L_s = M_m * C_m * T_m + f_v * L_v \qquad (20)$$

Where fs is steam flow rate (Kg/h), Ls is heat content in steam (Kcal/kg), f_v vapor flow rate, L_v is heat contents in a vapors leaving(Kcal/kg) , Mm is mass of milk in vessel (Kg), Tm is temperature of milk (^{0}C) and C_m is specific heat of milk in Kcal /(Kg . ^{0}C).

$$f_v = (f_s * L_s - M_m * C_m * T_m) \div L_v \qquad (21)$$

The mass of water evaporated in time ΔT is then written as $Mw_{ev} = f_v \Delta T$. The recursive calculation then leads to increase in milk concentrations (B_x) with respect to flow of steam fs the results of which are shown in figure 4.

D. Dependence of time constant (τbxfs) on Initial Mass of Milk (Mmi)

The data regarding dependence of time constant (τ_{Bxfs}) with respect to initial mass of milk (M_{mi}) is shown in Table III and related plot is shown in figure 5. Table IV shows the flow rate f_s for different time intervals T.

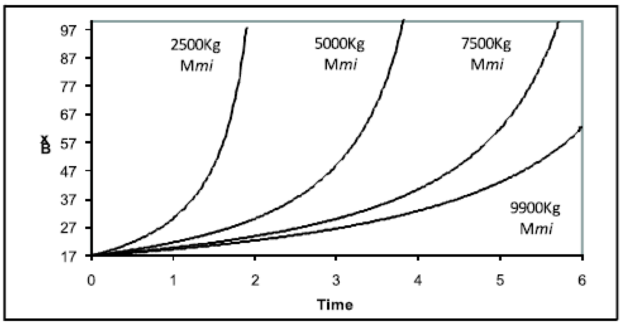

Fig. 4. Step Response of Milk concentration (B_x) with respect to a step steam flow rate (fs) for various values of initial mass of milk M_{mi} in the evaporator

Table III: Time constant (τBxfs) dependency on Initial Mass of Milk (Mmi) when step of steam flow (fs =2500 Kg/h) is applied.

Sr. No.	Mass of milk (Mmi) in kg	Time constant T	Transfer function (T_{Bxfx})
1	2500	9.72	83 / (9.72 s-1)
2	5000	20.4	83 / (20.4s-1)
3	7500	30.12	83/ (30.12s-1)
4	9000	42.36	83/ (42.36s-1)

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The plot of time constant (τ Bxfs) with respect to initial mass of milk (Mmi) is shown in figure 5.

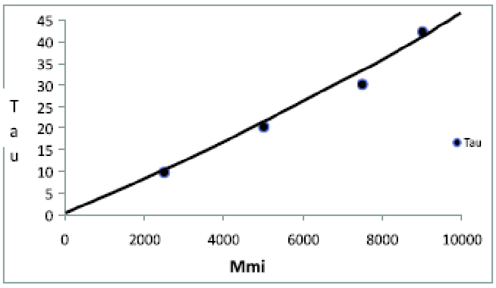

Fig. 5. Dependence of time constant (τ_{Bxfs}) on Initial Mass of Milk (M_{mi}) when step of steam flow (fs=2500Kg/h) is applied.

The relation of time constant (τ Bxfs) and initial mass of milk is given by equation as follows

$$\tau_{Bxfs} = (1.248)\times 10^{-10} * M_{mi}^3 - (1.949)\times 10^{-6} * M_{mi}^2 + 0.01343 * M_{mi} - 13.62 \quad (22)$$

The Fat Purity (FP) again remains constant because it is the ratio of two solid quantities.

Table IV: Sample Readings

Time	Fs=500 kg/h	Fs=1000kg/h	Fs=1500kg/h	Fs=2000kg/h	Fs=2500kg/h	Fs=3000kg/h	Fs=3500kg/h
0	0	0	0	0	0	0	0
0.02	17.010271	17.020555	17.030851	17.041159	17.051481	17.061815	17.072161
0.04	17.020555	17.041159	17.061815	17.08252	17.103275	17.124079	17.144936
0.06	17.030851	17.061815	17.09289	17.124079	17.155382	17.186802	17.218334
0.08	17.041159	17.08252	17.124079	17.165842	17.207809	17.249983	17.292364
0.1	17.051481	17.103275	17.155382	17.207809	17.260559	17.313633	17.367033
0.12	17.061815	17.124079	17.186802	17.249983	17.313633	17.377752	17.44235
0.14	17.072161	17.144936	17.218334	17.292364	17.367033	17.44235	17.518322
0.16	17.08252	17.165842	17.249983	17.334953	17.420763	17.507429	17.594959
0.18	17.09289	17.186802	17.281748	17.377752	17.474829	17.572996	17.67227
0.2	17.103275	17.207809	17.313633	17.420763	17.52923	17.639053	17.750263
0.22	17.11367	17.228872	17.345633	17.463989	17.583969	17.705612	17.828949
0.24	17.124079	17.249983	17.377752	17.507429	17.639053	17.772675	17.908333
0.26	17.134501	17.271149	17.40999	17.551085	17.694485	17.840246	17.988428
0.28	17.144936	17.292364	17.44235	17.594959	17.750263	17.908333	18.069244
0.3	17.155382	17.313633	17.474829	17.639053	17.806396	17.976944	18.150789
0.32	17.165842	17.334953	17.507429	17.683371	17.862885	18.04608	18.233074
0.34	17.176315	17.356327	17.54015	17.727909	17.919733	18.115753	18.316107
0.36	17.186802	17.377752	17.572996	17.772675	17.976944	18.185965	18.3999
0.38	17.197298	17.399233	17.605963	17.817665	18.034521	18.256721	18.484465
0.4	17.207809	17.420763	17.639053	17.862885	18.09247	18.328032	18.569809
0.42	17.218334	17.44235	17.672272	17.908333	18.150789	18.3999	18.655945
0.44	17.228872	17.463989	17.705612	17.954016	18.209488	18.472336	18.742884
0.46	17.23942	17.485682	17.73908	17.999931	18.268568	18.545343	18.830637
0.48	17.249983	17.507429	17.772675	18.046082	18.328032	18.618933	18.919214
0.5	17.260559	17.52923	17.806396	18.09247	18.387882	18.693106	19.008631
0.52	17.271149	17.551085	17.840246	18.139095	18.448128	18.767872	19.098896
0.54	17.281748	17.572996	17.874226	18.185965	18.508768	18.843239	19.190023
0.56	17.292364	17.594959	17.908333	18.233074	18.569809	18.919214	19.282022
0.58	17.302992	17.61698	17.942574	18.28043	18.631252	18.995806	19.374908
0.6	17.313633	17.639053	17.976944	18.32803	18.693106	19.073019	19.468695
0.62	17.324286	17.661184	18.011446	18.375883	18.755369	19.150862	19.563393
0.64	17.334953	17.683371	18.04608	18.423983	18.818048	19.229343	19.659016
0.66	17.345633	17.705612	18.080851	18.472336	18.881149	19.30847	19.755579
0.68	17.356327	17.727909	18.115753	18.520943	18.944675	19.388252	19.853096
0.7	17.367033	17.750263	18.150789	18.569807	19.008631	19.468695	19.951578
0.72	17.377752	17.772675	18.185963	18.618931	19.073017	19.549807	20.051046

E. Transfer Functions between Pressures (P) with respect to Air suction rate (fa)

Milk evaporation takes under vacuum which is created by air suction and condensation. The mass of air in vessel at particular instance of time is mass of air at previous instance minus mass of air removed by air suction as shown in equation 23. Table V shows values of pressure p and mass of air M_a at different time instants t.

$$M_a = M_{ai} + M_{aev} \quad (23)$$

Mass of air removed

$$M_{aev} = f_a * \Delta t \quad (24)$$

Change in pressure in vessel due to removal of air in Time ΔT is dP / dt so pressure in vessel becomes Pressure at current instance minus change in pressure due to air suction Mass of air removed as shown in equation 25.

$$P = P_{prev} - \Delta P \quad (25)$$

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Table V: Sample Readings

t	P[i]	Ma[i]
0.100000	0.319185	191.559601
0.200000	0.319161	191.545319
0.300000	0.319137	191.531021
0.400000	0.319113	191.516739
0.500000	0.319089	191.502457
0.600000	0.319066	191.488174
0.700000	0.319042	191.473877
0.800000	0.319018	191.459595
0.900000	0.318994	191.445312
1.000000	0.318970	191.431030
1.100000	0.318947	191.416733
1.200000	0.318923	191.402451
1.300000	0.318899	191.388168
1.400000	0.318875	191.373886
1.500000	0.318851	191.359589
1.600000	0.318828	191.345306
1.700000	0.318804	191.331024
1.800000	0.318780	191.316742
1.900000	0.318756	191.302444
2.000000	0.318732	191.288162
2.100000	0.318709	191.273880

The following graph in figure 6 shows transfer function between Pressure and air suction rate for milk evaporator.

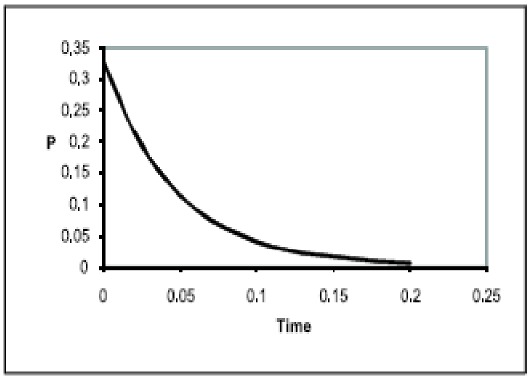

Fig.6. Plot of Pressure and air suction rate

The transfer function is then written as in equation 26.

$$G_{33}^{P}(s) = (4.4 * 0.075 * s) \div (1 + 0.075 * s) \qquad (26)$$

IV. CONCLUSION

Evaporation being one of the important process steps in dairy industry from point of preservation, this process step is considered for study in this paper from the angle of various aspects controlling such process. In order to control the process, mathematical model plays vital role and is to be derived at the _rest instance and hence in above work, attempts have been made to derive the transfer elements of overall transfer matrix of the process of milk evaporation using step response characteristics for which results are presented. The work presented here is based on recursive calculations of various components of process in real time domain. The output variables such milk concentration in terms of Brix (B_x), fat purity (FP) and pressure (P) in the evaporator are considered. The mathematical expressions are derived to predict the process dynamics which ultimately lead us to design of the controller for the process under consideration. It is also highlighted that process is a complex and cross coupled and it had been always a challenge to design the controllers for such processes from the point of view of decoupling aspects and hence this study is presented.

REFERENCES

1. C. Delgado, "Growth and concentration in India, Food and Agricultural organization (FAO "), IFPRI Agreement with UNPR20803, July 24, 2003.
2. V. Knips, ."Developing countries and the global dairy sector, Food and Agricultural organization (FAO)", Part I: Global Overview, Nov 13, 2006.
3. Chronicles of World Health Organization, WHO Interim Commission Report, 1947.
4. T. J. Geurts, A. Jellema, A. Noomen, P. Walstra, and M. van Boekel, Eds., "Dairy Technology: Principles of Milk Properties and Processes". 6000, Broken Sound, Park Way, NW Suite 300,Boca Raton, FL 33487-2742: CRC Press, Taylor and Francis Group, 2006.
5. R. Early, Ed., "The Technology of Dairy Products", and 2nd ed. 2-6 Boundary Row London SE1 8HN (UK): Blackie Academic and Professionals, an imprint of Thompson Science, 1992.
6. A. H. Varnam and J. P. Sutherland, "Milk and Milk Products: Technology, Chemistry and Microbiology". Originally Published by Chapman and Hall in 1994, 2001, vol. 1, Food Product Series.
7. R. P. Aneja, B. N. Mathur, R. C. Chandan, and A. K. Banerjee, "Technology of Indian Milk Products". Dairy India Year Book, 2002.
8. B. Gail, "Concentrated milk (sweet milk), Scientific American", vol. 11, no. 51, p. 405, Aug 1856.
9. "Concentrated milk, Scientific American", vol. 12, no. 49, p. 387, Aug 1857.
10. .Milk and its Preservation, Scientific American, vol. 3, pp. 2.3, July 2 1860.
11. P. Walstra, "Dairy Technology: Principles of milk properties and processes: Food Science and technology." 270 Madison Avenue, New York, NY 10016, USA: Marcel Dekker, 1999.
12. R. E. Christian Kiesner, "Concept of a sterile concentration process for milk by multistage _ash evaporation", ser. Chemical Engineering and Technology. KGaA, Weinheim: WILEY-VCH Verlag GmbH and Co, 1994, vol. 17, no. 6, 374381.
13. F. E. Rice Evaporated Milk. Chicago, ILL, "USA: Industrial Engineering Chemistry", 1930, vol. 22, no. 1, 45-48.
14. L. C. Dickey, J. C. Craig, J. E. R. Radewonuk, A. J. Mcaloon, and V. H. Holsinge, ."Our industry today: Vacuum evaporation", vol. 78, pp 1369.1376, 1995, USDA ARS Eastern Regional Research Center 600 East Mermaid Lane Philadelphia, PA 19118.
15. L.Wang and W.R.Cluett, "Estimation of process step response weights based on closed-loop step response data", in IEEE American Control Conference, San Francisco, CA, USA, March 10 2009, pp. 808. 812, ISBN 0-7803-0860-3.
16. C. C. Huang and C. C. Yu, "Evaluation of the process transfer function using partial pulse response data, Journal of Industrial and Chemical Research", vol. 28, no. 9, p. 13041308, Sept 1989.
17. F. Haugen, .Ziegler-Nichols "open-loop methods, Technical Report", July 17 2010.
18. J. G. Ziegler and N. B. Nichols, "Optimum settings for automatic controllers, ASME Transactions", vol. 64, pp. 759.768, 1942.
19. K. Astrom and T. Hagglund, "Revisiting the Ziegler and Nichols step response method for PID control", Journal of Process Control, vol. 14, pp. 635.650, 2004.
20. R. Srivastava, L. You, J. Summers, and J. Yin, "Stochastic vs. deterministic modeling", Journal of Theoretical Biology, vol. 218, pp. 309.321, 2002.
21. N. Schrammar, "On deterministic models for wireless networks, Licentiate Thesis in Telecommunications', KTH, School of Electrical Engineering Communication Theory Laboratory, Stockholm, Sweden, April 2011.

Retrieval Number: 100.1/ijeat.E28000610521
DOI:10.35940/ijeat.E2800.0610521
Journal Website: www.ijeat.org

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication

22. T. Loeblein and M. Dubson, PhET: "Interactive Simulation Tools", University of colarado, PhET and Evergreen HS, Boulder, 13 Nov 2008.
23. The Kaleida Graph "Guide to Curve Fitting, Synergy Software", 2457 Perkiomen Avenue Reading, PA 19606-2049 USA, 2009.

AUTHORS PROFILE

Vijaya N. Aher, has completed her Bachelor's degree in Electronics Engineering in 2000 from Pune University and Master's Degree in Electronics Engineering in the year 2004 from Dr. Babasaheb Ambedkar Marathwada University, Aurangabad. From past 20 years she has been working as Lecturer and Assistant Professor. At present she is working as Assistant Professor in Department of Electronics and Telecommunication Engineering at Vishwakarma Institute of 1nformation Technology, Pune and pursuing her PhD degree from Dr. Babasaheb Ambedkar Marathwada University, Aurangabad.

Dr. Ganesh Sable, Ph.D., is a Professor with Maharashtra Institute of Technology, Aurangabad, Maharashtra, India affiliated with Dr. Babasaheb Ambedkar Marathwada University, and accredited by the All India Council for Technical Education. He has 20 years of experience in teaching, research and innovation. He is having around 10 years of administrative experience as, Principal, Vice Principal and Head of Department. He has more than 186 research citation indices with Google scholar (h-index score 7 and i-10 index 4). He has filled and published 3 Patent. His research areas include Medical Imaging, Image Processing, Human Machine Interaction, Data Sciences, Pattern Recognition, Computer Vision, Artificial Intelligence, Robotics, Biometrics, Bio-informatics, Embedded Systems, Internet of Things and Industry 4.0 etc .He has received a Best Academician Award, by ESN Research Group of Publication, Chennai, India. He is working as Board of study member for Electronics and Telecommunication faculty.

Dr. Minakshi Rajput, is Assistant Professor with P.E.S. College of Engineering, Aurangabad, Maharashtra, India affiliated with Dr. Babasaheb Ambedkar Marathwada University, and accredited by the All India Council for Technical Education. She has 14 years of teaching experience. She has published 1 patent and published 13 research papers in International journals and 3 book chapters in Springer book series. She has participated in different international conferences all over India. Her research areas include Image Processing, Deep Learning, Data Science and Embedded Systems etc.