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Study of Performance of Shaft output with Rotor-to-Casing Ratios versus Different Vane Angles Adopting Practical Approach on a Novel Multi-Vane Air Turbine

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Strictly as per the compliance and regulations of:

Study of Performance of Shaft output with Rotor-to-Casing Ratios versus Different Vane Angles Adopting Practical Approach on a Novel Multi-Vane Air Turbine

Bharat Raj Singh[α] , Onkar Singh[Ω]

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Keywords : zero pollution, compressed air, air turbine, vane angle, rotor / casing diameter ratio, air-o-cycle.

I. Introduction

It is an established fact that the Worldwide faster consumptions of fossil fuel in transport vehicles have resulted fast depletion to energy resources and releasing huge quantities of pollutant in the atmosphere.. A US geologist Marian King Hubbert [1] in 1956 indicated that the conventional crude-oil production will attain Peak Oil within 20 years and thereafter it will start depleting which may cause serious threat to mankind within 40 years i.e. by 1995. Aleklett K. and Campbell C.J., [2] in 2003 illustrated that with current rate of consumptions, the production of oil and gas in many country will peak and begin to decline by around 2010. Such apprehension has led the search for environment friendly alternative to fossil fuel oil, or some method of conserving natural resources using non-conventional options, such as; bio-diesel, wind power, photo voltaic cells etc. and or energy conversion systems like battery storage, hydrogen cell, compressed air etc to obtain shaft work for the engines of vehicles [3-9].

Guy Negre [10] a French technologist and G. Saint Hillarie [11] an inventor of quasi turbine have carried out very important work in the area of compressed air engine. They stored highly compressed air in the energy storage systems up to 300 bar pressure within 15–20 minutes, and reused for running compressed air engines. In view of such attractive features of nearly zero pollution and air compression by using non-conventional resources, the compressed air engine became comparable in place of the other technology in vehicle markets.

In this paper author has carried out the parametric analysis of a small capacity air turbine having vane type rotor and describes the investigation of the effect of rotor to casing diameter ratios with different vanes fitted in the rotor. Results obtained by using a mathematical model are presented and analyzed here.

II. Feature of Vane Type Air Turbine

In this study a multi-vane type air turbine having casing diameter =D mm and rotor diameter =d mm is proposed as shown in Fig. 1. The considered air turbine works on the reverse working principle of vane type compressor. In this arrangement total shaft work is seen to be the cumulative effect of isobaric admission of compressed air jet on vanes and the adiabatic expansion of high pressure air. In earlier study conducted by authors a prototype of air turbine was developed [12].and its functionality was examined A storage cylinder for the compressed air having capacity of 30 minutes stored air, for the requirement of running turbine at initial stage at working pressure of 10 bar, is used as a compressed air energy source. This storage cylinder is designed to produce constant pressure for the minimum variation of torque at low volumes of compressed air and attached with filter, regulator and lubricator. The clean air then admits into air turbine

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through its inlet nozzle and vanes of air turbine are also fitted into rotor under spring loading to maintain their regular contact with the casing wall. This arrangement is proposed to minimize leakage through mating contacts and is novelty of improvement in the vane turbine. A study on highly efficient energy conversion system for liquid nitrogen [13], design and verification of airfoil and its tests, influence of tip speed ratios for small wind turbine and parabolic heat transfer and structural analysis were also carried out for conceptualizing the energy conversion system [14-17]. The study of design feasibility of vane type novel air turbine has also been carried out [18-21].

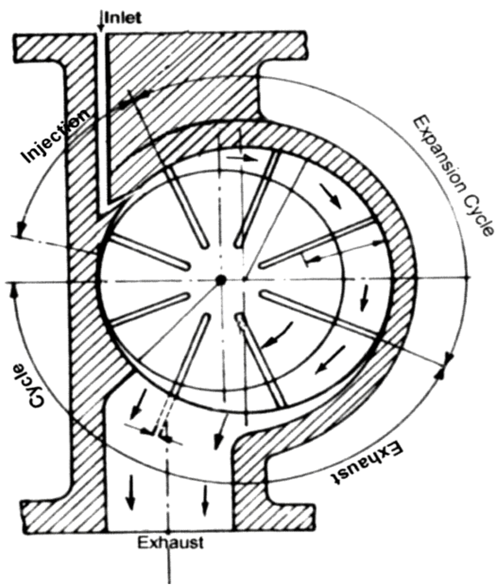

Fig.1 : Air Turbine-Model

The present objective of this study is to investigate the power output of an air turbine with different number of vanes in rotor, i.e. angle between first two consecutive vanes and the rotor/casing ratio (*d/D*). The air turbine considered has capability to yield output of 5.0 to 5.6 HP at injection pressure 4-6 bar and speed of 2000–2500 rpm and is suitable to run a motorbike.

III. Mathematical Model

The mathematical model shown here is already presented in author's earlier publications [22-34] and is reproduced here for maintaining the continuity and benefits to the readers[**1]. The high pressure jet of air at ambient temperature drives the rotor in novel air turbine due to both isobaric admission and adiabatic expansion. The high pressure air when enters through the inlet passage, pushes the vane for producing rotational movement and thereafter air so collected between two consecutive vanes of the rotor is gradually expanded up to exit passage, also contributes to the shaft out. This isobaric admission and adiabatic expansion of high pressure air both produces the total shaft power output from air turbine. Compressed air leaving the air turbine after expansion is sent out from the exit passage. It is thus noticed that the scavenging of the rotor is perfect and the work involved in recompression of the residual air is absent as seen from Fig. 1.

From Fig. 2, it is seen that work output is due to isobaric admission (E to 1), and adiabatic expansion (1 to 4) and reference 2, 3 in the figure shows the intermediate position of vanes. Thus, total work output due to thermodynamic process may be written as:

Total work output = [Thermodynamic expansion work (w_1)] + [Exit steady flow work (w_2)]

or

$$w = [(w_1) + (w_2)] \qquad (1)$$

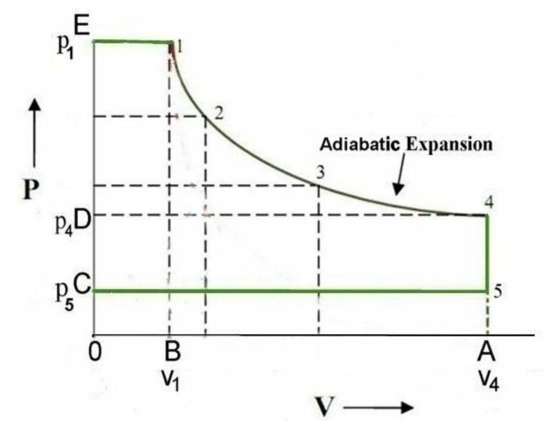

Fig.2 : Thermodynamic Processes (Isobaric, adiabatic and Isochoric Expansion)

Now thermodynamic expansion work (w_1), considering adiabatic process between state 1 and 4, it can be written as:

$$w_1 = \left(\frac{\gamma}{\gamma - 1}\right) . p_1 . v_1 . \left\{ 1 - \left(\frac{p_4}{p_1}\right)^{\frac{\gamma-1}{\gamma}} \right\} \qquad (2)$$

The process of exit flow (4-5) takes place after the expansion process (E - 4) as shown in Fig. 2 and air is released to the atmosphere. In this process; till no over expansion takes place pressure p_4 can't fall below atmospheric pressure p_5. Thus at constant volume when pressure p_4 drops to exit pressure p_5, no physical work is seen. Since turbine is functioning as positive displacement machine and hence under steady fluid flow at the exit of the turbine, the potential work is absorbed by the rotor and flow work (w_2), can be written as:

[**1] Mathematical model is reproduced here from author's earlier publications [22-34].

$$w_2 = \int_4^5 v.dp = v_4(p_4 - p_5) \qquad (3)$$

Applying equations (2), (3) into equation (1), considering air turbine has *n* number of vanes, then shaft output [35] can be written as:

$$w_n = n.\left(\frac{\gamma}{\gamma-1}\right).p_1.v_1\left\{1-\left(\frac{p_4}{p_1}\right)^{\frac{\gamma-1}{\gamma}}\right\}+n.(p_4-p_5).v_4 \qquad (4)$$

where w_n is work output (in Nm), for complete *one cycle.*

Therefore, the total power output or work done per unit time (W), for speed of rotation N rpm, will be:

$$W_{total} = n.(N/60).\left(\frac{\gamma}{\gamma-1}\right).p_1.v_1.\left\{1-\left(\frac{p_4}{p_1}\right)^{\frac{\gamma-1}{\gamma}}\right\}+n.(N/60).(p_4-p_5).v_4 \qquad (5)$$

Figure 1 shows that if vanes are at angular spacing of θ degree, then total number of vanes will be *n* = (360/θ). The variation in volume during expansion from inlet to exit (i.e. v_1 to v_4) can be derived by the variable extended length of vane as shown in Fig. 3 at every point of movement between two consecutive vanes.

From Fig. 3, shows that when two consecutive vanes at OK and OL move to position OH and OB, the extended vane lengths varies from SK to IH and LM to BG, thus the variable length BG at variable α_i is assumed as $X_{at'variable'\alpha}$ can be written from the geometry:

$$BG = x_{at,variable'\alpha'} = R.cos\left[\sin^{-1}\left\{\left(\frac{R-r}{R}\right).\sin\alpha\right\}\right]+(R-r).\cos\alpha - r \qquad (6)$$

where 2R=D is diameter of casing and 2r=d is diameter of rotor, α is angle ∠BOF, β is angle ∠BAF and θ is angle ∠HOB or ∠H'OF or ∠KOL, between two consecutive vanes and ϕ is angle ∠KOJ at which injection pressure admits to the air turbine.

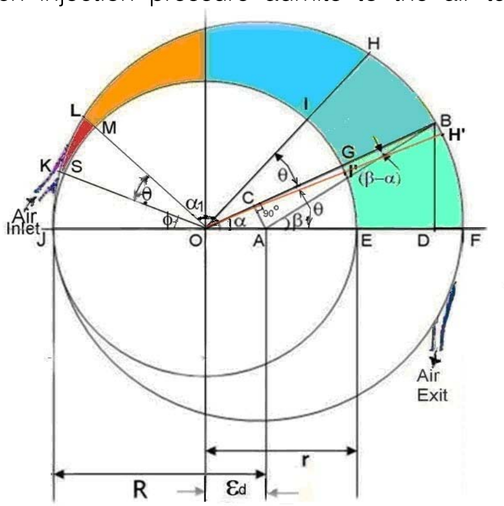

Fig.3 : Variable length BG and IH and injection angle∅

Variable volume of cuboids B-G-I-H-B can be written as:

$$v_{cuboids} = L.\left\{\frac{(X_{1i}+X_{2i})(2r+X_{1i})}{4}\right\}.\sin\theta \qquad (7)$$

where BG= X_{1i} and IH= X_{2i} variable length of vanes when rotate into turbine as shown in Fig. 3 and i stands for min or max length. Thus

a) The volume at inlet v_1 or v_{min} will fall between angle ∠LOF= $\alpha_{1min} = (180-\theta-\phi)$ and angle ∠KOF= $\alpha_{2min} = (\alpha_{1min}+\theta) = (180-\phi)$ as seen in Fig. 3, when air is admits into turbine at angle ϕ .

b) The Volume at exit v_4 or v_{max} will fall between angle ∠BOF = $\alpha_{1max} = \alpha = 0$ and angle ∠HOF = $\alpha_{2max} = (\alpha_{1max}+\theta) = \theta$.

Applying above conditions into equations (6), then LM=X_{1min} , SK=X_{2min}, FE=X_{1max}=Corresponding to BG at α =0 degree and I'H'=X_{2max}=Corresponding IH at $(\alpha+\theta) = \theta$ degree

Applying values of X_{1min} and X_{2min} to equation (7),

$$v_{min} = v_1 = L.\left\{\frac{(X_{1min}+X_{2min})(2r+X_{1min})}{4}\right\}.\sin\theta \qquad (8)$$

Applying values of X_{1max} and $X_{2\,max}$ to equation (7),

$$v_{max} = v_4 = L.\left\{\frac{(X_{1max}+X_{2max})(2r+X_{1max})}{4}\right\}.\sin\theta \qquad (9)$$

Applying values of v_1 and v_4 from equations (8) and (9) to equation (5), the total power output available W_{total} can be written as :

$$W_{total} = n.(N/60).\left(\frac{\gamma}{\gamma-1}\right).\left\{1-\left(\frac{p_4}{p_1}\right)^{\frac{\gamma-1}{\gamma}}\right\}p_1.\left[L.\left\{\frac{(X_{1min}+X_{2min}).(2r+X_{1min})}{4}\right\}.\sin\theta\right]$$
$$+n.(N/60).(p_4-p_5).\left[L.\left\{\frac{(X_{1max}+X_{2max}).(2r+X_{1max})}{4}\right\}.\sin\theta\right] \qquad (10)$$

IV. Parametric Considerations and Analysis

In this study various input parameters are listed in Table 1 for investigation of performance of vane turbine at different rotor to casing diameter ratios (*d/D*) with respect to different vane angle when *D*=100 mm, injection pressure 6 bar (90 psi) and its optimization for larger shaft output.

Table 1 : Input Parameters

Symbols	Parameters
d /D Ratio	0.95, 0.9, 0.85, 0.80, 0.75 and 0.70 when casing diameter is kept D=100 mm
p_1	6 bar(≈ 90 psi) – inlet pressures
p_5	$(p_4/1.2)$ >1.0132 bar (atmospheric pressure)
p_4	$(v_1/v_4)^{\gamma}\cdot p_1$ > p_5 assuming adiabatic expansion
N	2500 rpm (as total power is directly proportion to rpm)
L	45 mm length of rotor (assumed minimum)
γ	1.4 for air
n	Number of vanes in the rotor=(360 / θ)
θ	Vane angle =30°(12 vanes), 36°(10 vanes), 45° (8 vanes), 60°(6 vanes), and 90° (4 vanes)
ϕ	60° angle at which compressed air enters through nozzle into rotor

While actual fabrication of air turbine is carried out, it is noticed that the rotor / casing (d/D) ratio can possibly be varied from 0.95 to 0.70 only.

V. Results and Discussion

Based on the various input parameters listed in Table-1 and mathematical model, the effects of different rotor to casing diameters ratios, at different vane angles, 2500 rpm of speed of rotation and 6 bar of injection pressure on the expansion work, exit flow work and total work output from air turbine are studied. Here the injection angle (ϕ) of the air turbine is considered to be constant at 60° for whole study.

The results obtained have been plotted in Figs. 4 to 9, for the rotor to casing diameter ratio (d/D), varied as 0.95, 0.90, 0.85, 0.80, 0.75 and 0.70 at different vanes of rotor 12, 10, 8, 6, 4 (i.e. corresponding vanes angles of 30°, 36°, 45°, 60°, 90°) and injection angle of 60° at injection pressures of 90 psi and at the speed of rotation 2500 rpm.

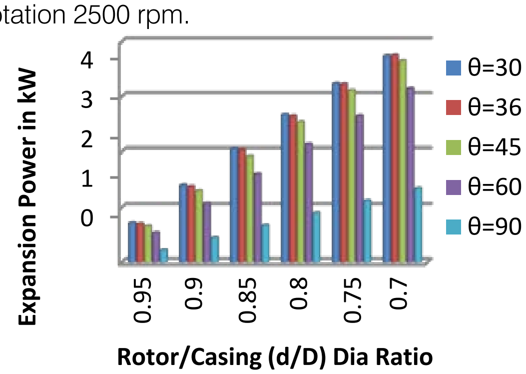

Fig.4 : Expansion power versus rotor / casing diameter (d/D) ratio at different rotor vanes when D= 100 mm, injection pressure = 6 bar and speed of rotation =2500 rpm.

Figure 4 shows the variation of expansion power for the rotor vanes =12 nos. (θ=30°), 10 nos. (θ= 36°), 8 nos. (θ= 45°), are increasing linearly at rotor / casing ratios =0.95, 0.90, 0.85, 0.80, 0.75 to 0.70 and it almost varies in similar values. Thus optimal performance of expansion power is seen at rotor / casing ratios =0.70 for vanes number 12 to 8. But variation of expansion power for the rotor vanes =6 nos. (θ=60°), and 4 nos. (θ= 90°), are increasing almost linearly at rotor / casing ratios =0.95, 0.90, 0.85, 0.80, 0.75 & 0.70 and developed power values are smaller.

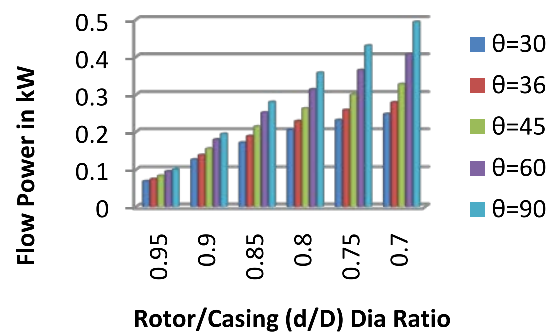

Fig.5 : Exit flow power versus rotor / casing diameter (d/D) ratio at different vane number (vane angles) when D=100 mm, injection pressure = 6 bar and speed of rotation =2500 rpm.

Figure 5 shows the variation of flow power for the rotor vanes =12 nos. (θ=30°), 10 nos. (θ= 36°), and 8 nos. (θ= 45°), 6 nos. (θ=60°), and 4 nos. (θ= 90°), are increasing parabolically at rotor / casing ratios =0.95, 0.90, 0.85, 0.80, 0.75 and 0.70 and it almost varies at different power values. It is also noticed that for the rotor vanes 6 nos. (θ=60°), and 4 nos. (θ= 90°) the values of power are found large.

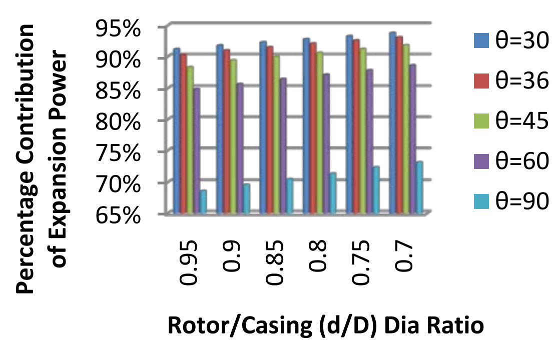

Fig.6 : Percentage contribution of expansion power versus rotor / casing diameter (d/D) ratio at different vane number (vane angles) when D=100 mm, injection pressure = 6 bar and speed of rotation =2500 rpm

Figure 6 shows the percentage contribution of expansion power against total power output for different rotor / casing ratios =0.95, 0.90, 0.85, 0.80, 0.75 and 0.70 at the rotor vanes =12 nos. (θ=30°), 10 nos. (θ= 36°), and 8 nos. (θ= 45°), are increasing from 91-94%, 90-93% and 88-92% respectively. But at the rotor 6 nos., (θ=60°), and 4 nos. (θ= 90°), it varies from 85% to 87% and from 69% to 73% respectively.

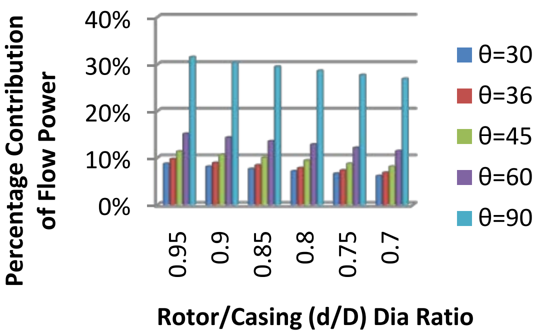

Fig.7 : Percentage contribution of exit flow power versus rotor / casing diameter (d/D) ratio at different vane number (vane angles) when D=100 mm, injection pressure = 6 bar and speed of rotation =2500 rpm

Figure 7 shows the contribution of flow power against the total power output for different rotor / casing ratios =0.95, 0.90, 0.85, 0.80, 0.75 and 0.70 at the rotor vanes =12 nos. (θ=30°), 10 nos. (θ= 36°), and 8 nos. (θ= 45°) are decreasing from 11% to 6% and at the rotor 6 nos. (θ=60°), and 4 nos. (θ= 90°), it varies from 15% to 11% and from 31% to 27% respectively.

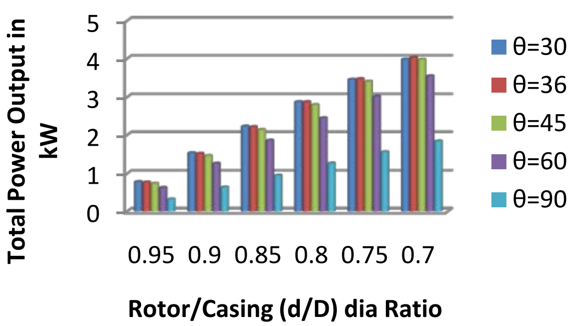

Fig.8 : Total power output versus rotor/casing diameter (d/D) ratio at different vane angle when injection pressure = 6 bar and speed of rotation =2500 rpm

Variation of total power output is seen from Fig. 8, with respect to different vane angle =30° (12 vanes), 36° (10 vanes), 45° (8 vanes), 60° (6 vanes) and 90° (4 vanes) are increasing linearly at rotor / casing ratios =0.95, 0.90, 0.85, 0.80, 0.75 to 0.70 and it almost varies in similar values. Thus optimal performance of total power is seen to be 4.02 kW at rotor / casing ratios =0.70 for vanes number 10 nos. (θ= 36°). But variation of total power for the rotor vanes =6 nos. (θ=60°), and 4 nos. (θ= 90°), are increasing linearly from rotor / casing ratios =0.95 to 0.75 and found smaller in its value than (*d/D*) =0.70.

From Fig. 8, a critical study is carried out and it is observed that the total power bar lines are almost equals at vane angle 30°-36° (vanes= 12-10 nos.) for *d/D* ratios 0.90, 0.85, 0.80 and 0.75. The power output appears to be maximum when vane angle is 36° (vanes= 10 nos.) at *d/D* ratio=0.70. Accordingly a graph is drawn between "Total output power versus different vane angles" e.g., = 30° (12 vanes), 36° (10 vanes), 45° (8 vanes), 60° (6 vanes) and 90° (4 vanes) as shown in Fig. 9. It is thus observed that in the vane turbine total shaft power output is although the combined effect of the component of expansion power and exit flow power, but contribution of expansion power is predominant. The contribution of exit flow power due to steady flow in respect to total power output varies from 6.2% to 31.4% for injection pressure of 6 bar and speed of rotation at 2500 rpm.

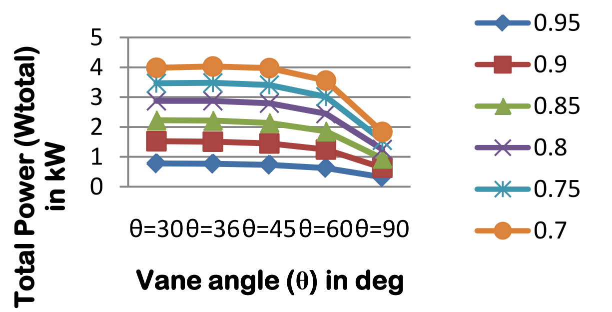

Fig.9 : Total power output versus vane angles (vane numbers) at different rotor / casing (d/D) ratio when injection pressure = 6 bar and speed of rotation =2500 rpm

From Fig. 9, it is obvious that the expansion power output as well as total power output is found optimum when vane angle ranges from 30°-45° (12-8 vane nos.), injection angle at 60° or above, at rotor/casing diameter ratio 0.70, speed of rotation at 2500 rpm and injection pressure at 6 bar and will be a deciding factor for desired shaft power output.

VI. Conclusions

From the above investigations based on input parameters, such as; injection pressure, injection angle and speed of rotation when kept 6 bar, 60° and 2500 rpm respectively, following conclusions are drawn:

Total output power from the air turbine is seen to be larger at injection pressure 6 bar, speed of rotation 2500 rpm and different rotor/casing diameter ratios at particular vane angles and total power ranges as shown below :

- 3.98 kW to 4.02 kW, when rotor to casing diameter ratio is 0.70 and vane nos. 12-8 (vane angle 30° -45°),
- 3.46 kW to 3.48 kW, when rotor to casing diameter ratio is kept 0.75 and vanes nos. 12-10 (vane angle 30° to 36°),
- 2.79 kW to 2.87 kW, when rotor to casing diameter ratio is kept 0.80 and vanes nos. 12-10 (vane angle 30° to 36°).

Thus optimum shaft power output of a novel vaned type air turbine is obtained when the design parameters for rotor diameter to casing diameter (*d/D*) ratios are kept between 0.75 to 0.70 and vanes nos. 12-10 (vane angle is of 30° to 36°) and plays an important role in designing the air turbine.

VII. Nomenclature

d diameter of rotor (2r) in meter

D diameter of outer (2R) cylinder in meter

L length of rotor having vanes in meter

n no. of vanes=(360/θ)

N no. of revolution per minute

p pressure in bar

p_1, v_1 pressure and volume respectively at which air strike the Turbine,

p_4, v_4 pressure and volume respectively at which maximum expansion of air takes place,

p_5 pressure at which turbine releases the air to atmosphere.

v volume in cu-m

w theoretical work output in Nm

W theoretical power output (Nm/s)

X_{1i} variable extended lengths of vane at point 1

X_{2i} variable extended lengths of vane at point 2

bar (1 / 1.0132) atmospheric pressure

Subscripts

1, 2...4, 5 subscripts – indicates the positions of vanes in casing

e, exp expansion

f, flow flow

t, total total

min minimum

max maximum

Greek symbols

α angle BOF

α_1 angle LOF(=180-ϕ)

α_2 angle KOF (=180- θ-ϕ)

β angle BAF

γ 1.4 for air

θ angle between 2-vanes (BOH)

ϕ angle at which compressed air enters into rotor through nozzle

ξ_d eccentricity *(R-r)*

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Study on Algorithms of Graphic Element Recognition for Precise Vectorization of Industrial Computed Tomographic Image

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Abstract - Circle, line and circular arc are the common basic graphic elements in industrial computed tomography (ICT) image. The algorithm of recognizing such elements is the key to industrial CT image precise vectorization. An industrial CT image vectorization system has been studied, including different recognition methods for these elements. Firstly, based on facet model, the sub-pixel edge of an industrial CT image is extracted. Then, the circles are recognized by an improved algorithm based on probability of existence map, while the lines are recognized with the set intersection algorithm of fitting a straight line, and the circular arcs are recognized by the combination of the perpendicular bisector tracing algorithm and least squares function. Finally, the graphic element parameters are measured according to recognition results, and the drawing exchange file (DXF) is produced and transmitted into the computer aided design (CAD) system to be edited and consummated. The experimental results show that these methods are capable of recognizing graphic elements in industrial CT image with an excellent accuracy, besides, the absolute errors of circles are less than 0.1 mm, and the relative errors are less than 0.5%. It can satisfy the industrial CT vectorization requirements of higher precision, rapid speed and non-contact.

Keywords : Computed tomography, facet model, edge detection, vectorization.

GJCST Classification : I.4.9

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Fenglin Liu[α] , Bing He[Ω] ,Bi Bi[β]

Abstract - Circle, line and circular arc are the common basic graphic elements in industrial computed tomography (ICT) image. The algorithm of recognizing such elements is the key to industrial CT image precise vectorization. An industrial CT image vectorization system has been studied, including different recognition methods for these elements. Firstly, based on facet model, the sub-pixel edge of an industrial CT image is extracted. Then, the circles are recognized by an improved algorithm based on probability of existence map, while the lines are recognized with the set intersection algorithm of fitting a straight line, and the circular arcs are recognized by the combination of the perpendicular bisector tracing algorithm and least squares function. Finally, the graphic element parameters are measured according to recognition results, and the drawing exchange file (DXF) is produced and transmitted into the computer aided design (CAD) system to be edited and consummated. The experimental results show that these methods are capable of recognizing graphic elements in industrial CT image with an excellent accuracy, besides, the absolute errors of circles are less than 0.1 mm, and the relative errors are less than 0.5%. It can satisfy the industrial CT vectorization requirements of higher precision, rapid speed and non-contact.

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I. Introduction

There has been remarkable research achievement in developing and applying computerized tomography (CT)technology for medical and industrial applications, particularly in the industrial area, such as aerospace, aviation, military, machinery and automobile. Industrial CT is not only effective to detect the inner construction and flaws of an object, but also necessary to nondestructively measure the size of workpiece [1, 2]. However, the two dimensional slice images acquired by the 3rd generation ICT device can't be edited in the existing computer aided design (CAD) system. And most industrial CT images are the workpieces' dislocation images, which have many geometrical elements, such as lines, circular arcs and circles. Several conventional vectorizaion methods, applied in engineering drawings and maps, come with disadvantages, including noise sensitivity, computational complexity and low accuracy. These shortcomings make it difficult to accurately measure the size of workpieces' inner construction. In order to overcome these problems, in this paper we investigate methods of industrial CT images precise vectorization.

Since the research of image vectorization started in the early 1970s, numerous approaches have been developed [3, 4]. Broadly, these algorithms can be divided into several groups: thinning algorithm, contour tracking, Hough Transform (HT), dynamic window method and global recognition algorithm. The main advantage of thinning algorithm is that it holds a better reservation of image topology information, and its processing data points are decreased. Nevertheless, it is sensitive to noise. As a solution of this problem, the contour tracking method is provided. Its processing rate is high, and the impact of the air bubble and burr defects on the vectorization effect is reduced. However, the recognition accuracy is low since the vector image is discontinuous. In terms of accuracy and robustness, the HT and its variants have been successfully used in image vectorization. These methods are robust against outlier and occlusion, but computationally expensive. Dynamic window vectorization algorithm was proposed as a relatively novel method. A major advantage of this method presents at its high recognition accuracy to crossing point. Unfortunately, the window is changing continually, so the robustness is not enough. With the vectorization technology improving, some researchers have presented global recognition method. In process of vectorization, the line width can be obtained. Meanwhile, the corresponding tracking mode is adopted for reducing the impact of line fracture and missing data. But the accuracy of crossing point should be further improved.

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In view of the disadvantages of the current image vectorization methods, the key contribution of this paper is to investigate a vectorization system for industrial CT image. In this system, the sub-pixel edge of an industrial CT image is extracted based on facet model. Its execution time is reduced significantly by removing invalid data points. Then, the circles, lines and circular arcs are recognized respectively with the corresponding recognition algorithms. These algorithms improve recognition accuracy. Also, in the process of recognition, the obtained elements parameters are dynamically saved in the corresponding linked lists. Hence, the required computation storage space is much cheaper than the previous methods.

II. System Overview

In the process of industrial CT image vectorization, it is critical to detect edges in the image which is an important stage as the quantity and quality of edge data will affect greatly the vectorization performance of the system. The sub-pixel edge contour is extracted by the edge detection algorithm based on facet model, after the pre-processing as Gaussian filter, binarization. For this contour, the recognition algorithms of graphic elements are implemented. Firstly, determine whether the contour is a circle by calculating the center's probability. If it is a circle, the improved fast algorithm of circle detection based on probability of existence map is utilized to recognize it. The obtained circle parameters by the least squares function (LSF) are saved in the circle chained list. Reversely, if it is not a circle, the contour curve is fitted into many short line segments by adopting the improved set intersection algorithm of fitting a straight line. Then, merge the short line segments into the long line segments. Finally, the perpendicular bisector tracing algorithm is adopted to find the long line segments which can be fitted into circular arcs. And the merged circular arcs' parameters are derived from the least squares function. These parameters are saved in the circular arc linked list. Another long line segments' parameters are saved in the line linked list. After recognizing these elements, their parameters are outputted for vector graph. The system architecture is summarized in Fig. (1).

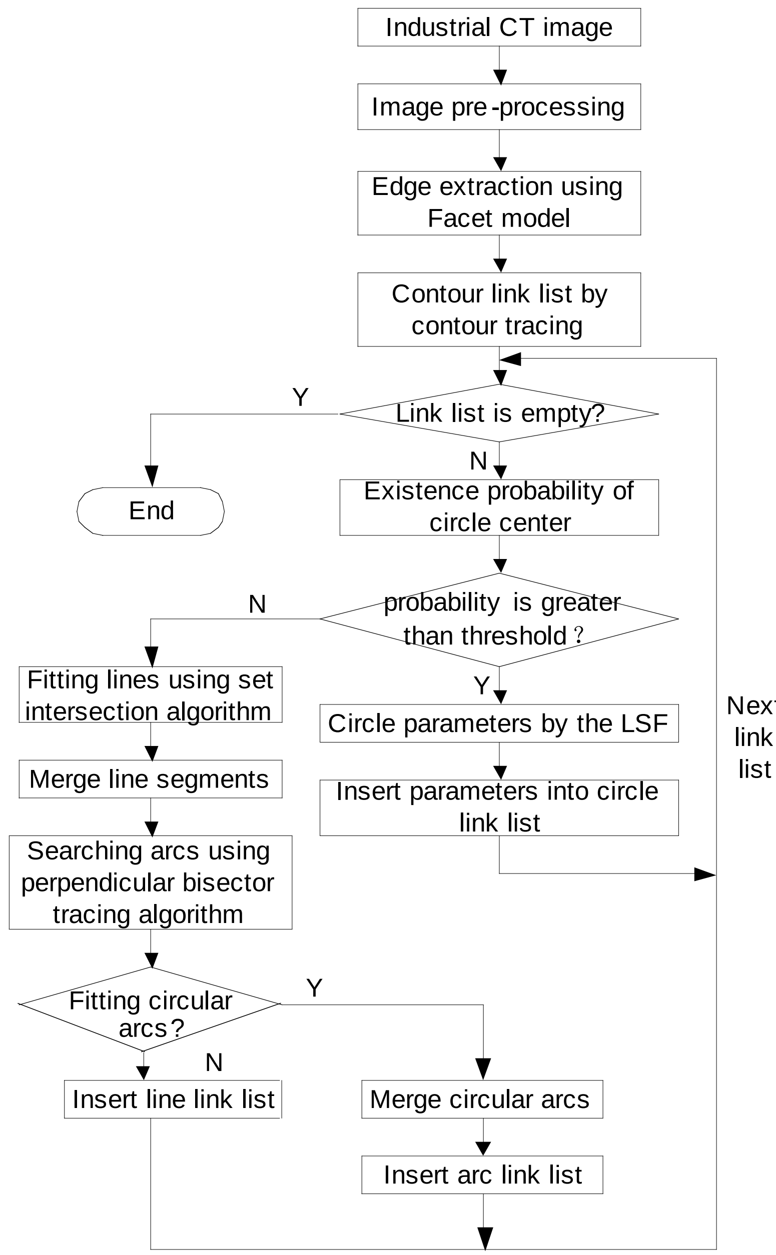

Fig. 1: Architecture of system.

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III. Edge Detecting Algorithm Based on Facet Model

The exact location of edge is obtained by using the edge detection algorithm based on facet model. Through calculating the second-ordered directional derivative, edge point is defined as the zero-crossing point of facet model along the gray gradient direction [5]. Third-ordered facet model of the pixel (*x*, *y*) in 5×5 regions can be expressed as follows:

$$f(r,c) = k_1 + k_2 r + k_3 c + k_4 r^2 + k_5 rc + k_6 c^2 + k_7 r^3$$
$$+ k_8 r^2 c + k_9 rc^2 + k_{10} c^3 \qquad (1)$$
$$r, c \in [-2, -1, 0, 1, 2].$$

Where (*r*, *c*) is the coordinate of any point in this pixel's neighborhood; *k1~k10* are the coefficients which are obtained by the least square method [6]. So

$$\sin\alpha = k_2 \Big/ \sqrt{k_2^2 + k_3^2}, \cos\alpha = k_3 \Big/ \sqrt{k_2^2 + k_3^2} \qquad (2)$$

Define *r* = ! sin" ,*c* = ! cos" (*ρ* is the distance between edge point and the center of pixel), the first-ordered, secondordered and third-ordered partial derivatives of the model can be expressed as follows:

$$\begin{cases} f'(\rho) = m_1 + 2m_2\rho + 3m_3\rho^2 \\ f''(\rho) = 2m_2 + 6m_3\rho \\ f'''(\rho) = 6m_3 \end{cases} \qquad (3)$$

The edge point is the location of local extremum of the first-ordered derivative in local fitting surface; meanwhile it is the zero-crossing point of the second-ordered derivative as well. (*r*, *c*) is the edge point, if we can obtain *ρ0* (*ρ0* is within the 5×5 sub-region whose center is (*r*, *c*)) which satisfies (4), and the third-ordered partial derivative negative, as in (5).

$$f''(\rho) = 2m_2 + 6m_3\rho = 0 \Rightarrow |m_2/3m_3| = \rho_0 \qquad (4)$$

$$f'''(\rho) < 0 \Rightarrow m_3 < 0 \qquad (5)$$

Adopting this algorithm, the subtle image detail is located. The edge detection accuracy is high enough, and the image noise is restrained to some extent.

IV. Recognitiion of Graphic Elements

a) Recognition of Circle

i. Existence Probability of Circle

Circles in the X-Y plane can be completely represented by the following quadratic equation with three parameters (*u*,*v*, *r*) as other 2nd order curves can be.

$$(x-u)^2 + (y-v)^2 = r^2 \qquad (6)$$

In order to obtain the size and position of circles in industrial CT image, the method based on probability of existence map is applied [7]. *Pe* is the existence probability of the circle whose center is (*u*, *v*) and radius is *r*. It is given by:

$$P_e = A(r)/2\pi r \qquad (7)$$

Where *A*(*r*) is the amount of edge points, whose distance from the center equals *r*, 2*πr* is the amount of discrete pixels of the circle with radius *r*.

Every pixel (*x*, *y*) in the image is regarded as the center, the existence probability *Pe* is calculated and saved in the two dimensional array {*P*(*x*, *y*)}. The probability of existence map is produced, and the radius *r* is saved in the two dimensional array {*R*(*x*, *y*)}. Each peak in probability of existence map represents that a circle may exist in this image, taking the peak coordinates as the center and *r* as the radius. *Pe* is the probability of such existence. Fig. (2) is an industrial CT image with a circle. The existence probability of the center point is calculated, and the probability map isshown in Fig. (3). The following information can be obtained : Center point (139,139), *r* =42.4946, *Pe* =0.8996

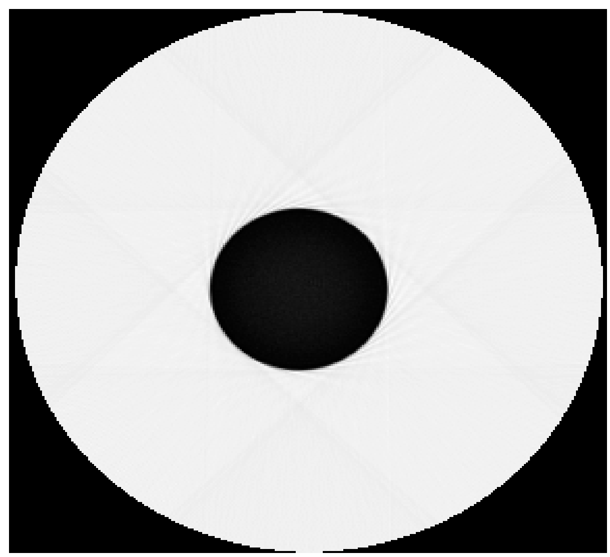

Fig. 2 : Industrial CT image.

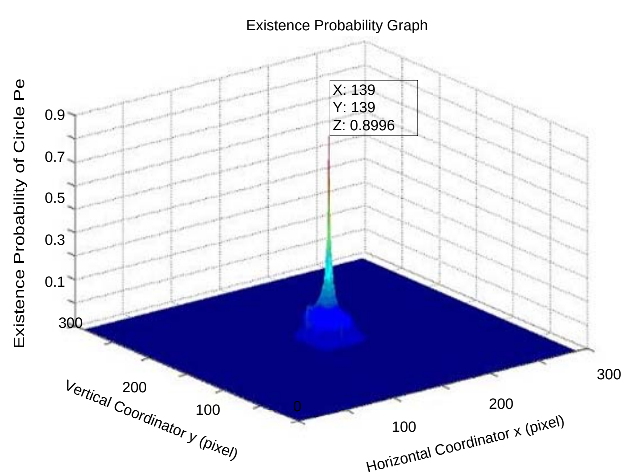

Fig.3 : Probability map of circle.

ii. *Improved Algorithm of Existence Probability*

The above algorithm regards each pixel in the image as the center of a circle, but most pixels in the image are not the center of the circle actually. As a result, the computation is complicated and the required computational storage is expensive. The center of the circle should lie in a mini-realm in the target region, thus, we improve the above algorithm by decreasing the select range of circle center to the square *C* [8]. If a closed curve has been recognized as a circle, the maximum distance of two points on the circle is defined as diameter, and the middle point of the diameter is the circle center. As illustrated in Fig. (**4**), for every closed contour, we first have to find the nethermost point *A*, then, calculate all distances from *A* to the other points. The point *B* that has the maximum distance *D* is the endpoint of the diameter. The midpoint *O* of the diameter is approximately regarded as the centroid of the closed contour. Therefore, a square *C* is obtained, whose center and sides are the centroid *O* and $D \times w$ (D = 100, w = 0.1), respectively. The square *C* is the area within which the potential circle center will be sought. In this way, the improved method constrains the search for potential circle center only in the specified small range and thereby reduces the computational cost.

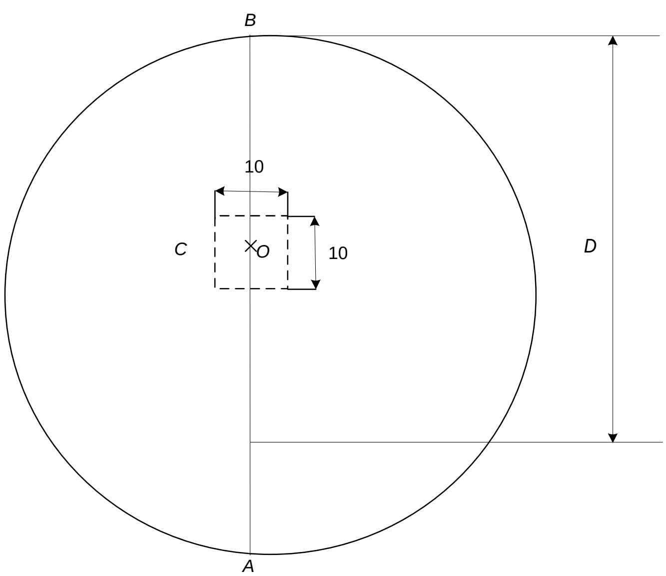

Fig. 4 : Select range of circle center.

Besides, we improved the storage mode for saving memory space as well. Circle parameters, such as the coordinates of the circle center, radius and existence probability, are stored by a series of two dimensional arrays in the previous algorithm, which has to allocate memory beforehand. Thus, different types of images require different memory size. If the allocated memory is oversize, the memory space will be wasted; on the contrary, if undersized, memory space will cause data overflow. In this paper, we store the above parameters using the chained-list, referred to as the mode of allocating memory is dynamic, not beforehand. There is no need for this rule to redefine the memory size, even though the image size is different. As described in the following, the constructed list structure is effective in that it influences not only memory allocation, but also the recognition efficiency of a circle.

```
typedef struct
    {int x; // x-coordinate of circle center
     int y; // y-coordinate of circle center} Point;
struct NODE
     {Point point; // coordinates of circle center
      float r; // radius of circle
      int k; // number of edge points
      float p; // existence probability of circle
      NODE *next; // the pointer of next node};
```

b) Recognition of Line

After recognizing the circles in industrial CT image, the remaining contours are fitted into short line segments by an improved method of fitting a straight line. Based on the set intersection algorithm of fitting a straight line [9], the method makes use of least square technique [10] to get line segment parameters. Generally, the procedure of the method is as follows:

As shown in Fig. (**5a**). For a contour, the starting point is P_0, the current point is P_c. At the beginning of fitting, $P_c = P_0$. First, determine whether the next field of P_c is empty. If the next field is empty, end tracking the current line, get the line segment P_0P_c. If the next field isn't empty, judge whether the following point P_n belongs to the current line. If P_n is in the current line, then $P_n \rightarrow P_c$, and continue determining the following one. Or else, terminate tracking the current line, and get the line segment P_0P_c. Next, let P_n be the new starting point, and continue recognizing other line segments of the contour. After finishing a contour recognition, the above process is repeated for another contour of industrial CT image.

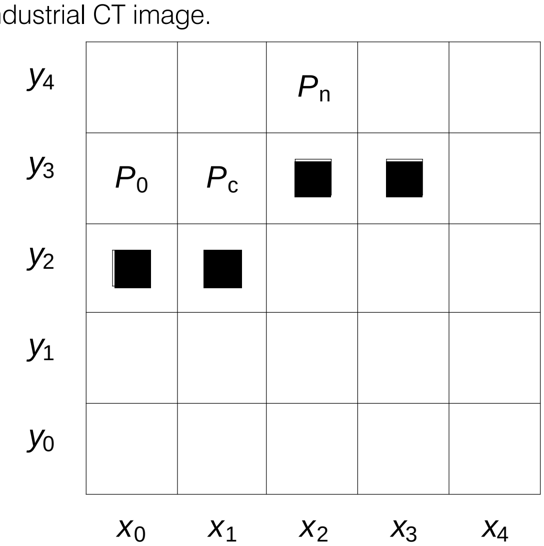

Fig.5(a) : Sketch map of straight line fitting

Due to low image quality and improper image preprocessing,the straight line may be mistaken as a series of short line segments, which we should merge into the long segments. The merging condition of two adjacent short line segments: the difference of slopes between two line segments must fall within the prescribed limits; and the distance between the endpoint of line segment and the merged long segment should be less than the specified value. As illustrated in Fig. (5b), if the angular difference between the adjacent line segments *AB* and *CD* is less than the prescribed value (using the angle value to represent the slope of line segment; here we choose 10°); and the distance from the point *B* to the line segment *AC* is less than the specified value (here 3 is appropriate), we will merge the short line segments *AB* and *BC* into the long segment *AC*. Then,determine whether the distance between the point *C* and the line segment *AD* is less than 3, and determine whether the angle difference between the line segment *CD* and the line segment *AC* is less than 10°. If the above two conditions are both met, get the long line segment *AD*. Or else, insert the merged line segment *AC* into the merged line link list, then, let *CD* be the new starting line segment, and continue merging the subsequent line segments.

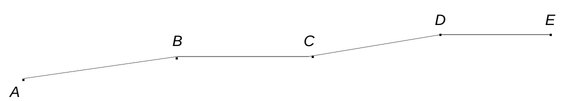

Fig. 5 (b) : Sketch map of merging line segment.

c) Recognition of Circular Arc

The obtained short line segments by implementing the above strategy are merged into the long line segments. These long line segments are fitted into circular arcs by means of the perpendicular bisector tracing algorithm [11]. The basic idea of the algorithm is that the perpendicular bisector of any chord on a circle passes through the circle center, and every endpoint of the chord is at an equal distance from the circle center.

As illustrated in Fig. (6a), any obtained line segment may be an approximation of an arc. We first consider the obtained line segment L_0 as seed arc, its perpendicular bisector P_0 is constructed. For every line segments L_i (i =1, 2…N), we then construct its perpendicular bisector P_i, and calculate the intersection C_i of P_i and P_0. Due to errors, the intersection C_i is not unique. However, all C_i are located along the line P_0. We define the point $C_{\min}$ is the nearest point from L_0, and the point $C_{\max}$ is the farthest point from L_0. Therefore, a rectangle C is obtained, whose length is the distance between $C_{\min}$ and $C_{\max}$, and whose width is equal to the length of L_0 and is bisected by P_0. The rectangle C is the area within which the potential arc center is sought.

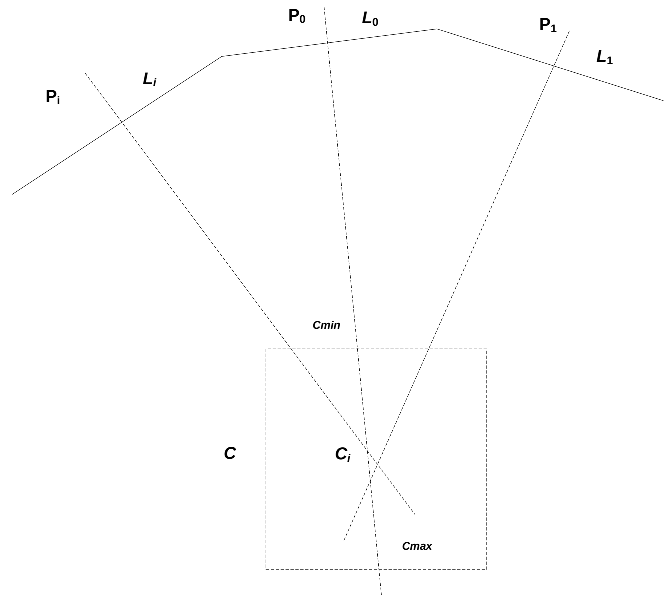

Fig. 6 (a) : Sketch map of circular arc fitting.

Having determined the potential center area, we check every pixel within it as a center candidate $c\,(x, y)$, the distances $R_i\,(x, y)$ between $c\,(x, y)$ and endpoints of line segments are gained. Then, we calculate the average radius $R\,(x, y)$ and the mean square error $ASD\,(x, y)$, using (8) and (9), respectively.

$$R(x,y) = \frac{1}{N+1}\sum_{i=0}^{N} R_i(x,y) \tag{8}$$

$$ASD(x,y) = \frac{1}{N+1}\sum_{i=0}^{N} (R(x,y) - R_i(x,y))^2 \tag{9}$$

The point whose $ASD(x, y)$ is minimal is taken as the circle center of circular arc, and the corresponding $R\,(x, y)$ is the radius of circular arc. The long circular arc may be recognized as some short circular arcs by using the perpendicular bisector tracing algorithm, so we merge these short circular arcs into the long circular arc. As shown in Fig. (6b), the merging condition of two adjacent short circular arcs: the coordinate difference between the circle centers O_1 and O_2 must fall within the prescribed limits (5 is fine); the radius difference between the radius R_1 and the radius R_2 should be less than the specified value (also 5 is enough); and the angular difference between the ending angle α_2 of the first circular arc and the starting angle α_3 of the second circular arc should be less than the threshold value (the threshold value is 3°). If there are two circular arcs meeting the above-mentioned three conditions, they can be merged into a new longer circular arc. The new circle center coordinates of this longer arc can be defined by the average value of the circle center coordinates of the two shorter arcs, and the radius of this new longer arc can be replaced by the average value of the radius of the two shorter ones. Also, the starting angle and ending angle of this new arc are substituted with the starting angle α_1 of the first arc and the ending angle α_4 of the second arc, respectively.

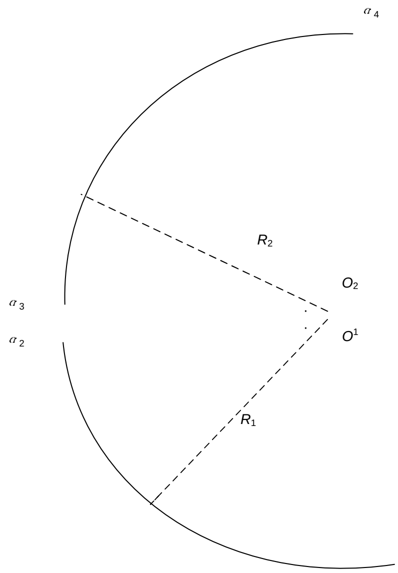

Fig. 6 (b) : Sketch map of merging circular arc.

V. Experimental Results and Evaluation

a) Recognition of Circle

In this section, the performance of the proposed algorithms has been tested with the real industrial CT images. The algorithms are implemented in C++ with MS Visual C++ 6.0 complier on a desktop PC with AMD 64 processor 1.81GHZ and 512MB RAM. The vectorization system for industrial CT image is designed, which provides the platform for our experiments. Fig. (**7a**) is an original industrial CT image of a socket set by the ICT system of CD-650BX in Chongqing University ICT Research Center. The technical indexes of the ICT system are as follows: the ray source is a 6/9MeV electron linear accelerator, the spatial resolution is 2.0lp/mm, the density resolution is better than 0.5%, the diameter of field of view is 398.872mm, the size of image is 800pixel*800pixel. Fig. (**7b**) is the sub-pixel edge image of circles in Fig. (**7a**); Fig. (**7c**) is the probability map of circles in Fig. (**7a**).

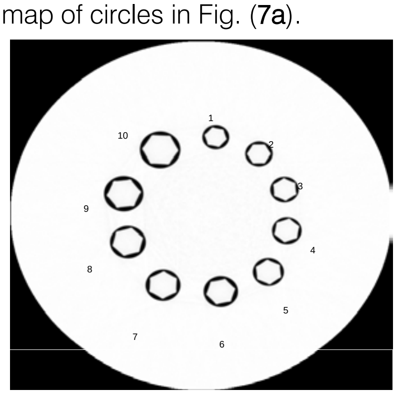

Fig.7 (a) : Industrial CT image of a socket set

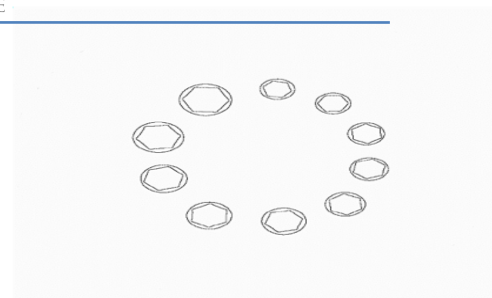

Fig.7 (b) : Sub-pixel edge image

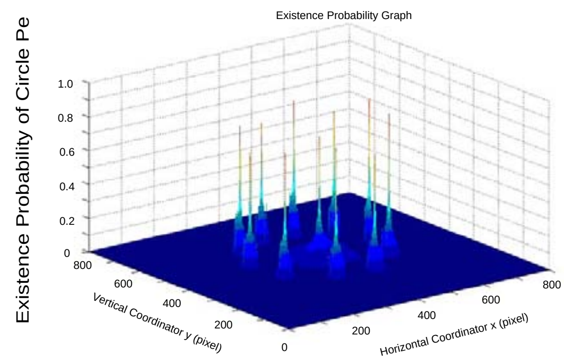

Fig.7 (c) : Probability map of circles.

b) Measurement of Circle Parameters

The results of our algorithms on the industrial CT image of the socket set are summarized in Table **1**. While in Table **2**, we list the absolute error *e* between the true and measured values of a parameter, and we evaluate the relative error *er* as well. As can be seen from Table **2**, our algorithms are able to achieve good accuracy. The absolute errors *e* of radius are less than 0.10mm, and the relative errors *er* are less than 0.5%.

Table 1 : Measurement Results of Circles

Number	Circle Center (pixel)	Radius (pixel)	Radius (mm)	P_e
1	(430, 576)	27.798	13.860	0.867
2	(520, 538)	28.452	14.186	0.919
3	(573, 455)	29.520	14.718	0.908
4	(578, 360)	30.635	15.274	0.774
5	(540, 264)	32.172	16.040	0.870
6	(440, 219)	35.642	17.770	0.785
7	(320, 233)	36.254	18.076	0.847
8	(246, 333)	37.170	18.533	0.729
9	(237, 445)	40.871	20.378	0.841
10	(314, 547)	42.133	21.007	0.877

Table 2 : Measurement Errors of Circles

Number	True Value (mm)	Measured Value (mm)	Error (mm)	Relative Error (%)
1	13.925	13.860	-0.065	0.467
2	14.240	14.186	-0.049	0.379
3	14.780	14.718	-0.062	0.419
4	15.350	15.274	-0.076	0.495
5	16.075	16.040	-0.035	0.218
6	17.810	17.770	-0.040	0.225
7	18.125	18.076	-0.049	0.270
8	18.590	18.533	-0.057	0.307
9	20.420	20.378	-0.042	0.206
10	21.230	21.007	-0.023	0.109

c) Vectorization Results of Whole industrial CT image

In addition, we evaluate the vectorization performance on two complicated images shown in Figs. (8a and 9a). Fig. (8a) displays an original industrial CT image of a car engine. Based on facet model, its edge image is extracted and shown in Fig. (8b). As seen from the edge image, the contour is clear and intact. Also, all small contours are extracted correctly. Fig. (8c) is the vector graph of the car engine by our algorithms; it is edited and perfected in AutoCAD2008. In this experiment, a threshold is set for determining whether the closed graphic element is circle. As observed in Fig. (8c), setting the threshold is 0.7, our algorithms not only detect these four large circles correctly, but also fit them with good accuracy. The sizes of circles are marked in AutoCAD2008. Nevertheless, the small circles and slight contours can't be detected completely. If we decrease the threshold value appropriately, these small circles and slight contours will be detected. But the vectorization accuracy may be dropped.

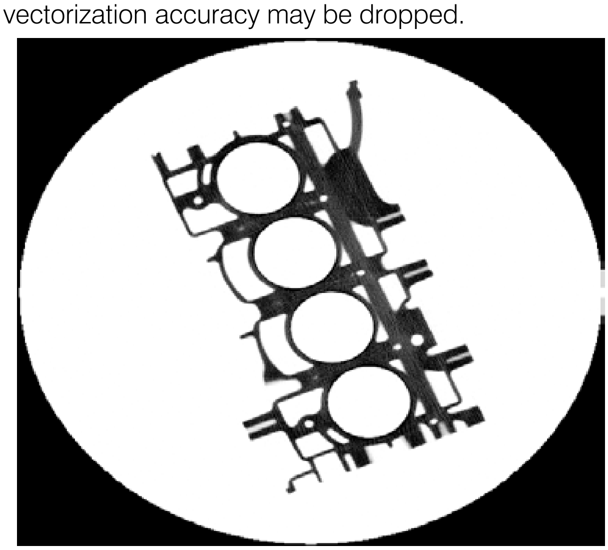

Fig.8 (a) : Industrial CT image of car engine

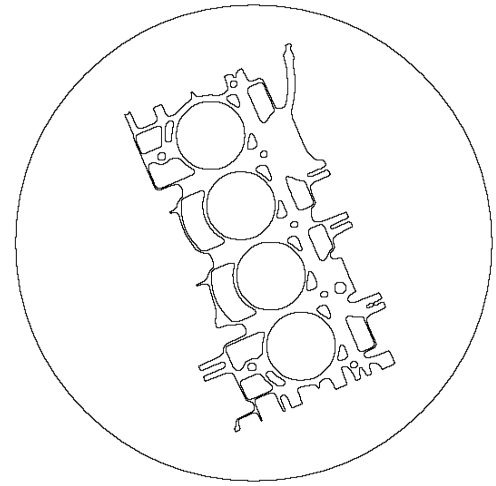

Fig. 8 (b) : Sub-pixel edge image of car engine

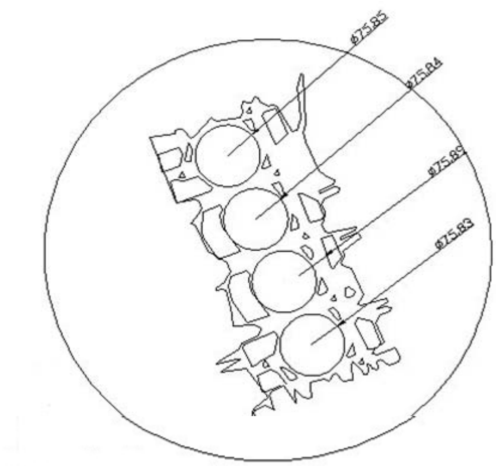

Fig.8 (c) : Vector graph of car engine

Fig. (9a) shows an original industrial CT image of a gearbox cover. Unlike the previous industrial CT image of the car engine, this image has relative complex contours. In the top left corner are several small contours, which are difficult to be detected correctly. Despite this, its edge map is extracted completely and shown in Fig. (9b). Of particular interest is the vector graph of the gearbox cover in Fig. (9c) which evaluates our algorithms, and it is edited in AutoCAD2008. As shown in this picture, all circles are detected. Furthermore, several small circles are also detected and fitted correctly. Notice that the left isolated circle, which has the inner and outer concentric contours, is detected correctly. Also, the line contour can be fitted with ideal precision. However, Fig. (9c) also shows the limitation of our algorithms in the slight and complicated details of image. The circle with diameter of 16.55mm is nonexistent, it should not be found. And some contours are not with respect to the original contours ideally. For instance, the circular arc is represented by the irregular arc segments and curves. The following work will aim to resolve these problems.

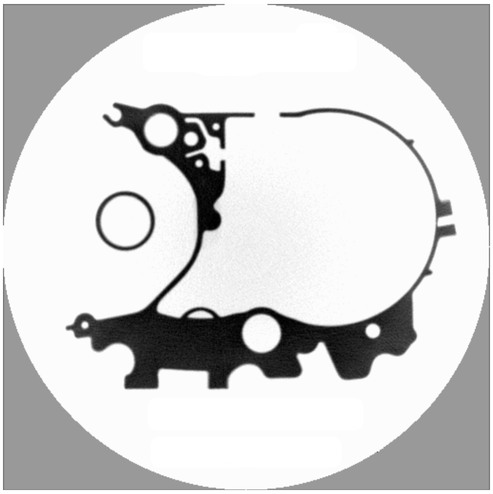

Fig. 9 (a) : Industrial CT image of gear box cover

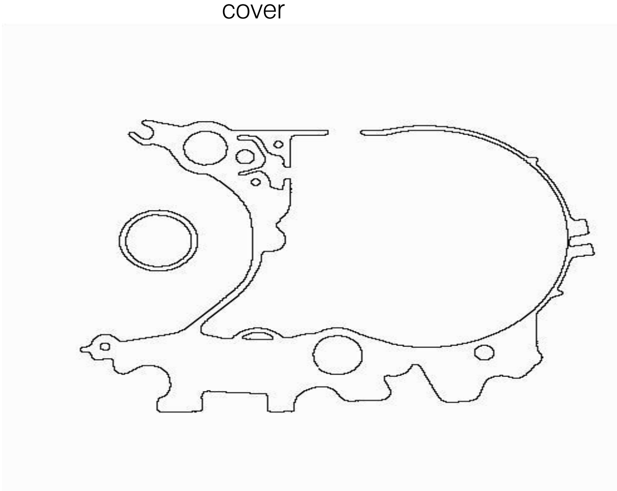

Fig . 9 (b) : Industrial CT image of gear box cover

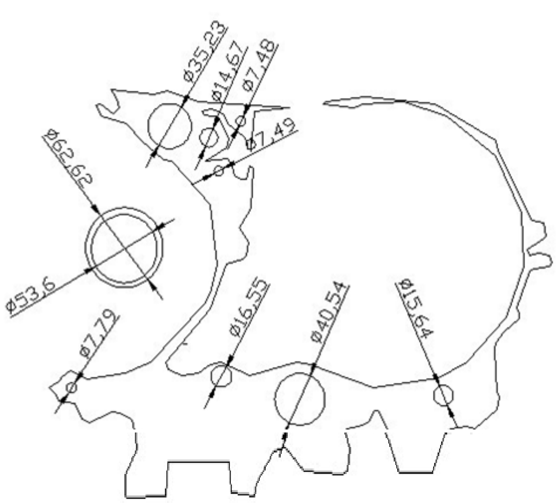

Fig . 9 (c) : Industrial CT image of gear box cover

VI. Conclusions

In this paper, an algorithm for sub-pixel edge detecting based on facet model is adopted for the pre-processed industrial CT image. For the obtained contour, we can calculatethe parameters of circle using the improved fast algorithm based on probability of existence map. Then, a set intersection algorithm of fitting a straight line is applied for recognizing the line. Finally, use the perpendicular bisector tracing algorithm and the least squares function to recognize circular arc. Thus, a vectorization system of industrial CT image is designed, which provides the platform for our experiments. Experimental results show indeed that our algorithms are capable of recognizing the circle, line and circular arc with an excellent accuracy. Furthermore, the vectorization performance for the whole image is preferable. It can satisfy the industrial CT image vectorization requirements of higher precision, rapid speed and non-contact. In the future, we will focus on extending this work by recognizing the relative complex graphic elements as ellipse, regular polygon.

VII. Acknowledgments

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Numerical Computation of Economic Cooling Water rate for Two-stage Azeotropic Refrigerating systems

By D.V. Mahindru, Priyanka Mahendru

Abstract - With a view to conserve energy, the use of azeotropes in a multistage refrigerating system is quite timely. Depending upon the requirement, such a system incorporates conventionally either a water cooled or air cooled condenser. The total operating cost of a refrigerating system with a water cooled condenser comprises the cost of water and the cost of electricity needed to drive the compressor(s). There is enough potential for research in finding out the ways to achieve maximum coefficient of performance and the least operating cost simultaneously for multi-stage azeotropic refrigerating system. However, to avoid overloading of sewage facilities and to comply with municipal codes for the use of water, the water flow rate required in refrigerating system should be minimized.

In the present investigation, economic water rates for two stage refrigerating systems, operating on most commonly used azeotropes R-500 and R-502, have been searched out over a wide range of operating limits. Such economic rates, if followed, would produce maximum COP and consume minimum power. The effects of controlling variables, e.g. approach, cost ratio etc have also been studied on the heat transfer to condenser, optimum condensing temperature and economic water rate. The results have been presented in tabular form only.

Keywords : Azeotropes ,Multi – Stage , Refrigeration , Condenser,Thermodynamic Concept.

GJRE- C Classification : FOR Code: 091307, 091502

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Strictly as per the compliance and regulations of:

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D.V. Mahindru[α], Priyanka Mahendru[Ω]

Abstract - With a view to conserve energy, the use of azeotropes in a multistage refrigerating system is quite timely. Depending upon the requirement, such a system incorporates conventionally either a water cooled or air cooled condenser. The total operating cost of a refrigerating system with a water cooled condenser comprises the cost of water and the cost of electricity needed to drive the compressor(s). There is enough potential for research in finding out the ways to achieve maximum coefficient of performance and the least operating cost simultaneously for multi-stage azeotropic refrigerating system. However, to avoid overloading of sewage facilities and to comply with municipal codes for the use of water, the water flow rate required in refrigerating system should be minimized.

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Keywords : Azeotropes ,Multi – Stage , Refrigeration , Condenser,Thermodynamic Concept.

I. Description

The total cost of a multistage refrigerating system with water cooled condenser comprises the cost of power required to run the compressors and the cost of water needed in the condensing unit to make the system work in a closed and continuous cycle. To minimize the total operating cost, the power consumed by compressors may be reduced by properly selecting their compression ratio, while cost on water can be diminished by consuming cooling water as low as possible. The compression ratio of a compressor gets affected, if either the condensing pressure or inter-stage pressure is changed. The quality of cooling water gets controlled by the quantity of heat to be transferred to the condenser. It is evident that larger is the water flow rate through a condenser, the lower will be the condensing temperature resulting in lower compression ratio for high pressure (HP) compressor and hence lower cost for compressor power, but more cost on water. To the contrary, if the lower quantity of water is used , condensing temperature would be higher and thereby expenditure on water decreases while that oncompressor power increases. Hence it calls for a compromise between condensing temperature and cooling water rate to achieve minimum total operating cost. The cooling water rate that minimizes the total operating cost is usually termed as *Economical Cooling Water Rate*.

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II. Review of Previous Work

To cope with the existing energy shortages and the need to conserve the expended energy to the maximum possible extent, attempts have been made by Macharnen and Chapman (4) and Downing (5) on various refrigerants and their mixtures. Among the mixtures of refrigerants, R-500 and R-502 have become very common. These are known as azeotropes. An azeotrope, by definition, is the mixture of refrigerants that does not separate in to their original components with pressure/temperature changes. It has fixed thermodynamic properties unlike those of their components.

Azeotrope R-500 consists of 73.8% R-12 and 26.2% R-152. Its normal boiling point is about 3.5°C lower than that of R-12. It produces refrigerating effect per unit of swept volume about 18% more than that of R-12 .A Freon-12 system designed for 60 cycle current can be shifted to 50 cycle current by using azeotrope R-500. It would result in approximately the same refrigerating capacity and evaporator and condenser conditions.

Azeotrope R-502 is a mixture of 48.8% refrigerant R22 and 51.2% refrigerant R-115. It boils at a temperature of about 4.8°C lower than that of R-22. Significantly lower discharge temperatures and lower winding temperatures are realized because of the higher capacities and lower values of compression ratio associated with R-502. Further R-502 decreases the swelling or softening effect on the common electrical insulating materials caused by the presence of R-115.The inter-stage pressure for the two stage refrigerating system is conventionally selected as the geometric mean of operating pressure limits to minimize the total compression work. But it has been established in (6) that if power input to the system is to be minimized, the inter-stage pressure should be optimized with coefficient of performance (COP) as the objective function.

III. Thermo Dynamic Concept

In general, one may write the heat rejected to condenser for a refrigerating system as :

$$\dot{Q}_h = P(1+COP) \qquad 1.1$$

But $\dot{Q}_h$ per unit of cooling is expressed by :

$$\dot{Q}_h/\dot{Q}_c = P(1+COP)/\dot{Q}_c = (1=1/COP) \qquad 1.2$$

Further, for a two stage refrigerating system, COP becomes maximum if inter-stage pressure is optimized for minimum power input. Equation 1.2 may be written as :

$$\dot{Q}_h/\dot{Q}_c = (1+1/COP) \qquad 1.3$$

As $COP_o > COP$, We get

$\dot{Q}_{ho} < \dot{Q}_h$ from equations 1.2 and 1.3

"It means that heat rejection to condenser would be minimum and hence minimum quantity of cooling water would be required for given condenser when a two stage system operates with optimum inter-stage pressure/temperature as decided on the basis of minimum power input."

Thus the problem of finding out economical cooling water rate for a two stage refrigerating system is coupled optimization problem, that is, first the system needs to be optimized for its minimum power consumption, and then optimum condensing temperature is to be searched out to minimize the total operating cost.

IV. Present Work

In the present investigation, azeotropes R-500 and R-502 have been selected as the working fluids for two stage refrigerating system. Economic water rates that minimize the total operating cost and maximum COP are searched out over a wide range of operating temperature limits. Optimum design quantities of interest are presented in the form of tables. Effects of operating variables on the design quantities are also displayed through tables.

V. System Analysis

a) System Employing Water Cooled Condenser

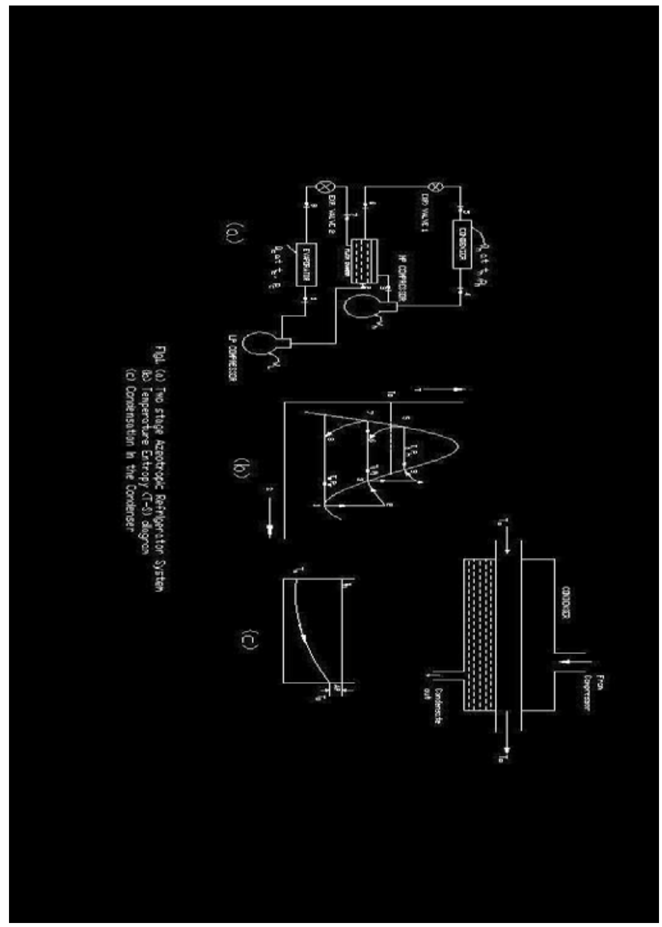
Figure -1(a) shows the schematic of idealized two stage refrigeration system. The various heat and work quantities and pressure levels are indicated in the figure. The following simplifying assumptions are made for this system analysis :

i. The thermodynamic cycle of the system is a standard one comprising isentropic compression, isentropic expansion and absence of superheating of the suction vapour and sub cooling of the high pressure (HP) condensate.

ii. The pressure drop in evaporator, compressor valves, condenser piping etc are neglected.

iii. Entire condensation of HP gas inside the condenser takes place at a fixed temperature (T_h).

Referring to fig-1(b), one may write refrigerant mass flow through LP compressor on per ton-hour basis as :



By energy balance on the flash chamber, refrigerant mass flow through HP compressor turns out to be :

$$\dot{M}_3 = \dot{M}_1 (h_2 - h_1)/((h_3 - h_6) = 12{,}600(h_2 - h_1)/(h_1 - h_5)(h - h_5) \qquad 5.2a$$

If we consider that refrigerant mass flow through LP compressor is unit kg, then mass flow through HP compressor based on similar lines, would be :

$$M_3 = (h_2 - h_1)/((h_3 - h_6) \qquad 5.2b$$

and, total compression work shall be :

$$W_T = (h_2 - h_1) + M_3 ((h_4 - h_3) \qquad 5.3a$$

However, on the basis of per ton hour, the total compression work may be written as :

$$W = W_1 + W_2 = \dot{M}_1(h_2 - h_1) + \dot{M}_1(h_4 - h_3) \qquad 5.3b$$

power consumption of the system :

$$P = W/(3600) \qquad 5.4$$

For preliminary design purposes, the enthalpies per unit mass of superheated vapour at points 2 and 4 can be approximately related to the enthalpies per unit mass of the saturated vapours at points 3 and 4, respectively as:

$$h_2=h_3+T_i\,(s_1-s_3) \quad 5.5$$

$$h_4=h_9+T_h\,(s_3-s_9) \quad 5.6$$

saturated properties of both the azeotropes are estimated from the correlations available in reference (10)

The coefficient of performance of system shall be :

$$COP=\dot{Q}_c/W=12{,}600/W \quad 5.7$$

Economic water rate expression as developed in ref (7,8) per unit ton of refrigeration, when total operating costs are minimized, is given by :

$$\dot{M}_{we}=15.45\,(\dot{Q}_h\,\Delta P_{\cdot c}/_cW)^{0.5} \quad 5.8$$

When $\dot{Q}_h$ is heat rejection to condenser per ton per hour and is given as :

$$\dot{Q}_h=\dot{M}\,(h_4-h_5) \quad 5.9$$

ΔP is the increase in power 'P' per degree rise in condensing temperature.

Optimum condensing temperature is expressed as :

$$T_{ho}=T_{wi}+DT_o \quad 5.10$$

Where $$DT_o=0.1545(\dot{Q}_h/P.C_w/C)^{0.5}+AP \quad 5.11$$

With AP as the approach, Fig 1(c) representing the end temperature difference.

It is evident that the expressions given in equation 5.4 and 5.7 to 5.9 can be expressed in temperature alone. An explicit expression has not been attempted at as it becomes extremely involved. Moreover, it serves no useful purpose because We can directly feed the above expressions in computer program to evaluate the objective function. The governing performance quantities in terms of operating parameters/variables can be expressed as:

$$P=P(T_i,T_h,T_e,T_{wi},AP,\dot{Q}_c) \quad 5.12$$

$$\Delta P=P(T_h+1,T_i,T_e,T_{wi},AP,\dot{Q}_c)-P(T_h,T_i,T_e,T_{wi},AP,\dot{Q}_c) \quad 5.13$$

$$\dot{Q}_h=\dot{Q}_h(T_h,T_i,T_e,T_{wi},AP,\dot{Q}_c) \quad 5.14$$

$$\dot{M}_{we}=\dot{M}_{we}(T_h,T_i,T_e,T_{wi},AP,\dot{Q}_c,c,c_w) \quad 5.15$$

$$COP=(T_h,T_i,T_e,T_{wi},AP,\dot{Q}_c) \quad 5.16$$

b) *Objective Function And Optimization*

For case 1, the objective function is the total operating cost together with the COP as given by equations (5.15) and (5.16) above. The total operating costs are to be minimized producing maximum COP as well.Since total operating costs have been minimized while deriving expressions for economic water rate ($\dot{M}_{we}$).from equations 5.15 and 5.16, it is clear that $\dot{M}_{we}$ and COP depend upon interstage and condensing temperatures (T_i and T_h) if other parameters are kept fixed. It leads to a two dimensional maximization problem with the two decision variables (T_i and T_h) subject to the constraints:

$$T_e<T_i<T_h \quad 5.17$$

And

$$T_h>T_{wi}+AP \quad 5.18$$

c) *Solution Technique*

To find T_{ho}, where total operating cost is minimum together with the optimum system performance, initially some convenient $T_h>T_a$ was assumed. With the help of this T_h and given values of evaporator temperature(T_e) subroutine maximises the COP and transfers required optimum quantities ($\dot{M}_3$ and P) to the main program. Now T_h is increased by unit degree and the above process is repeated. P is determined. $\dot{Q}_h$ is found from equation 5.9 in the main program. Thereafter, DT_o is estimated from equation 5.11 to determine T_{ho} from equation 5.10. With this new value of T_{ho}, the above computations are repeated till two successive values of T_{ho} differ by $\pm$ 0.1% . Condensing temperature , thus predicted , is the required optimum condensing temperature (T_{ho}) because it produces minimum operating cost for maximum COP. Finally, at T_{ho} , $\dot{M}_{we}$ is determined from equation 5.8, Fig 1.2(a) and 1.2(b).

Different ranges of various operating parameters considered for the azeotropic systems are based upon practical considerations and their commonly adopted values. They are as follows:

a) Evaporator temperature : 5 to -50°C
b) Ambient/Cooling Water Temperature :15 to 75
c) Approach Temperature : 2 to 5°C
d) Cost ratio : 0.5 to 10

VI. Results and Discussions

SYSTEM WITH WATER COOLED CONDENSER

Besides the direct use of Tables 6-1 to 6-3 for preliminary optimum design of the systems, they also exhibit the quantitative effects of operating variables on the design quantities for a specified set of operating parameters. Not only this, the feasible operating conditions can also be achieved with the help of the figures achieved. The approach (AP) has been kept at 3°C. For a fixed set of R_c, AP, t_a and t_e values, t_{ho} for R-500 is found to be slightly higher than that of R-502. On the other hand, economic water rate and heat rejection to condenser $\dot{Q}_{ho}$ are seen to be higher in case of R-502 for given R_c (except equal to 10) ,AP, t_a and t_e refer Tables 6.1 to 6.3, the detailed graphical presentation is available in reference-11 (page 27 to 44).

COP's of R-500 system is observed to be higher than that of R-502 systems (Ref. Tables 6.1 to 6.3)

Table 6.1 : Effect of ambient temperature on the optimum design quantities for two stage azeotropic refrigerating system incorporating water cooled condenser

Design Parameters : R= 3.0 AP = 3°C

Azeotrope		R-502					R-500				
t_a(°C)	t_e (°C)	t_{io} (°C)	t_{ho} (°C)	$\dot{M}_{we}$ (Kg/ton-h)	$\dot{Q}_{ho}$ (KJ/ton-h)	COP_o	t_{io} (°C)	t_{ho} (°C)	$\dot{M}_{we}$ (Kg/ton-h)	$\dot{Q}_{ho}$ (Kg/ton-h)	COP_o
20	-50	-7.66	30.34	595.01	18,289.2	2.21	-12.25	31.13	527.79	18096.5	2.29
	-40	-3.01	30.53	547.61	17280.1	2.69	-3.38	30.95	512.50	17067.8	2.82
	-30	1.73	30.73	506.17	16392.8	3.32	1.46	31.11	477.37	16215.0	3.49
	-20	6.55	30.93	469.5	15602.9	4.20	6.27	31.27	446.45	15462.3	4.40
40	-50	4.12	49.72	725.90	20435.5	1.61	2.91	49.94	680.87	19808.5	1.75
	-40	8.55	49.92	662.23	19193.4	1.91	7.43	50.8	628.80	18663.4	2.08
	-30	13.06	50.12	606.87	18106.1	2.29	12.28	50.22	583.64	17663.9	2.49
	20	17.56	50.33	558.34	17143.3	2.77	16.95	50.36	544.00	16784.4	3.01
60	-50	16.17	69.13	911.86	23414.2	1.17	15.10	69.32	831.87	22028.1	1.34
	-40	20.27	69.32	824.51	21817.0	1.37	19.69	69.47	761.94	20659.7	1.56
	-30	24.45	69.51	749.28	20429.9	1.614	24.27	69.63	700.83	19458.9	1.84
	-20	28.71	69.71	683.87	19210.3	1.91	28.81	69.79	647.39	18404.9	2.17

Table 6.2 : Effect of approach on the optimum design quantities for two-stage azeotropic refrigerating system incorporating water cooled condenser

Design Parameters : R_c = 3.0 t_a = 30 °C

Azeotrope		R-502					R-500				
AP (°C)	t_e (°C)	t_{io} (°C)	t_{ho} (°C)	$\dot{M}_{we}$ (Kg/ton-h)	$\dot{Q}_{ho}$ (KJ/ton-h)	COP_o	t_{io} (°C)	t_{ho} (°C)	$\dot{M}_{we}$ (Kg/ton-h)	$\dot{Q}_{ho}$ Kg/ton-h)	COP_o
2	-50	-2.44	39.10	645.29	19184.6	1.91	2.57	40.29	527.79	18096.5	2.01
	-40	2.10	39.30	591.51	18081.3	2.30	2.02	40.57	512.50	17067.8	2.42
	-30	6.72	39.50	544.63	17,113.0	2.79	6.83	40.74	477.37	16215.0	2.94
	-20	11.43	39.71	503.26	16252.9	3.45	11.63	40.91	446.45	15462.3	3.63
4	-50	-1.32	41.03	658.27	19397.3	1.85	-1.82	41.90	680.87	19808.5	1.97
	-40	3.34	41.23	602.83	18,271.2	2.22	2.86	42.09	628.80	18663.4	2.37
	-30	7.87	41.44	554.58	17283.0	2.69	2.69	42.23	583.64	17663.9	2.88
	-20	12.50	41.65	512.05	16405.7	3.31	3.31	42.39	544.00	16784.4	3.54
6	-50	-0.71	42.0	665.00	19,505.8	1.82	-1.41	42.72	831.87	22028.1	1.95
	-40	3.86	42.20	608.76	18367.9	2.18	3.30	42.89	761.94	20659.7	2.34
	-30	8.50	42.41	559.74	17,359.5	2.64	8.14	43.03	700.83	19458.9	2.84
	-20	13.03	42.62	516.64	16,483.5	3.24	12.85	42.7	647.39	18404.9	3.49

Table 6.3 : Effect of Cost Ratio on the optimum design quantities for two-stage azeotropic refrigerating system incorporating water cooled condenser

Design Parameters : AP= 3.0(°C) t_a = 30°C

Azeotrope		R-502					R-500				
R_c	t_e(°C)	t_{io} (°C)	t_{ho} (°C)	$\dot{M}_{we}$ (Kg/ton-h)	$\dot{Q}_{ho}$ (KJ/ton-h)	COP_o	t_{io} (°C)	t_{ho} (°C)	$\dot{M}_{we}$ (Kg/ton-h)	$\dot{Q}_{ho}$ (Kg/ton-h)	COP_o
0.5	-50	3.92	49.48	295.59	20,407.2	1.61	2.90	50.013	277.90	19,806.0	1.75
	-40	8.57	49.94	270.49	19198.4	1.91	7.54	50.34	257.40	18,677.5	2.07
	-30	13.2	50.41	248.71	18138.0	2.28	12.43	50.67	239.05	17,698.2	2.47
	-20	17.82	50.89	229.41	17,196.7	2.74	17.29	51.01	223.10	16,832.8	2.98
5.0	-50	-2.78	38.51	828.24	19,121.7	1.93	-2.96	39.62	679.22	18,832.1	2.02
	-40	1.73	38.67	759.07	18020.7	2.32	1.62	39.87	617.21	17,765.7	2.44
	-30	6.42	38.83	698.75	17054.8	2.83	6.42	40.02	572.77	16,843.3	2.97
	-20	11.00	38.99	645.65	16,196.9	3.50	11.2	40.17	534.11	16032.8	3.67
10.0	-50	-3.75	36.92	1153.26	18,953.4	1.98	-4.83	36.49	1271.04	18,564.3	2.11
	-40	0.82	37.03	1057.20	17,865.8	2.39	0.11	36.82	1098.81	17,575.4	2.53
	-30	5.38	37.15	973.64	16,912.1	2.92	4.54	37.39	904.37	16,616.3	3.14
	-20	10.02	37.26	899.93	16065.0	3.64	9.41	36.79	998.34	15,847.3	3.88

VII. Conclussions

1. For a preliminary design of two stage azeotropic refrigerating system, the Tables 6-1 to 6-3 presented can directly be used.
2. Economic water rate and heat transfer to condenser turns out to be relatively lower in case of R-500 for a given set of condenser, evaporator, ambient and approach temperatures and cost ratio.
3. R-500 system produces comparatively higher COP than R-502 system for specified operating conditions.
4. The effect of approach temperature is more pronounced on the economic water rate than the other quantities. It should be selected quite carefully.
5. Though, the initial investment in case of R-500 system turns out to be more than R-502 system, it would get compensated over a small span of time because of lower operating cost of the R-500 system.

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VIII. Nomenclature

AP : Approach ℃
C_1 : Cost of Electricity (Rs/kw-h).
c_w : Cost of Water (Rs/k- litre).
COP_o : Maximum co-efficient of performance.
h_x : Enthalpy per un it mass at state condition 'x' (kJ/kg).
$\dot{M}_1$: Refrigerant mass flow through LP compressor 9kg/ton-h).
$\dot{M}_3$: Refrigerant mass flow through HP compressor (kg/ton-h).
$\dot{M}_{we}$: Economic water rate (kg/ton -h).
M_3 : Refrigerant mass flow through HP compressor per unit mass flow through Lp compressor(kg/kg).
P : Power 9kw/ton).
P_o : Minimum power (kw/ton).
ΔP : Power increase per ton per degree rise in condensing Temperature (kw/ton -℃).
P_h : Condensing pressure (bar).
P_e : Evaporating pressure (bar).
P_{io} : Optimum inter -stage pressure (bar).
$\dot{Q}_h$: Heat transfer to condenser (kJ/ton -h).
$\dot{Q}_{ho}$: Heat transfer to condenser pertaining to minimum operating cost and maximum COP (kJ/ton-h).
$\dot{Q}_c$: cooling effect per unit mass flow throu gh LP compressor (kJ/kg).
r_1 : Compression ratio (P_{io}/P_e) of LP compressor.
r_2 : Compression ratio (P_h/P_{io}) of HP compressor.
R_c : Cost ratio (c/c_w).
s_x : Entropy per unit mass at state condition(kJ/kg-k).
t_a, T_a : Ambient temperature (℃,K).
t_{w1}, T_{w1} : Inlet water temperature (℃,K).
t_h, T_h : condensing temperature (℃,K).
t_e, T_e : evaporating temperature (℃,K).
t_{ho}, T_{ho} : Optimum condensing temperature(℃,K).
t_i, T_i : Interstage temperatures (℃,K).
t_o, T_o : Outlet water temperature (℃,K).
t_{io}, T_{io} : Optimum interstage temperature(℃,K).
V_1 : Minimum volume flow through LP compressor per unit mass flow through LP compressor (m^3/kg).
V_3 : Minimum volume through HP compressor per unit mass flow through LP compressor (m^3/kg).
W_1 : compression work of LP compressor (kJ/ton-h).
W_2 : compression work of HP compressor(kJ/ton-h).
W : Total compression work (kJ/ton-h).
W_T : Total compression work (kJ/ton-h).

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Dynamic Programming and Taguchi Method Optimization of Water-Treatment-Plant Design

By Khezri-S.M, Dadras-P, Dadvar-E

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Keywords : Optimization of water Treatment - Plants, Process Optimization -Taguchi Design of Experiments.

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DYNAMIC PROGRAMMING AND TAGUCHI METHOD OPTIMIZATION OF WATER-TREATMENT-PLANT DESIGN

Strictly as per the compliance and regulations of:

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Khezri-S.M[α], Dadras-P[Ω],Dadvar-E[β]

Abstract - System and process optimization are both necessary for overall system design in system optimization models, the objective is to determine the optimal system configuration while assuming the design and operating parameters of each individual process. In process optimization models the objective is to find the design and operating parameters of individual processes. The major disadvantages of GP and NLP algorithms are that global optima is not assured and they can not be directly used for system optimization because of the presence of discrete decision variables and required high computer storage [Dharmappa 1994] [Desmond F. Lawler. 2005] Using DP solely for large problems requires very high computer time for Data Processing [Mhiaisalkar 1993]. The model of this research is DP model that employs Taguchi Experimental Design Method, whereupon the time of model analysis has reduced considerably. . Case study showed the capability of model in savings of roughly 9.5% in capital and annualized costs, compared to the conventional design besides the software has capability to performing sensitivity analysis and showing interactions between various Decision variables.

Keywords : Optimization of water Treatment - Plants, Process Optimization - Taguchi Design of Experiments.

I. Introduction

The water Industry is one of the principal industries in every country. The total expenditure for water supply, including operation and maintenance, accounts to nearly 6 billion dollars per year in the U.S alone, of this approximately 15% is spent on actual water treatment (Wiesner, 1985). This massive investment requirement calls for more economical system design to allow for an efficient use of public funds. This objective can be achieved using "Optimization". Because in many cases pilot scale studies are conducted prior to full-scale plant construction, the use of an optimization model can greatly reduce the time and money spent on the pilot scale study.

A water treatment system is a combination of several unit processes. Design of such a system is a difficult task and the least cost design is most difficult of all. The principal unit process in a conventional water-treatment systemincludes coagulation-flocculation, sedimentation, filtration and disinfection. The performance of each treatment unit affects the efficacy of the subsequent units. Ideally, therefore, the design decisions should be made with regard to the interaction between various unit operations. So for very few works have been done on the optimization of a water treatment system. Letterman & Iyer (1977) analyzed the effects of selected process decision variables on overall system cost and performance. The authors used simplified process models (mostly empirical relationships). One comprehensive work is that of Wiesner et. al(1978)which is an important step towards the optimal design of water treatment system. The authors have provided a number of optimization models for integral analysis and economic optimization of the components of a water treatment plant. Mhiasalkar(1993) has developed a mathematical model incorporating the Performance relationships and cost functions for the component units of conventional water treatment system, and an algorithm using dynamic programming has described by them for functional and minimal cost design of the system. The last and one of the comprehensive models in this ground belongs to Dharmappa et. al (1994). The authors believe the incorporation of particle size distribution (PSD) is necessary for optimal process design and selection. In this context this works includes not only all three levels of system design but also process design and selection using PSD and the Algorithm they have used was a GP and NLP programming.

The major disadvantages of GP and NLP algorithms are that, global optima is not assured and they can not be directly used for system optimization because of the presence of discrete decision variables and requirement high computer storage. Using Dynamic Programming solely for large problems requires very high computer storage. Accordingly, this paper addresses it self to the development of a model for minimal cost and Energy design of a conventional water treatment plant using dynamic programming and Taguchi Design Of Experiments methods optimization model. The scope of this research was restricted to the economic optimization of conventional water treatment system for turbidity removal comprising four water treatment processes, which are listed in table 1.

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Table 1 : Conventional water treatment processes considered in this study

1. Rapid Mixing (back Mix)
2. Flocculation (Horizontal)
3. Sedimentation (Rectangular)
4. Granular filtration (Downflow & constant Rate)
   (Note: Specific type considered is given in parenthesis)

The serial and interactive nature of the various unit processes favors application of Dynamic Programming for minimal cost design. Dynamic Programming is a mathematical technique often useful for making a sequence of interrelated decisions. It provides a systematic procedure for determining the combination of decisions that maximizes overall effectiveness [Hillier 1967]. Deterministic dynamic programming can be described diagrammatically, as shown in Fig. 1

Fig. 1: The basics structure for deterministic dynamic programming.

Thus at stage n the process will be in some state S_n. Making policy decision X_n then moves the process to some state S_{n+1} at stage (n+1). From that point onward the objective function value for the optimal policy has been previously calculated to be $f^*_{n+1}(S_{n+1})$. Conventional water Treatment systems can be considered as a multistage process, with the stages represented by various unit processes. The states represented by the levels of water quality parameters such as turbidity and suspended solids . The decision variables are design parameters depending on the type of unit.

Traditionally, measuring nonspecific parameters like turbidity units (Tu) suspended solids (SS); etc assesses the performance of water treatment plants. Though their parameters describe the Important aspects regarding the water quality of the effluent form the treatment processes (AWWA: water 1990). Insofar as turbidity is used as a measure of the efficiency of the removal of particulate matter throughout the purification process of water, low turbidity in the finished water is an indication of effectiveness of unit processes (Guidelines 1984). Because mathematical models of water treatment describe the behavior of systems in relation to the removal of mass concentration of suspended solids. And we can in some ways correlate turbidity measurements with suspended solids data, suspended solids has been used as a state parameter to indicate the effectiveness of the system at various stages of treatment. Fig. 2 Show the sequence of stages and the stage return for each input-decision combination.

II. Taguchi Method

Taguchi approach to parameter design provides the design engineer with a systematic and efficient method for determining near optimum design parameters for performance and cost (Kackar, 1985: phadke, 1989; Taguchi, 1986). In this research we have used orthogonal arrays from design of Experiments theory to study a large number of variables with a Small number of experiments. Whereupon the time of DP model analysis reduced considerably.

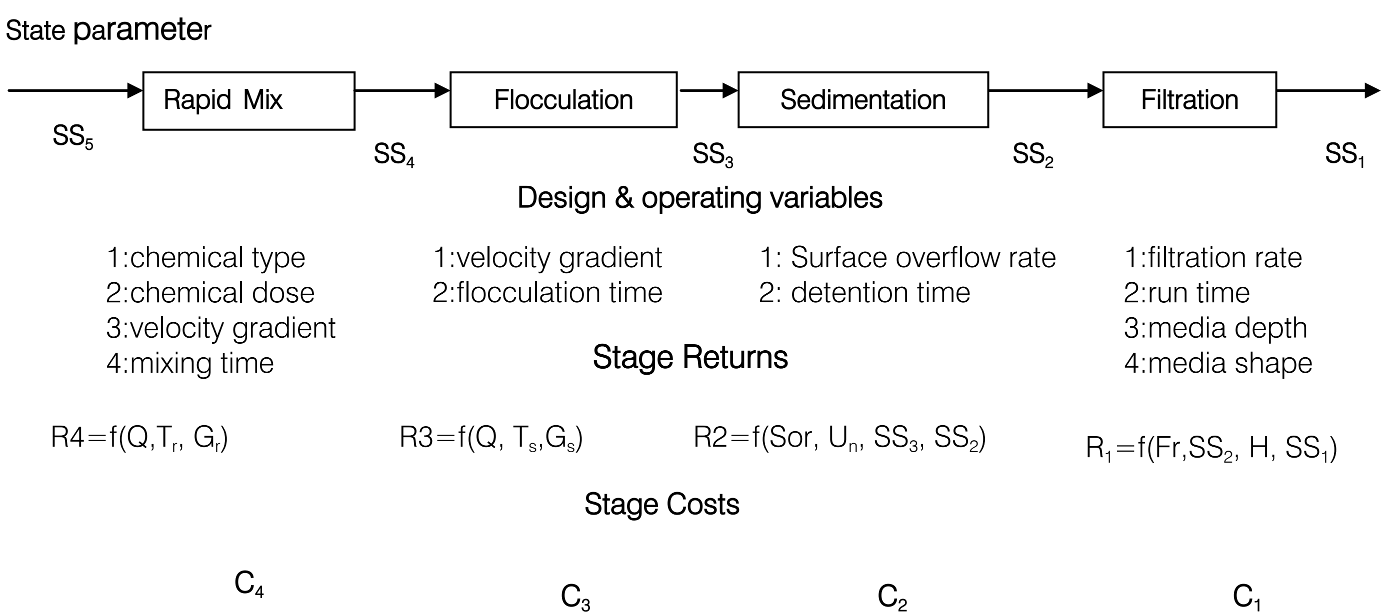

Fig.2 : Unit sequences & Return of Conventional Water Treatment system

a) Functional relationships of units

Functional relationships for each unit process, linking input and output states parameters with a characteristic loading parameter, have been established based on the mechanics of unit process. These relationships are largely empirical models. Table 2 shows these relationships and key assumptions for each of the process models.

III. Cost Functions

Since the present study seeks to incorporate multiple design criteria in the optimization, there are three design criteria to be evaluated from the cost functions:

1. Annualized Capital Cost (ACC)
2. Operation & Maintenance cost (O & M)
3. Energy requirement (ER)

There is a substantial literature on cost functions for water treatment plant component (Hinomoto, 1977; Clark, 1982). The annualized capital and operation and maintenance cost functions are most taken from Clark (1982). Some changes have been made by Dharmappa (1994) so as to make them more generals. Capital cost functions as presented by Clark (1982) were based on the annualization factor 0.102 (interest 8% and amortization 20 years). There were modified to incorporate a general annualization factor, of, which can be calculated by (assuming zero salvation value:

$$a_f = \left(\frac{i(1+i)^n}{(1+i)^n - 1} \right.$$

Where a_f = annualization factor;
i= interest rate, Fraction; and
n= amortization period, years.

Table 2 : Relationships and keys Assumption for each of the process models.

Unit	Functional Relationships Unit processes	
Rapid Mix	$SS_5 + K.A = SS_4$	A :alum dose K : Constant
Flocculation	$SS_4 = SS_3$ $d_f = 26.88 G_s^{-0.91}$ $T_s G_s^{2.8} = \frac{44 \times 10^5}{A}$	Ts: detention time Gs: applied velocity gradient d_f: average diameter of the floc
Sedimentation	$Vs = \frac{g}{18}(S_s - 1)\frac{d_f^{\,2}}{\nu}$ $\frac{ss_3 - ss_2}{ss_3} = 1 - [1 + n\frac{Vs}{Q/A}]^{-1/n}$	Q/A: surface overflow rate n: coefficient basinperformance Vs: surface overflow rate for ideal basin
Rapid sand filter	$\frac{ss_2 - ss_1}{ss_2} = Pc$ $Y = 0/725.Fr^{0/29} d^{0/62} t$ $R = \frac{4/55.d^{2/5} H}{Fr^{1/2} ss_2}$	SS_1:influent suspension concentration H: increase in head loss at the end of t d : diameter of sand grain t: filter run time Fr: filtration rate
	$\log(\frac{U}{13/3L}) = -0/208 + 1/950\log[\frac{Y}{(13/3L)^{1/2}}] - 0/645[\log\frac{Y}{(13/3L)^{1/2}}]^2$ $\log(\frac{R}{13/3L}) = -3/250 + 1/013\log[\frac{Y}{(13/3L)^{1/2}}] - 0/036[\log\frac{Y}{(13/3L)^{1/2}}]^2$ $Pc = \sum_{j=0}^{(t/2-1)} \frac{e^{(-u/2)}(u/2)^j}{J!}$	

The relationships for energy requirement are developed from Gumerman et al. (1979). Cost functions for unit processes (extracted and compiled from Clark, 1982, with Dharmappa (1994) modifications are listed in Table 3.

In this table PR; DHR, PPI are: Power cost, Direct Hourly wages Rate and Producer Price Index respectively.

Table 3 : Cost function for various unit processes

Unit processes	Annual Construction Cost(ACC) Operation and Maintenance Cost (O & M)
Rapid mix	$ACC = 0.08507(Q \times Tr)^{0.79}(CCI)^{0.988}(1.0007)^{Gr}(a_f)$ $OM = 1.56947(Q \times Tr)^{0.799}(PR)^{0.717}(DHR)^{0.181}(1.00251)^{Gr}$
Alum dry stock	$ACC = 0.0197(A \times Q)^{0.656}(CCI)^{0.994}$ $OM = 3.30366 \times 10^{-4}(A \times Q)^{0.849}(PR)^{0.1847}(PPI)^{0.0259}(DHR)^{0.743}$
Flocculation	$ACC = 642.48(Q \times Ts)^{0.6916}(CCI)^{0.992}(1.00383)^{Gs}(a_f)$ $OM = 0.040581(Q \times Ts)^{0.785}(PR)^{0.357}(PPI)^{0.399}(1.0081)^{Gs}$
Clarifier	$ACC = 1872.527(A_c)^{0.701}(CCI)^{0.993}(U_n)^{1.00047}(a_f)$ $OM = 53.487(A_c)^{0.969}(PPI)^{0.181}(DHR)^{0.756}(U_n)^{1.006}$
Filter structure	$ACC = 13317.11(A_f)^{0.671}(CCI)^{0.989}(a_f)$ $OM = 913.377(A_f)^{0.549}(PR)^{0.147}(PPI)^{0.183}(DHR)^{0.61}$
Filter Media(single)	$ACC = 71.3413(A_f)^{0.9336}(CCI)^{0.996}(a_f)$ $OM = 0$
Filter backwash	$ACC = 108.127(6.1A_f)^{0.59}(ACC)^{0.966}(a_f)$ $OM = 747.398(6.1A_f)^{0.65}(PR)^{0.543}(PPI)^{0.219}(DHR)^{0.137}$
Filter surface wash	$ACC = 568.4533(A_f)^{0.801}(CCI)^{0.982}(a_f)$ $OM = 204.732(A_f)^{0.7146}(PR)^{0.526}(DHR)^{0.315}$

IV. Model Optimization

There are a number of designs that satisfy water quality standards. The objective, therefore, is to minimize the system cost satisfying all constrains. The bounds used in the optimizations are given in table 4. The general form of objective function is expressed as.

$$\text{Opt} \cdot \sum_{i=1}^{4} [R_i]$$

Design variables

Where: R= Stage Returns

Table 4 : bounds on variables used in optimizations

Variable	Units	Symbol	Lower bound	Upper bound
Velocity Gradient	s^{-1}	G_r	400	1000
Mixing Time	S	T_r	10	50
Velocity Gradient	s^{-1}	Gs	20	70
Flocculation time	min	Ts	10	60
Settling Time	hr	T_c	2	4
Settling Efficiency	-	-	0	0.95
Surface Overflow Rate	M hr^{-1}	SOR	0.9	2.0
Filter Area	m^2	A_f	1	∞
Filter run time	hr	T_f	8	100
Filtration Rate	hr^{-1}	Fr	3	15
Backwash fraction	-	B	0	0.15
Time for backwash	Hr	T_b	0.33	0.33
Terminal head loss	m	H	0	2.5
Filtrate mass Concentration	mg/L	C_{max}	0	2
Clarifier effluent Concentration	mg/L	C_e	2	20

V. Recursive Equations

For deriving Recursive equations it is necessary the Return functions for each unit process be prepared with economic data. The values of parameters for determining Return functions that are used in the optimizations, as well as the assumed chemical costs are listed in Table 5.The Return functions for all unit processes are given in table 6

Table 5 : Economic data used in Return function

Item	Value
Power(PR)	0.04$/kWh
Labor Wage Rate(DHR)	11.00$/hr
Construction Cost Index/100(CCI)	3.25
Producer Price Index/100(PPI)	2.44
Alum	140$/tone
Polymer	400$/ tone
Polymer demand	$6*10^{-8}$moles/m^2 of particle
Polymer molecular weight	$5*10^4$

Table 6 : Return Equations of different unit processes

Units	Return Equation of units
Sand Filter	$R_1 = 8636.59(A_f)^{671} + 4688.94(A_f)^{546} + 46.877(A_f)^{9336}$ $293.847(A_f)^{.59} + 2006.13(A_f)^{.65} + 363.86(A_f)^{.801} + 119.195(A_f)^{.7146}$
Sedimentation Tank	$R_2 = 1223.52(A_c)^{.701}(U_n)^{1.00047} + 599.165(A_c)^{.469}(U_n)^{1.006}$
Flocculation	$R_3 = 1.45443(Q.T_s)^{.6916}(1.00383)^{G_s} + 0.0345(Q.T_s)^{.785}(1.0081)^{G_s}$
Alum feed & Rapid mix	$R_4 = .54067(Q.T_r)^{.79}(10007)^{G_r} + 0.3817(Q.T_r)^{.794}(1.00251)^{G_r} +$ $o.12662(A.Q)^{.656} + 0.00160934(A.Q)^{.849}$

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Now by using there Return functions we can derive the Recursive equations for all of the unit processes. The general forms of recursive equations for unit processes are given in table 7.

Table 7 : Recursive equations of different unit processes

Units	Recursive equations of Units
Filter	$f_1^*(SS_2) = \underset{A_f, Q}{opt.}[R_1]$
Sedimentation	$f_2^*(SS_3) = \underset{A_c, Q, G_s}{opt.}[R_2 + f_1^*(SS_2)]$
Flocculation	$f_3^*(SS_4) = \underset{G_s, T_s, Q}{opt.}[R_3 + f_2^*(SS_3)]$
Rapid mix	$f_4^*(SS_5) = \underset{A, Q, G_s, T_r, G_r}{opt.}[R_4 + f_3^*(SS_4)]$

VI. Optimization Algorithm

The sequential structure of serial systems can be exploited to transform the N-decision, one-state problems. This is accomplished by the procedure called dynamic programming, due to Richard Bellman (1957). The DP algorithm for functional and minimal cost design of water treatment system was developed in this research. The major inputs required are the design data on flow; raw-water suspended-solids concentration; alum dose; water temperature; and effective size, uniformity coefficient, and depth of filter sand. Data on unit costs of excavation, plain and reinforced cement concrete, steel, filter sand and appurtenances are also necessary. Data on discount rate, and chemical costs are required for economic evaluation. The algorithm involves four stages in DP programming, and the optimal function of the previous stage is implemented in the next stage. In each stage in addition to the previous optimal function, the return function concerning to the current stage is also used to optimize the existing stage.

This procedure will be followed until the last stage. The solution of this system is computed by backward form. With this parametric solution of stages, we can derive the optimal objective function in a parametric form. This parametric form includes all design parameters of the water treatment system. This objective function could be optimized by appropriate software based on the Taguchi Design of Experiments again could be calculated.

VII. Case Study

The application of the optimization algorithm is illustrated for a 6250-m3/hr conventional water treatment plant. The optimal results of this model have been compared with EPA traditional water Treatment plant. Design criteria and cost calculation of EPA conventional water treatment plant exists in EPA Documents Gumerman et al. (1979). The optimal design results in saving of 9.5% in capital and Annualized cost. The comparison is presented in table 8.

Table 8 : Comparison of Total Annualized Cost with EPA and Model 6250 m^3/hr

Items \ Water treatment Plant	EPA WaterTreatment Plant	Suggested Model Water Treatment Plant
Total Annualized Cost($)	1046570	955757
Reduction(%)	9.5	

VIII. Sensitivity Analysis

One particularly important feature of this model is the ease with which a sensitivity analysis can be carried out. This technique analyzes the sensitivity of the optimal solution to changes in various decision variables without re-solving the problem for each new value. It is highly unlikely that cost data of sufficient accuracy will ever be available (Walski 1991). Therefore, variation in total Annualized cost was also studied. The results of this analysis have been presented in table 9.

Table 9 : Optimum cost versus 3 more sensitive variables.

Parameter	Change in parameter over base value(%)	Optimal Design Value					Change in total annualized cost (%)
		SS_2	SS_3	G_r	T_r	T_s	
Flow	+10	7.5	150	400	20	20	+6.8
	+20	7.5	150	400	20	20	+12.6
	-10	7.5	150	400	20	20	-7.5
	-20	7.5	150	400	20	20	-15.2
Alum dose	+10	7.5	150	400	20	20	+3.6
	+20	7.5	150	400	20	20	+7.1
	-10	7.5	150	400	20	20	-3.76
	-20	7.5	150	400	20	20	-7.9
Filter Headloss	+10	7.5	150	400	20	20	-1.5
	+20	7.5	150	400	20	20	-2.95
	-10	7.5	150	400	20	20	+1.6
	-20	7.5	150	400	20	20	+3.39

The results signifies the objective function is more sensitive to Design flow rate (Q), alum dose (A) and gravity sand filter head loss (H) respectively. If the design flow is varied in the range of ±20%, the total annualized cost will vary +12.6% and 15.2 %

A practical approach to analyzing either uncertain or variable situation is to test the sensitive of the optimal design to variation in key system parameters.

IX. Conclusion

So far very few works have been done on the optimization of a water treatment system. The scope of this research was restricted to the economic optimization of conventional water treatment systems for turbidity removal, comprising four water treatment processes (viz.-rapid mix, flocculation, sedimentation, and rapid send filters). Mathematical models describing the performance relationships and cost functions for component units of a conventional water-treatment system have been formulated. By combining these models, an algorithm using Dynamic programming and Taguchi Design of Experiments methods software was developed for functional and minimal design of the system. The proposed approach is tested with a case study. The conclusions are listed as follows:

- The computer times requirements for this model is very less than other similar model doing the same task.
- The optimal design results in savings of roughly 9.5% in capital and annualized cost compared to the conventional design.
- The sensitivity analysis results signifies the objective function is more sensitive to design flow rate (Q), alum dose (A) and gravity sand filter head loss (H), respectively.

Suspension characteristics such as particle size and distribution are of significance in the overall process of water treatment. There are some shortcomings in major requirements for the successful incorporation of PSD in the process design and selection. (Dharmappa, 1994). Future research dynamic programming & Taguchi methods optimization of water treatment plant design may be directed to test the feasibility of considering PSD and molecular particle size distribution in water and further research in the field of software development with more levels for control factors.

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3. Think Like Evaluators: If you are in a confusion or getting demotivated that your paper will be accepted by evaluators or not, then think and try to evaluate your paper like an Evaluator. Try to understand that what an evaluator wants in your research paper and automatically you will have your answer.

4. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

5. Ask your Guides: If you are having any difficulty in your research, then do not hesitate to share your difficulty to your guide (if you have any). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work then ask the supervisor to help you with the alternative. He might also provide you the list of essential readings.

6. Use of computer is recommended: As you are doing research in the field of Computer Science, then this point is quite obvious.

7. Use right software: Always use good quality software packages. If you are not capable to judge good software then you can lose quality of your paper unknowingly. There are various software programs available to help you, which you can get through Internet.

8. Use the Internet for help: An excellent start for your paper can be by using the Google. It is an excellent search engine, where you can have your doubts resolved. You may also read some answers for the frequent question how to write my research paper or find model research paper. From the internet library you can download books. If you have all required books make important reading selecting and analyzing the specified information. Then put together research paper sketch out.

9. Use and get big pictures: Always use encyclopedias, Wikipedia to get pictures so that you can go into the depth.

10. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

14. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. **Pick a good study spot:** To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. **Think technically:** Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page

- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.
- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.

- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

Administration Rules Listed Before Submitting Your Research Paper to Global Journals Inc. (US)

Please carefully note down following rules and regulation before submitting your Research Paper to Global Journals Inc. (US):

Segment Draft and Final Research Paper: You have to strictly follow the template of research paper. If it is not done your paper may get rejected.

- The **major constraint** is that you must independently make all content, tables, graphs, and facts that are offered in the paper. You must write each part of the paper wholly on your own. The Peer-reviewers need to identify your own perceptive of the concepts in your own terms. NEVER extract straight from any foundation, and never rephrase someone else's analysis.
- Do not give permission to anyone else to "PROOFREAD" your manuscript.
- Methods to avoid Plagiarism is applied by us on every paper, if found guilty, you will be blacklisted by all of our collaborated research groups, your institution will be informed for this and strict legal actions will be taken immediately.)
- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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