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Research Paper

Estimation of hazen williams's constant for a residential water distribution network; GMDH and PSO approach

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Abstract

Hazen-William equation is used to estimate the Fluid flow in closed channel. There are various models for estimation of pipe flow, however the accuracy and reliability of models varies due to the empirical nature of the Hazen-William constant .the applicability of model also become constrained due to the dependency of constant on pipe material, dimension and flow potential. Different type of pipeline arranged in different Networks will require different value of the constant and is generally retrieved from the data collected for the pipe network. The case dependency of the model has makes the model erroneous and often subjective that is why the present study tries to propose a model which can be used for any network where the output will depend upon the inputs. In this aspect the soft computation techniques: - GMDH and PSO was utilized in an unconventional way to establish the value of C_{HW} =f (H, L, V, D). According to result the GMDH becomes the better model than the PSO where the accuracy is about 76.315%.

Key words: *Group method of data handling (GMDH); Hazen-Williams Constant (C_{HW}); Particle Swarm Optimization (PSO); Water Distribution Network (WDN).*

1. Introduction

Hydraulic models of water distribution networks (WDNs) are efficient decision support tools for development of various management scenarios to improve efficiency and reliability of existing networks and to design new ones. In hydraulic models, well-known hydraulic equations are solved to calculate main hydraulic parameters; such as Net head, pipe length, velocity and diameter of pipe, at many points for the described WDN and the obtained results are displayed in tabular and graphical forms to be evaluated by the users [1-4]. The success of hydraulic model predictions depends on accurate determination/estimation of input parameters and model calibration and verification studies.

Adequate hydraulic analysis of multi-outlet pipelines is very important for the proper design and evaluation of water distribution system [18, 19]. Multi-outlet pipes of small diameter in which D < 50 mm, (where D is pipe internal diameter) [7, 21] are considered as smooth pipes and generally made from plastic [polyethylene (PE) or polyvinyl chloride (PVC)] material.

The design of these hydraulic structures varies with the values of pipe parameters as inlet pressure head, total head losses, field topography, level of water application, and outlet hydraulic characteristics. These criteria are essential for hydraulic design procedure of a water distribution network (WDN) system, which can be either to be accepted or rejected [21].

1.1 Methods of calculating head loss:

In usual the analysis of friction head loss computation is theoretical-based on Darcy–Weisbach (D-W) equation or empirical-based on Hazen–Williams (H-W) equations. It is most universally accepted that the Darcy -Weisbach equation for computing the friction loss through pipes is a highly accurate pipe-flow resistance equation [20, 18,].

1.1.1 Darcy-Weisbach Equation:

$$h_f = f\,\frac{L}{D}\,\frac{V^2}{2g} \tag{1}$$

Where

h_f = friction head loss (m);
f = D-W friction coefficient;
L = length of the pipe (m);
D = pipe internal diameter (m);
V = average velocity of flow ($m\ s^{-1}$);
g = acceleration due to gravity ($m\ s^{-2}$).

1.1.2 Hazen-Williams Equation:

The H-W equation in SI units is usually given as the following general form:

$$h_f = KL\frac{(Q/C_{HW})^{1.852}}{D^{4.871}} \tag{2}$$

Where

h_f = friction head loss (m);
C_{HW} =Hazen–Williams friction coefficient;
D and L =Pipe geometric characteristics previously defined (m);
Q = discharge ($m^3\ s^{-1}$);
K =10.56 For Q in $m^3 s^{-1}$ and D in m; and
=1.2* 10^{10} For Q in Ls^{-1} and D in mm;

In usual hydraulic computations, the commonly recommended typical values for the C_{HW} coefficient range from 130 to 140 regardless of the pipe diameter [26].

In his analysis Liou [17], compare the H–W equation with the D-W and found that the H-W equation may produce errors as high as 40 when applied outside a limited and somewhat controversial range of Reynolds number (R_N), pipe internal diameter (D), and C_{HW} coefficient. While on the basis of his experiments Christensen [4] argued that the H-W equation is only valid between smooth and transitional turbulent flow.

Since the value of Friction coefficient varies as so many practicing engineers usually hesitate to use the generalized D-W equation and prefer simpler empirical power form flow resistance equations such as the H-W equation [26]. Although the range of applicability of H-W equation is limited and not dimensionally homogeneous yet it is very popular among users because of its simplicity in hydraulic computations [17, 4]. However, this simplification may lead substantial error in calculating the friction loss because of flow rate, Q is directly proportional to friction coefficient, C_{HW}, according to Eq. (2) [18].

We conclude that the corrected values of C_{HW} coefficient, the maximum error generally does not exceed7, [26] and for the typical fixed value of C_{HW} =135 the maximum error varies from +12% for large diameters to -19% for small diameters [13].

In a recent study, an experimental investigation [18] has been presented to determine the proper values of the C_{HW} coefficient for commonly used polyethylene plain pipes with different diameters. It is reported in this research, there is a strong dependence of the Hazen–Williams coefficient (C_{HW}) on parameters as diameter of pipe (D), and others therefore a single value of the C_{HW} cannot be used for all pipes of different diameters.

2. Methods used

2.1.1 GMDH shell

GMDH is a family of inductive algorithm for computer, developed by “Prof. Alexey G. Ivakhnenko” at the institute of Cybemetics in Kyiv (Ukraine), which is based on mathematic modeling of multi-parametric database which makes it fully automatic.

The GMDH is based on the Voltera series Or Kolmorgorov-Gabor Polynomial, which is given as-

$$Y=a_0+\sum_{i=1}^{m}\sum_{j=1}^{m} a_i x_i x_j+\sum_{i=1}^{m}\sum_{j=1}^{m}\sum_{k=1}^{m} a_i x_j x_k. \quad (3)$$

This is a Polynomial neural network, which is ‘Self Organizing’ in nature, which means that in this method the connections between neurons are not fixed but are selected during training to optimize the network.it also select the layers automatically in the network, to produce the maximum accuracy, without any over fitting. And at the time of Training of data it also select the neurons from the pool of candidates and add it with hidden layers.

It is a data mining, discovery, system modeling, optimization and pattern recognition tool, which perform better than the conventional forecasting algorithms as Double Exponential Smooth, Single Exponential Smooth, Back propagation neural Network[26].

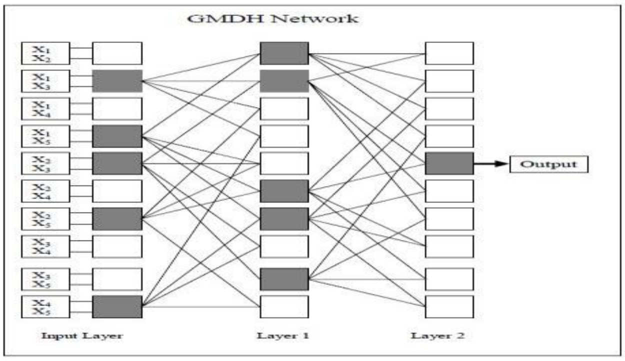

Fig.1: Network of GMDH

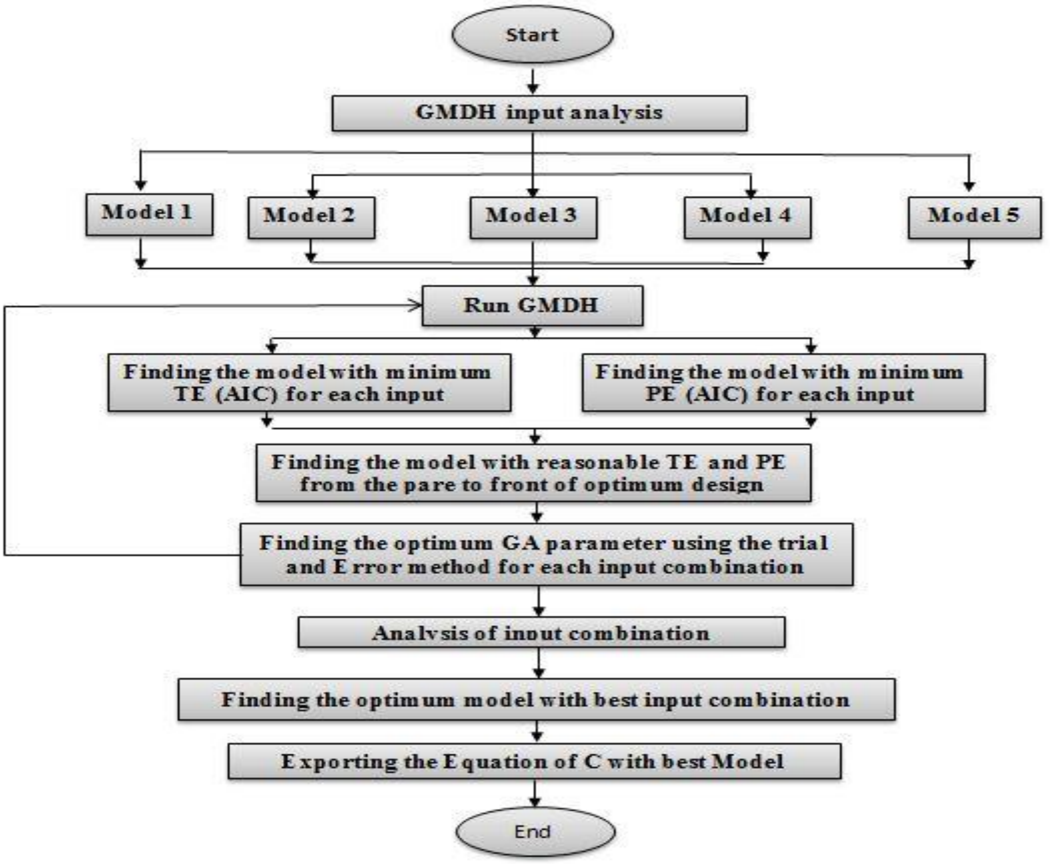

Chart-1: schematic diagram for GMDH

2.1.2 Particle Swarm Optimization(PSO)

Particle Swarm Optimization (PSO) is an evolutionary computation method developed by ‘Kennedy and Eberhart’. [4, 5]. In a PSO system, it starts with the random initialization of a population (Swarm) of individuals (particles) in the search space and works on the social behavior in the swarm. The position and the velocity of the i^{th} particle in the n-dimensional search space can be represented as

$X_i = [X_1, X_2, X_3 \ldots\ldots X_n]$ And

$V_i = [V_1, V_2, V_3 \ldots\ldots V_n]$ Respectively.

Each particle has its own best position (P best) $P_i = [P_1, P_2, P_3 \ldots\ldots P_n]$

Corresponding to the personal best objective value obtained so far at time t. The global best particle (g best) is denoted by P_g, which represents the best particle found so far at time t in the entire swarm. The new velocity of each particle is calculated as follows;

$$V_{i,j}(t+1)=wV_{i,j}(t)+C_1 rand_1\left(P_{i,j}-X_{i,j}(t)\right)+C_2 rand_2\left(P_{g,j}-X_{i,j}(t)\right) \quad (4)$$

Where: j = 1, 2, 3 …………n

Where c_1 and c_2 are acceleration coefficients, w is inertia factor, $rand_1$ and $rand_2$ are two independent random numbers uniformly distributed in the range of [0, 1].

Thus, the position of each particle is updated in each generation according to the following equation:

$$x_{i,j}(t+1)=x_{i,j}(t)+v_{i,j}(t+1), \quad (5)$$

Where: j=1, 2, 3…n.

Generally, the value of each component in V_i can be clamped to the range $[-V_{max}, V_{max}]$ to control unnecessary roaming of particles outside the examine space. Then, the particle flies toward a new position. This process is repeated until a user-defined stopping criterion is reached.

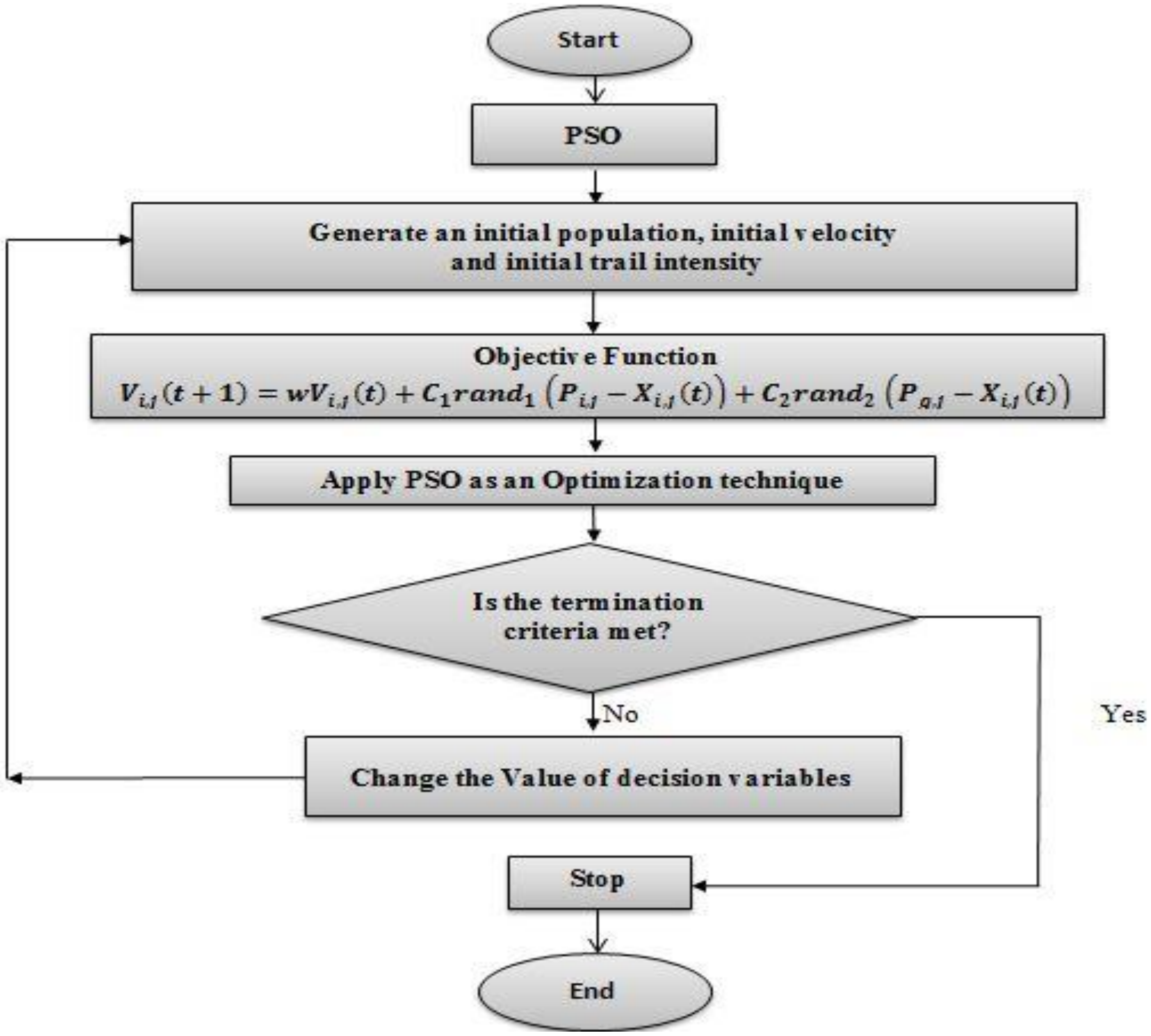

Chart-2: schematic diagram for PSO

The procedure of standard PSO is summarized as follows.

1) Reset Population of particles with arbitrary positions and velocities.
2) Estimate the independent values for all particles.
3) Change the velocity and position of each particle according to (i) and (ii).
4) Estimate the independent values for all particles.
5) Compare the existing value with the best value and if the obtained value is better than the best value than update.do this for each particle.
6) With the help of best objective value determine the best particle of the present swarm. If the obtained value is better than the global value than update g best.
7) If criteria met, than g best and its independent value will be the output; otherwise repeat the procedure from steps (3).

3. Data collection:

For conducting this study R.N.Tagore Hostel, a Residential apartment of NIT Agartala is taken as Case study area.

Details related to this area are as-

Longitude: - 91.42E; Latitude 23.84N

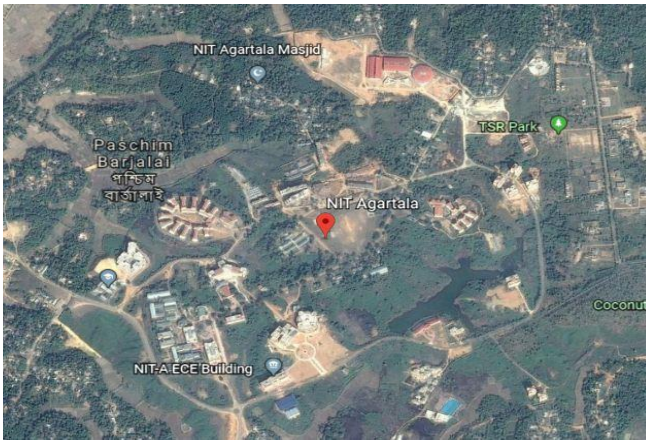

Fig. 2: Residential apartment of NIT Agartala

The data provided by N.C.C, as shown in Table-2, is used here for model development and actual analysis of project.

For optimizing the value of constant the all data related to equation is converted on a single scale by normalizing method.

In this way the all dada converts between two extreme limits one is higher as 1 while other is lower as 0.

Another form of Hazen-William Equation-

$$\boldsymbol{V = 0.85C(m)^{0.63} \times S^{0.54}}$$

Where:

$$\boldsymbol{S = h_f/L \quad \& \quad m = \mathrm{D}/4}$$

$X=0.85(D/4)^{0.63}\times S^{0.54}$ (Say)

Then

$$C = V/X$$

After developing model and analyzing the result we get the following resultant equation as GMDH output.

```
Y1 = -0.00143645 - N652*0.00327724 + N2*1.00474 - N2^2*8.91402e-05
Where-
N2 = 0.00029273 - N216*0.0255442 + N3*1.02547
N3 = 0.0015216 - N32*0.360517 + N32*N4*0.0161387 + N4*1.3598 - N4^2*0.0161112
N4 = 0.00158493 + N445*N5*0.00917747 - N445^2*0.00470457 + N5*1.00229 - N5^2*0.00455757
N5 = -0.000248691 + N140*0.0502017 + N6*0.949862
N6 = 0.00827882 - N545*0.0144313 + N545^2*0.000585145 + N7*1.00991 - N7^2*0.000350778
N7 = 0.0166959 - N737*0.0184669 - N737*N9*0.00079484 + N737^2*0.00213143 + N9*1.00582
N9 = -0.00741662 - N426*N10*0.0180328 + N426^2*0.00906384 + N10*0.998819 + N10^2*0.00900619
N10 = -5.20005e-05 + N16*0.468577 + N18*0.531437
N18 = -0.0183197 - N208*N23*0.228436 + N208^2*0.105659 + N23*1.00387 + N23^2*0.122625
N23 = 0.00695225 + N62*0.512109 + N62*N69*2.45737 - N62^2*1.23752 + N69*0.490612 - N69^2*1.21995
N208 = -0.00894989 + N268*0.477446 + N273*0.524858
N273 = -0.102811 - N709*N314*0.0218342 + N709^2*0.0196601 + N314*0.959061 + N314^2*0.00653794
N268 = -0.171534 - N786*0.188454 - N786*N310*0.033503 + N786^2*0.034505 + N310*1.22825
N16 = 0.00598198 + N22*0.645626 + N22*N33*3.45787 - N22^2*1.73839 + N33*0.355039 - N33^2*1.7195
N33 = 0.00265252 + N62*0.608376 + N62*N64*2.98882 - N62^2*1.50982 + N64*0.394684 - N64^2*1.47911
N64 = -0.0406361 + N661*0.0399419 + N661*N72*0.00464267 - N661^2*0.00555187 + N72*0.996389 - N72^2*0.00138678
N661 = 3.04527 - N801*1.87397 + N801*N823*0.217111 + N801^2*0.283277 - N823*1.32895 + N823^2*0.173107
N801 = 8.98326 + "s=h/L"*0.896924 - "S^0.54"*5.51059
N62 = 0.0157028 + N72*0.543695 + N72*N100*3.27343 - N72^2*1.61833 + N100*0.462595 - N100^2*1.65535
N100 = -0.00426331 + N137*0.693981 + N205*0.307117
N205 = -0.214719 + N773*0.0318331 + N773^2*0.01349 + N269*0.921394 + N269^2*0.0018092
N269 = 0.0494994 + N723*0.237041 - N723*N338*0.0282272 + N338*0.680877 + N338^2*0.022285
N22 = -0.0275886 + N666*0.019491 - N666^2*0.00213349 + N38*1.00693
N38 = 0.0204151 + N73*0.431785 + N73*N76*3.46883 - N73^2*1.72005 + N76*0.570815 - N76^2*1.74892
N76 = -0.0180644 + N136*0.658951 + N196*0.348801 - N196^2*0.000252822
N196 = -0.343332 + N811*0.0333657 + N811^2*0.0195214 + N276*0.931551 + N276^2*0.00165469
N811 = 6.23518 - "D/4"*"X=0.85(D/4)^(0.63)×S^(0.54)"*69.1424 + "X=0.85(D/4)^(0.63)×S^(0.54)"^2*5.66497
N136 = -0.154125 - N756*N186*0.00933637 + N756^2*0.0141717 + N186*0.974306 + N186^2*0.00252856
N73 = -0.00392902 + N308*0.104832 + N91*0.89618
N308 = 0.500391 + N447*0.719522 + N501^2*0.0130728
N501 = 2.59345 - N748*0.351312 + N748*N751*0.256026 + N748^2*0.0170752 - N751*1.01295 + N751^2*0.0903289
N751 = 23.6423 + L*15.6174 - L^2*11.3166 - "h, cubert"*65.0165 + "h, cubert"^2*41.4432
N748 = 46.8354 + V*29.0919 - V*""(D/4)^0.63", cubert"*35.9416 - ""(D/4)^0.63", cubert"*163.775 + ""(D/4)^0.63", cubert"^2*139.769
N447 = 1.06248 - N671*1.04241 + N671*N781*0.209679 + N671^2*0.0484591 + N781^2*0.037745
N671 = 43.1929 - "S^0.54"^2*0.714557 - ""X=0.85(D/4)^(0.63)×S^(0.54)", cubert"*120.412 + ""X=0.85(D/4)^(0.63)×S^(0.54)", cubert"^2*87.59
N426 = 0.969542 + N536^2*0.0294951 + N651*0.307228 + N651^2*0.0104636
N651 = 2.45104 - N780*1.6144 + N780*N808*0.216998 + N780^2*0.264231 - N808*1.1607 + N808^2*0.135277
N780 = 9.23571 + h*"S^0.54"*1.85196 - "S^0.54"*6.49091 + "S^0.54"^2*0.607796
N536 = 0.91095 - N706*0.820316 + N706*N723*0.179382 + N706^2*0.05834 + N723*0.67438 - N723^2*0.0936616
N723 = 2.36911 + V*15.7381 - V*"S^0.54"*6.54714 - "S^0.54"*3.12576 + "S^0.54"^2*1.0342
N737 = 2.16391 - L*12.3768 + L*"V, cubert"*26.8705 - "V, cubert"*2.23066
N545 = 1.07039 - N706*0.752082 + N706*N709*0.161001 + N706^2*0.0584536 + N709*0.518399 - N709^2*0.0718756
N706 = 88.7194 - ""(D/4)^0.63", cubert"*174.538 + ""(D/4)^0.63", cubert"^2*134.671 - ""S^0.54", cubert"*49.4953 + ""S^0.54", cubert"^2*18.5293
N140 = 0.0449675 + N253*0.972665 - N253*N323*0.0212958 + N323^2*0.0225465
N323 = 0.629198 + N437*0.678827 + N437*N623*0.0204338 - N623*0.0389014
N623 = 0.122117 + N759*N789*0.346231 - N789*0.37423
N789 = 848.287 - "(D/4)^0.63"*42928.3 + "(D/4)^0.63"*""(D/4)^0.63", cubert"*28812.3 - "(D/4)^0.63"^2*5801.73 - ""(D/4)^0.63", cubert"*7608.9 + ""(D/4)^0.63", cubert"^2*26468.9
N759 = 28.5834 - "S^0.54"*3.44116 + "S^0.54"^2*0.377101 - "h, cubert"*64.6405 + "h, cubert"^2*45.0889
N437 = 1.23461 - N683*1.0214 + N683*N742*0.20496 + N683^2*0.0870667 + N742*0.101539 - N742^2*0.0209749
N742 = 0.35016 + V*12.2211 - V*"s=h/L"*2.38296 + "s=h/L"^2*0.0557065
N253 = -0.597432 + N781*0.264758 - N781*N319*0.0278078 + N319*0.967748 + N319^2*0.00740454
N319 = 1.23265 + N587*0.290542 + N587*N669*0.0791166 - N669*0.132746 - N669^2*0.0170139
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N445 = 0.634826 + N532*0.505766 - N532*N585*0.0869179 + N532^2*0.0434619 + N585^2*0.0675469
N585 = 3.51674 - N769*0.822269 + N769*N771*0.213215 + N769^2*0.0935685 - N771*1.91571 + N771^2*0.238537
N771 = 13.8848 - ""s=h/L", cubert"*12.9699 + ""s=h/L", cubert"^2*2.97753
N769 = 0.593703 - "(D/4)^0.63"*69.9628 - "(D/4)^0.63"*"V, cubert"*47.1103 + "(D/4)^0.63"^2*182.852 + "V, cubert"*21.703
N532 = 0.271607 + N704*N747*0.0501503 + N704^2*0.0441931 + N747^2*0.0501109
N747 = 9.12649 + "V, cubert"*31.502 - "V, cubert"*"D, cubert"*29.065 - "D, cubert"*55.3569 + "D, cubert"^2*48.5316
N704 = 18.4424 + V*38.4471 - V*"h, cubert"*25.3735 - V^2*15.9472 - "h, cubert"*63.9919 + "h, cubert"^2*48.4821
N32 = 0.00471807 + N61*0.611918 + N61*N69*2.4618 - N61^2*1.24331 + N69*0.391444 - N69^2*1.21861
N69 = -0.0109029 + N79*1.0041 + N79*N111*0.0861813 - N79^2*0.0862531
N111 = -0.0141693 + N666*0.109204 + N666*N143*0.00720353 - N666^2*0.00822418 + N143*0.904239
N143 = 0.0655394 + N266*0.973424 + N266*N270*0.0526784 - N266^2*0.0516941
N266 = -0.689568 + N781*0.350175 - N781*N326*0.0503453 + N326*0.954763 + N326^2*0.0146912
N326 = 1.1902 + N587*0.0664645 + N587*N683*0.111183 - N683*0.0702678 - N683^2*0.0290137
N683 = 31.6967 + h*""X=0.85(D/4)^(0.63)×S^(0.54)", cubert"*1.77054 - ""X=0.85(D/4)^(0.63)×S^(0.54)", cubert"*74.9593 + ""X=0.85(D/4)^(0.63)×S^(0.54)", cubert"^2*41.9423
N587 = 20.3911 + V*37.6187 - V*""X=0.85(D/4)^(0.63)×S^(0.54)", cubert"*48.3262 - ""X=0.85(D/4)^(0.63)×S^(0.54)", cubert"*73.5366 + ""X=0.85(D/4)^(0.63)×S^(0.54)", cubert"^2*61.5225
N666 = 2.10689 - N786*1.68132 + N786*N823*0.271536 + N786^2*0.260574 - N823*0.57567
N823 = 8.25492 + V*5.79002 - D*30.5632 + D^2*24.0421
N786 = 8.8775 - "D/4"*"S^0.54"*15.499 - "S^0.54"*3.53773 + "S^0.54"^2*0.884531
N79 = -0.00586988 + N167*0.645253 + N213*0.356259
N167 = -0.0609497 - N690*N194*0.0183167 + N690^2*0.0163022 + N194*0.946481 + N194^2*0.00675456
N194 = 0.0404927 - N756*N275*0.0153151 + N756^2*0.0138791 + N275*0.901436 + N275^2*0.00795414
N61 = 0.0154978 + N72*0.603893 + N72*N90*4.1312 - N72^2*2.05776 + N90*0.404952 - N90^2*2.07378
N90 = -0.00474648 + N137*0.684403 + N213*0.316819
N213 = -0.247982 + N773*0.0554769 + N773^2*0.0109532 + N276*0.921778 + N276^2*0.00177377
N276 = 0.0842263 + N709*0.193535 - N709*N338*0.0323537 + N709^2*0.00503846 + N338*0.708683 + N338^2*0.0221908
N338 = 1.08678 - N684*0.735724 + N684*N690*0.128361 + N684^2*0.076718 + N690*0.0568695
N709 = 0.546888 - "S^0.54"*"V, cubert"*8.23546 + "S^0.54"^2*0.889353 + "V, cubert"^2*15.9701
N773 = 7.38647 - "(D/4)^0.63"*"S^0.54"*15.3982 + "S^0.54"^2*0.725824
N137 = -0.0823283 + N714*0.0410372 + N714^2*0.00589228 + N186*0.916654 + N186^2*0.00171662
N186 = 0.166514 - N690*N275*0.0218873 + N690^2*0.0180636 + N275*0.826738 + N275^2*0.0130505
N714 = 1.27988 + L*26.6191 - L*"X=0.85(D/4)^(0.63)×S^(0.54)"*52.7848 - L^2*17.5259
N72 = -0.00139242 + N91*0.746295 + N161*0.254063
N161 = 0.0569179 + N275*0.587543 + N275*N270*0.0300385 - N275^2*0.0298816 + N270*0.397379
N275 = 1.12292 - N669*0.823776 + N669*N781*0.266295 + N669^2*0.00633684 + N781^2*0.0125748
N781 = 1.3525 - "X=0.85(D/4)^(0.63)×S^(0.54)"*8.83961 + "V, cubert"^2*9.00227
N91 = -0.0660798 + N684*0.16456 + N684*N192*0.00948148 - N684^2*0.0115693 + N192*0.871677
N192 = -0.179573 - N690*N314*0.0447798 + N690^2*0.0337766 + N314*0.931223 + N314^2*0.0155802
N314 = 0.111775 + V*2.1708 + V*N669*2.32943 - V^2*3.16655 - N669*0.142422 + N669^2*0.0077874
N684 = 31.3996 - ""X=0.85(D/4)^(0.63)×S^(0.54)", cubert"*73.7437 + ""X=0.85(D/4)^(0.63)×S^(0.54)", cubert"^2*42.2915
N216 = -0.80104 + N828*0.37923 - N828^2*0.036289 + N270*0.989852
N270 = -0.00118171 - N690*0.106793 - N690*N310*0.0380362 + N690^2*0.0330417 + N310*1.00253 + N310^2*0.0116896
N310 = 0.786122 - N669*0.113644 + N669*N690*0.115775 + N669^2*0.0133384 + N690*0.138242
N669 = 97.5701 -

4. Comparative analysis

Following parameters are used for the error estimation

- Absolute error (AE),
- Relative error (RE) (%)
- Mean-square error (MSE) and
- Correlation Factor (CF)

These are defined as:-

$$A\,E = |\ \text{actual value-predicted value}\ | \tag{6}$$

$$R\,E = \frac{|\text{actual value-predicted value}|}{\text{Actual value}} \tag{7}$$

$$M\,S\,E = \frac{\sum_{i=1}^{N}(actual\ value - predicted\ value)^2}{N} \tag{8}$$

$$C\,F = \frac{\sum_{i=1}^{N}\left(K_{xi(Actual)} - \overline{K}_{x(Actual)}\right)\left(K_{xi(Model)} - \overline{K}_{x(Model)}\right)}{\sqrt{\sum_{i=1}^{N}\left(K_{xi(Actual)} - \overline{K}_{x(Actual)}\right)^2 \sum_{i=1}^{N}\left(K_{xi(Model)} - \overline{K}_{x(Model)}\right)^2}} \tag{9}$$

Where, the term i denotes the i^{th} term of data and N denotes total number of sets of data.

5. Result

Result (as shown in Table -1) shows that the GMDH method provides the best result for the given set of input variables.
New H-W Equation becomes as-

$$\mathbf{(w_1V) = 0.85C(m)^{0.63} \times S^{0.54}}$$

Where:-

$$\text{Hydraulic Gradient(S)} = (w_2 h_f)/(Lw_3)$$

$$\text{Hydraulic Radius (m)} = \frac{(w_4 D)}{4}$$

w_1= weightage for Velocity
w_2= weightage for Head
w_3= weightage for Length of Pipe
w_4= weightage for Diameter of Pipe

The appropriate average value of weightage can be calculated by analyzing the given data using the GMDH algorithm.

Table 1: Absolute, root mean square error and correlation of result

Method	AE	RMSE	Correlation
PSO	0.046	0.067	0.999
GMDH	0.025	0.038	0.999

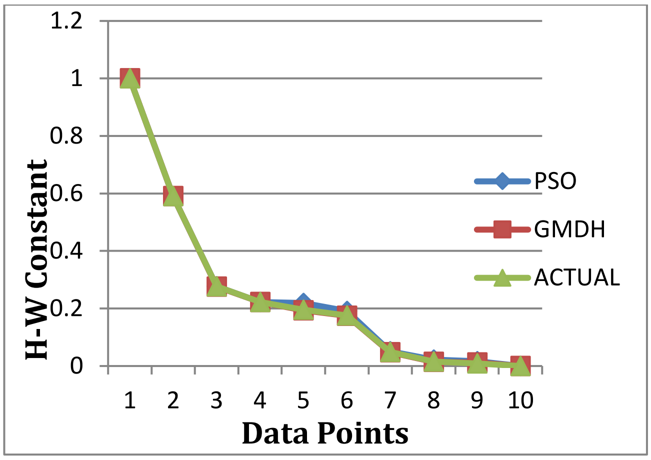

Fig: 3 H-W constant v/s data points

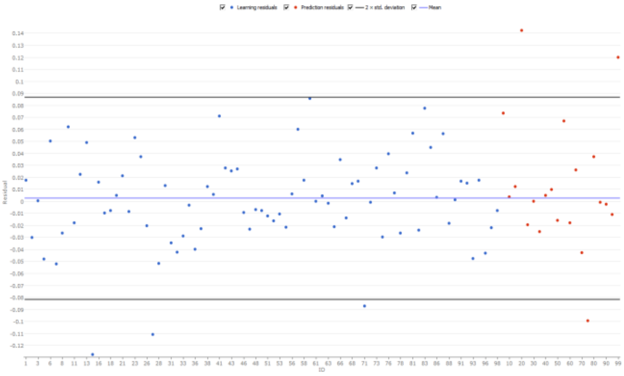

Fig: 4 Residual distribution v/s data points

6. Conclusion:

Although there are some limitations of H-W Equations, as- It is non-dimensional homogeneous and has limited uses, yet it is very popular in calculation for the calculation of pipe friction loss where the value of Hazen William coefficient varies at each section of the pipe and it is not easy to use Darcy–Weisbach equation.

This paper presents a GMDH and PSO computing technique to estimate proper values of C_{HW} regarding different pipe diameters for calculating friction losses through WDN pipes. In the proposed methodology pipe diameter, net head, pipe length and velocity are taken as the inputs variables whereas the C_{HW} friction coefficient is the output variables. The performance of proposed mode suggests that the Soft computing techniques can be used with highest degree of accuracy to identify the value of H-W Constant i.e. for accurately estimation of friction loss through pipes of Residential Water distribution Network.

The result shows that the RMSE of PSO is about 1.7631 times of RMSE of GMDH. Hence we can conclude that the GMDH method is highly recommended as compare to PSO for analysis of water distribution Network.

This work can be modified in future by using other optimization techniques and also on the basis of field validation of data by using actual environment.

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Table -2

	h	L	V	D	S=h/L	D/4	(D/4)^0.63	S^0.54	X	C=V/X
1	0.84	0.44	0.93	0.98	1.89	0.24	0.41	1.41	0.49	1.88
2	0.18	0.47	0.27	0.30	0.38	0.07	0.20	0.59	0.10	2.74
3	0.60	0.95	0.34	0.43	0.63	0.11	0.25	0.78	0.16	2.08
4	0.70	0.72	0.30	0.72	0.98	0.18	0.34	0.99	0.28	1.06
5	0.44	0.22	0.22	0.00	2.04	0.00	0.01	1.47	0.02	14.02
6	0.23	0.73	0.66	0.65	0.32	0.16	0.32	0.54	0.15	4.52
7	0.40	0.50	0.70	0.85	0.80	0.21	0.38	0.89	0.28	2.45
8	0.23	0.70	0.89	0.79	0.33	0.20	0.36	0.55	0.17	5.31
9	0.60	0.78	0.26	0.18	0.77	0.05	0.14	0.87	0.10	2.47
10	0.14	0.75	0.39	0.08	0.19	0.02	0.08	0.40	0.03	13.36
11	0.31	0.13	0.69	0.24	2.36	0.06	0.17	1.59	0.23	2.99
12	0.60	0.56	0.97	0.89	1.07	0.22	0.39	1.03	0.34	2.83
13	0.95	0.28	0.34	0.21	3.40	0.05	0.15	1.94	0.25	1.35
14	0.10	0.87	0.39	0.98	0.11	0.25	0.41	0.30	0.11	3.63
15	0.20	0.30	0.15	1.00	0.66	0.25	0.42	0.80	0.28	0.53
16	0.90	0.32	0.56	0.81	2.86	0.20	0.37	1.76	0.55	1.02
17	0.54	0.48	0.65	0.34	1.13	0.09	0.21	1.07	0.19	3.38
18	0.94	0.56	0.63	0.16	1.67	0.04	0.13	1.32	0.15	4.23
19	0.80	0.84	0.16	0.03	0.95	0.01	0.05	0.97	0.04	3.99
20	0.17	0.72	0.46	0.62	0.24	0.15	0.31	0.46	0.12	3.84
21	0.24	0.33	0.66	0.85	0.74	0.21	0.38	0.85	0.27	2.43
22	0.59	0.50	0.12	0.97	1.17	0.24	0.41	1.09	0.38	0.32
23	0.75	0.19	0.89	0.41	4.03	0.10	0.24	2.12	0.43	2.06
24	0.76	0.38	0.77	0.44	2.00	0.11	0.25	1.45	0.31	2.48
25	0.35	0.93	0.41	0.05	0.37	0.01	0.06	0.59	0.03	13.41
26	0.03	0.01	0.05	0.60	3.04	0.15	0.30	1.82	0.47	0.11
27	0.71	0.18	0.81	0.23	3.83	0.06	0.17	2.06	0.29	2.75
28	0.31	0.24	0.24	0.21	1.29	0.05	0.15	1.15	0.15	1.56
29	0.44	0.85	0.26	0.85	0.52	0.21	0.38	0.70	0.23	1.15
30	0.43	0.84	0.37	0.15	0.52	0.04	0.13	0.70	0.08	4.83
31	0.62	0.25	0.98	0.72	2.46	0.18	0.34	1.63	0.47	2.09
32	0.33	0.57	0.56	0.46	0.58	0.11	0.26	0.75	0.16	3.42
33	0.13	0.75	0.08	0.09	0.18	0.02	0.09	0.39	0.03	2.55
34	0.72	0.07	0.70	0.66	10.43	0.16	0.32	3.55	0.97	0.72

35	0.50	0.07	0.35	0.62	6.83	0.15	0.31	2.82	0.74	0.47
36	0.17	0.05	0.24	0.44	3.59	0.11	0.25	2.00	0.42	0.57
37	0.84	0.81	0.38	0.61	1.03	0.15	0.30	1.02	0.26	1.42
38	0.59	0.66	0.84	0.08	0.90	0.02	0.09	0.95	0.07	12.25
39	0.73	0.89	0.75	0.62	0.81	0.15	0.31	0.90	0.23	3.20
40	0.91	0.55	0.52	0.98	1.65	0.24	0.41	1.31	0.46	1.13
41	0.21	0.86	0.88	0.67	0.24	0.17	0.32	0.47	0.13	6.81
42	0.87	0.90	0.43	0.56	0.97	0.14	0.29	0.99	0.24	1.77
43	0.23	0.00	0.18	0.62	526.24	0.15	0.31	29.47	7.71	0.02
44	0.00	0.74	0.79	0.95	0.00	0.24	0.40	0.05	0.02	42.06
45	0.27	0.84	0.19	0.69	0.33	0.17	0.33	0.55	0.15	1.27
46	0.00	0.41	0.71	0.32	0.01	0.08	0.20	0.08	0.01	53.84
47	0.93	0.61	0.08	0.96	1.52	0.24	0.41	1.26	0.43	0.18
48	0.36	0.67	0.19	0.39	0.53	0.10	0.23	0.71	0.14	1.34
49	0.10	0.33	0.94	0.49	0.30	0.12	0.27	0.52	0.12	8.05
50	0.13	0.12	0.53	0.33	1.03	0.08	0.21	1.02	0.18	2.92
51	0.15	0.48	0.97	0.88	0.31	0.22	0.39	0.53	0.17	5.61
52	0.60	0.55	0.62	0.32	1.10	0.08	0.21	1.05	0.18	3.40
53	0.62	0.80	0.12	0.26	0.77	0.07	0.18	0.87	0.13	0.88
54	0.93	0.23	0.68	0.10	4.01	0.02	0.10	2.12	0.17	3.94
55	0.69	0.63	0.27	0.09	1.10	0.02	0.09	1.05	0.08	3.29
56	0.14	0.29	0.59	0.48	0.48	0.12	0.26	0.67	0.15	3.95
57	0.38	0.83	0.27	0.56	0.45	0.14	0.29	0.65	0.16	1.70
58	0.84	0.50	0.59	0.16	1.68	0.04	0.13	1.32	0.15	3.97
59	0.75	0.20	0.81	0.48	3.82	0.12	0.26	2.06	0.46	1.77
60	0.56	0.51	0.09	0.49	1.11	0.12	0.27	1.06	0.24	0.37
61	0.99	0.75	0.49	0.94	1.32	0.24	0.40	1.16	0.40	1.22
62	0.84	0.03	0.56	0.47	24.57	0.12	0.26	5.63	1.23	0.45
63	0.95	0.23	0.36	0.57	4.07	0.14	0.29	2.13	0.53	0.68
64	0.98	0.09	0.52	0.86	10.98	0.21	0.38	3.65	1.17	0.45
65	0.68	0.08	0.31	0.20	8.39	0.05	0.15	3.15	0.41	0.76
66	0.47	0.15	0.80	0.68	3.09	0.17	0.33	1.84	0.51	1.56
67	0.00	0.19	0.42	0.68	0.02	0.17	0.33	0.11	0.03	14.28
68	0.32	0.48	0.60	0.61	0.66	0.15	0.31	0.80	0.21	2.87
69	0.41	0.44	0.05	0.20	0.94	0.05	0.15	0.97	0.13	0.37
70	0.63	0.82	0.43	0.12	0.77	0.03	0.11	0.87	0.08	5.38
71	0.68	0.28	0.61	0.85	2.39	0.21	0.38	1.60	0.51	1.19
72	0.08	0.17	0.05	0.91	0.51	0.23	0.39	0.69	0.23	0.23
73	0.96	0.24	0.71	0.46	3.97	0.12	0.26	2.10	0.46	1.55
74	0.03	0.34	0.75	0.31	0.09	0.08	0.20	0.28	0.05	15.81
75	0.40	0.04	0.06	0.63	9.31	0.16	0.31	3.34	0.89	0.07
76	0.01	0.87	0.22	0.54	0.01	0.14	0.28	0.09	0.02	9.56
77	0.15	0.70	0.16	0.35	0.22	0.09	0.22	0.44	0.08	1.97
78	0.11	0.42	0.33	0.28	0.26	0.07	0.19	0.48	0.08	4.35
79	0.02	0.72	0.59	0.59	0.02	0.15	0.30	0.13	0.03	17.39
80	0.27	0.87	0.02	0.61	0.31	0.15	0.31	0.53	0.14	0.12
81	0.30	0.31	0.45	0.94	0.97	0.24	0.40	0.98	0.34	1.34
82	0.37	0.58	0.32	0.26	0.64	0.06	0.18	0.79	0.12	2.66
83	0.10	0.41	0.86	0.61	0.26	0.15	0.31	0.48	0.12	6.92
84	0.36	0.88	0.81	0.86	0.40	0.22	0.38	0.61	0.20	4.11
85	0.48	0.06	0.45	0.07	8.69	0.02	0.07	3.21	0.20	2.22
86	0.89	0.65	0.38	0.71	1.37	0.18	0.34	1.18	0.34	1.12
87	0.20	0.59	0.80	0.14	0.34	0.04	0.12	0.56	0.06	13.62
88	0.21	0.79	0.26	0.45	0.27	0.11	0.25	0.49	0.11	2.51
89	0.36	0.07	0.31	0.37	4.92	0.09	0.22	2.36	0.45	0.69
90	0.56	0.42	0.65	0.47	1.32	0.12	0.26	1.16	0.26	2.53
91	0.95	0.78	0.44	0.99	1.22	0.25	0.42	1.11	0.39	1.12
92	0.58	0.83	0.66	0.46	0.70	0.11	0.25	0.82	0.18	3.73
93	0.38	0.03	0.91	0.93	12.62	0.23	0.40	3.93	1.33	0.68
94	0.05	0.80	0.62	0.27	0.06	0.07	0.18	0.22	0.03	18.03
95	0.39	0.68	0.74	0.69	0.58	0.17	0.33	0.75	0.21	3.56
96	0.14	0.72	0.10	0.96	0.20	0.24	0.41	0.42	0.14	0.69
97	0.92	0.34	0.05	0.09	2.74	0.02	0.09	1.72	0.14	0.34
98	0.25	0.01	0.36	0.86	33.88	0.22	0.38	6.70	2.17	0.17
99	0.21	0.14	0.09	0.62	1.55	0.15	0.31	1.27	0.33	0.28
100	0.15	0.70	0.16	0.35	0.22	0.09	0.22	0.44	0.08	1.97

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