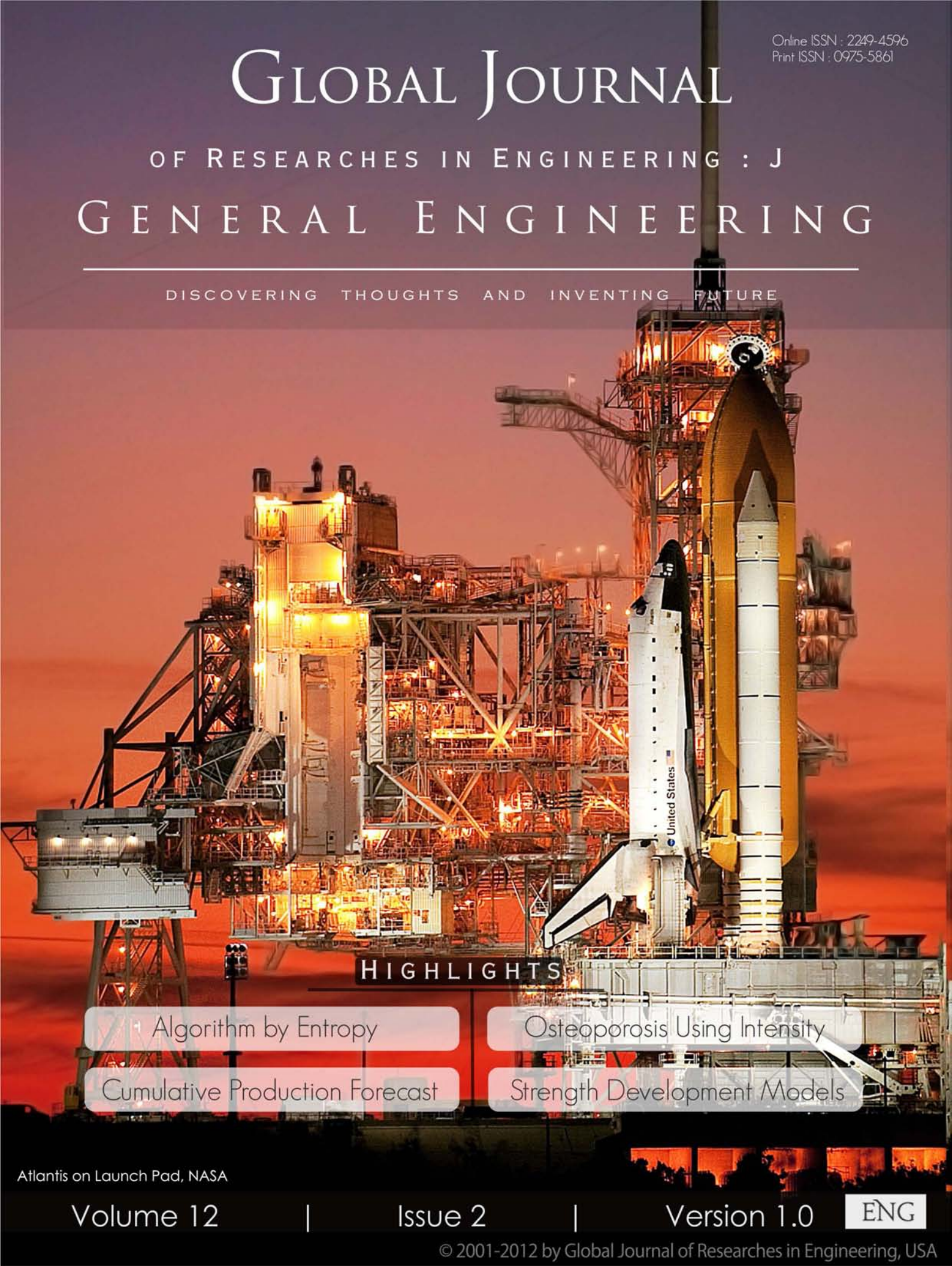


# GLOBAL JOURNAL

## OF RESEARCHES IN ENGINEERING : J GENERAL ENGINEERING

DISCOVERING THOUGHTS AND INVENTING FUTURE



### HIGHLIGHTS

Algorithm by Entropy

Osteoporosis Using Intensity

Cumulative Production Forecast

Strength Development Models

Atlantis on Launch Pad, NASA

Volume 12

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## Fuzzy Approach for Enhanced Edge Detection Algorithm by Entropy Optimization

By Gurpreet Kaur, Varun Raj

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**Abstract** - In this paper fuzzy based canny edge detection is explained. Global contrast intensification and local fuzzy edge detection are the two phases explained and is then merged with Canny operator for better results specially for noisy images and low contrast images. The resultant images are obtained using MATLAB which is the most convenient software and is efficient in terms of Image Processing as it is one of its toolbox. Although first-order linear filters constitute the algorithms most widely applied to edge detection in digital images but they don't allow good results to be obtained where the contrast varies a lot, due to non-uniform lighting, as it happens during acquisition of most part of natural images.

**Keywords** : *Edge detector, fuzzy image processing, image enhancement, entropy, contrast intensification operator, fuzzifier, crossover point, Gaussian membership function.*

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# Fuzzy Approach for Enhanced Edge Detection Algorithm by Entropy Optimization

Gurpreet Kaur<sup>α</sup>, Varun Raj<sup>α</sup>

**Abstract** - In this paper fuzzy based canny edge detection is explained. Global contrast intensification and local fuzzy edge detection are the two phases explained and is then merged with Canny operator for better results specially for noisy images and low contrast images. The resultant images are obtained using MATLAB which is the most convenient software and is efficient in terms of Image Processing as it is one of its toolbox. Although first-order linear filters constitute the algorithms most widely applied to edge detection in digital images but they don't allow good results to be obtained where the contrast varies a lot, due to non-uniform lighting, as it happens during acquisition of most part of natural images.

**Keywords** : Edge detector, fuzzy image processing, image enhancement, entropy, contrast intensification operator, fuzzifier, crossover point, Gaussian membership function.

## I. INTRODUCTION

Edge detection is one of the fundamental issues of digital image which is a method of segmentation. Edge detection significantly reduces the amount of data and filters out useless information, while preserving the important structural properties in an image. since edge detection is in the forefront of image processing for object detection, it is crucial to have good understanding of edge detection algorithms. Therefore, precise edge detection is required for numerous image analysis, evaluation and recognition techniques. In the past, a lot of research has been done in the area of image segmentation in various applications using edge detection.

The underlying idea of most edge detection techniques is by the computation of a local first or second derivative operator, followed by some regularization technique to reduce the effects of noise. Earlier edge detection methods, such as Sobel, Prewitt and Roberts' operator used local gradient method to detect edges along a specified direction.

The lack of noise control resulted in their poor performance on blurred or noisy images.

Canny [1] proposed a method to counter noise problems, wherein the image is convolved with the first order derivatives of Gaussian filter for smoothing in the local gradient direction followed by edge detection by thresholding. Marr and Hildreth [2] proposed an algorithm that finds edges at the zero-crossings of the image Laplacian. Non-linear filtering techniques for

edge detection also saw much advancement through the SUSAN method [3], which works by associating a small area of neighboring pixels with similar brightness to each center pixel.

More recently, techniques have been proposed that characterize edge detection as a fuzzy reasoning problem.

Fuzzy logic by the local approach has been used in [4] for morphological edge extraction method. Ho *et al.* [5] used both global and local image information for fuzzy categorization and classification based on edges.

In this paper, we have proposed a fuzzy-Canny based approach to edge detection that uses both global and local image information. Firstly, we used a modified Gaussian membership function to represent each pixel in the fuzzy domain. After which, a global contrast intensification operator is used to enhance the image by adjusting its parameters. In this process, pixels having more edginess will be enhanced while that with the lesser will be decreased. The optimization of the entropy function by gradient descent function produces new optimized parameters of contrast enhancement. The second phase involves the edge detection process with local image information by a local fuzzy mask, similar to the one suggested in [4, 5]. Then simple thresholding method based on experimental observations and in the last step Canny edge detection is performed to link the edges obtained and results for very low contrast and noisy images are discussed in the paper.

## II. GLOBAL CONTRAST INTENSIFICATION

### a) Fuzzy image representation

To represent an image in fuzzy domain from spatial domain, a gray tone image  $R$  of dimension  $M \times N$  and  $L$  levels can be considered as an array of fuzzy singleton sets:

$$R = \{(\mu_{mn}, x_{mn}) \quad \text{where } m=1, \dots, M; n=1, \dots, N;\} \quad (1)$$

Here each pixel has some intensity value  $x_{mn}$  and its grade its membership grade

$\mu_{mn}(0 \leq \mu_{mn} \leq 1)$  relative to some brightness level in the range  $[0, L-1]$

### b) Fuzzy membership function based on histogram

Membership function is used for expressing the fuzzy property. Modified Gaussian membership function which is a simple transformation functions containing only one fuzzifier is given by

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$$\mu_{mn} = G(x_{mn}) = e^{-\frac{(x_{max} - x_{mn})^2}{2fh^2}} \quad (2)$$

Here  $G(x_{mn})$  is a Gaussian function, and  $x_{max}$ ,  $x_{mn}$  are the minimum and (m, n) th gray values respectively. A fuzzy histogram is used to obtain the frequency of occurrence of membership functions of gray levels in the fuzzy image. Thus,

$$R = U \{ \mu(x), p(x) \} = \{ \mu_{mn}/x_{mn} \}; m=1, \dots, M; n=1, 2, \dots, N \quad (3)$$

Where  $\mu(x)$  is the membership of pixel with intensity value of  $x$ , and  $p(x)$  is the number of occurrences of the intensity value  $x$ , in the image R. The distribution of  $p(x)$  is normalized such that

$$\sum_{x=0}^{L-1} p(x) = 1 \quad (4)$$

Membership function which is based on histogram by which pixels of spatial domain can be represented in fuzzy domain by histogram fuzzification function as

$$\mu(k) = e^{-\frac{(x_{max} - k)^2}{2fh^2}} \quad (5)$$

$k$  is in the range  $[0, L-1]$  and the fuzzifier parameter,  $f_h$ , can be determined as

$$f_h = \frac{\sum_{k=0}^{L-1} (x_{max} - k)^4 p(k)}{2 \sum_{k=0}^{L-1} (x_{max} - k)^2 p(k)} \quad (6)$$

$p(k)$  stands for the frequency of occurrence of  $k$  in histogram R. In the fuzzy plane, a contrast-enhanced image is low perception (dark),  $\mu \in [0, 0.5]$  or high perception (bright)  $\mu \in [0.5, 1]$  values. The pixels near  $\mu=0.5$  which do not belong to any of the two classes describes the fuzzy boundary and hence they may contain edges.

### c) Contrast intensification function

We first enhance the image using non linear new contrast intensification function as image degradation is non linear in nature. NINT  $[\mu(k)]$  having 3 tunable parameters, that are intensification operator  $t$ , fuzzifier  $f_h$  and the crossover point  $x_c$  defined as

$$\mu'(k) = \text{NINT}[\mu(k)] = 1/(1 + \exp[-t(\mu(k) - x_c)]) \quad (7)$$

Here  $t$  controls the shape of the sigmoid function and the initial value of  $x_c$  is taken as 0.5. And other two parameters are adjusted through  $\mu(k)$  while  $t$  will be fixed instead to control the level of contrast enhancement in the image.

### d) Parameter $x_c$ and $f_h$ entropy optimization

To access the image quality different type of measures are reported which are difficult to be quantified. In the fuzzy based approach, entropy of the fuzzy set is a functional to measure the degree of

fuzziness of a fuzzy set, giving the value of indefiniteness of an image. Entropy  $E$  can be defined in terms of Shannon's function  $S_e$

$$E = \frac{1}{\ln 2} \sum_{k=0}^{L-1} S_e p(k) \quad (8)$$

Where

$$S_e(\mu'(k)) = -\mu'(k) \ln \mu'(k) - (1 - \mu'(k)) \ln(1 - \mu'(k)) \quad \text{and} \quad \{0 \leq \mu' \leq 1\} \quad (9)$$

Entropy optimization method with pre-set initial values of  $x_c$  and  $f_h$ . The derivatives of  $E$  w.r.to  $x_c$  and  $f_h$  are

$$\frac{\partial E}{\partial x_c} = \frac{\partial E}{\partial \mu'(k)} \frac{\partial \mu'(k)}{\partial x_c} = \frac{1}{\ln 2} \sum_{k=0}^{L-1} [t^2 (\mu(k) - x_c) g(\mu')] p(k) \quad (10)$$

$$\frac{\partial E}{\partial f_h} = \frac{\partial E}{\partial \mu'(k)} \frac{\partial \mu'(k)}{\partial \mu(k)} \frac{\partial \mu(k)}{\partial f_h} =$$

$$\frac{1}{\ln 2} \sum_{k=0}^{L-1} \left[ \frac{t^2 \mu(k) (\mu(k) - x_c) (x_{max} - k)^2 g(\mu')}{f_h^2} \right] p(k) \quad (11)$$

Where  $g(\mu')$  is defined by

$$g(\mu') = \mu'(k) (1 - \mu'(k)) = \frac{e^{-t(\mu(k) - x_c)}}{[1 + e^{-t(\mu(k) - x_c)}]^2} \quad (12)$$

Gradient descent technique is used for the recursive learning of the parameters  $x_c$  and  $f_h$

$$x_{c,new} = x_{c,old} - \epsilon_x \frac{\partial E}{\partial x_c} \quad (13)$$

$$f_{h,new} = f_{h,old} - \epsilon_f \frac{\partial E}{\partial f_h} \quad (14)$$

Here  $\epsilon_x$  and  $\epsilon_f$  are learning factors or learning rates for parameters  $x_c$  and  $f_h$ . If these two diverge and converge too quickly, the value of  $\epsilon_x$  and  $\epsilon_f$  have to be altered respectively in order that the convergence of these values is ensured. We note that the optimization of  $x_c$  moves in both decreasing positive and negative search directions. The nearest optimization point of the both is taken as  $x_{c,new}$ .

## III. LOCAL EDGE DETECTION

### a) Local edge detector mask

Redefining contrast intensification function, NINT(.) in terms of (m,n)th pixel

$$\mu'(k) = \text{NINT}[\mu_{mn}] = 1/(1 + \exp[-t(\mu_{mn} - x_c)]) \quad (15)$$

A fuzzy parameter-based new Gaussian-type edge detector is proposed as

$$\eta(m, n) = e^{-\frac{\sum_i \sum_j [\mu(m+i, n+j)]^\alpha}{2(fh)^\beta}} \quad (16)$$

where  $i, j \in [-(w-1), (w-1)]$ , and  $w \times w$  is the size of the edge detector mask.  $\mu(m, n)$  is the

membership value of central pixel of the mask at location  $(m, n)$  and  $\hat{\eta}(m, n)$  is the output edge pixel replacing the previous central pixel. The fuzzifier  $f_h$  is earlier optimized using equation.

Parameters  $\alpha$  and  $\beta$  are adjustable and are pre-selected by experiments. As the mask is a generalized Gaussian function, different values of  $\alpha$  and  $\beta$  would yield different functions, i.e. selecting  $\alpha = \beta = 1$  would produce an exponential mask, while  $\alpha = \beta = 2$  would yield a normal Gaussian mask. The operation performed by the mask is a nonlinear mapping process and the output pixel value  $\hat{\eta}(m, n) \in [-\infty, \infty]$ , though in general, the value of  $\hat{\eta}(m, n)$  lies in  $[0, 1]$ .

#### b) Entropy optimization of parameters $\alpha$ and $\beta$

At the local window, optimization is also required to fine-tune parameters  $\alpha$  and  $\beta$ , as the final edge output depends very much on the values of these two parameters. Taking into consideration that the edge mask is applied locally and does not involve the entire image, the entropy function is taken as

$$E(\hat{\eta}(m, n)) = \hat{\eta}(m, n) \ln \hat{\eta}(m, n) + (1 - \hat{\eta}(m, n)) \ln (1 - \hat{\eta}(m, n)) \quad (17)$$

Where the global membership value,  $\mu(k)$  is now replaced by the local edge pixel  $\hat{\eta}(m, n)$ . The derivatives of  $E$  with respect to  $\alpha$  and  $\beta$  are obtained as:

$$\frac{\partial E}{\partial \alpha} = \frac{\partial E}{\partial \hat{\eta}(m, n)} \frac{\partial \hat{\eta}(m, n)}{\partial \alpha} = \frac{n \sum_i \sum_j K \alpha \ln K}{2(fh)\beta} \ln \left\{ \frac{\hat{\eta}}{1-\hat{\eta}} \right\} \quad (18)$$

$$\frac{\partial E}{\partial \beta} = \frac{\partial E}{\partial \hat{\eta}(m, n)} \frac{\partial \hat{\eta}(m, n)}{\partial \beta} = \frac{n \ln fh \sum_i \sum_j K \alpha \ln K}{2(fh)\beta} \ln \left\{ \frac{\hat{\eta}}{1-\hat{\eta}} \right\} \quad (19)$$

These derivatives are used in the learning of the parameters  $\alpha$  and  $\beta$  recursively by the gradient descent technique:

$$\alpha_{\text{new}} = \alpha_{\text{old}} - \epsilon_{\alpha} \frac{\partial E}{\partial \alpha} \quad (20)$$

$$\beta_{\text{new}} = \beta_{\text{old}} - \epsilon_{\beta} \frac{\partial E}{\partial \beta} \quad (21)$$

Where  $\epsilon_{\alpha}$  and  $\epsilon_{\beta}$  are learning factors for both parameters  $\alpha$  and  $\beta$  respectively. Similarly, if  $\alpha$  and  $\beta$  diverge or converge too quickly, the value of  $\epsilon_{\alpha}$  and  $\epsilon_{\beta}$  have to be altered respectively to ensure stability.

Since the optimization formulae might be burdensome, we may not use all points  $(m, n)$  on the image. We proposed using only the maximum and minimum intensity points or a selection of points to represent different intensity ranges. Some conditions and assumptions are needed to monitor the convergence of these values and prevent optimization process from yielding local minima or maxima. The following are the selection criteria and feasible range of values for  $\alpha$  and  $\beta$

$$\alpha_{\text{new}} \geq 1 \text{ and } \alpha_{\text{new}} \geq \alpha_{\text{old}} + 0.2$$

$$\beta_{\text{new}} \geq \beta_{\text{old}}/2 \text{ and } \beta_{\text{new}} \leq \alpha_{\text{old}}$$

If the value of  $\alpha$  and  $\beta$  converges outside the above range of values, optimization can be discarded, and the old values,  $\alpha_{\text{old}}$  and  $\beta_{\text{old}}$ , are used.

#### c) Removal of strong edges and noise

However, when strong edge and impulse noise are encountered,  $\hat{\eta}(m, n)$  will have either very large values of  $\hat{\eta}(m, n) > 1$ ; or very small values of  $\hat{\eta}(m, n) < 0$

Thus, the AND operation is taken to avoid such situations, so that the membership is within  $[0, 1]$ , that is

$$\hat{\eta}(m, n) = \min[\hat{\eta}(m, n)] \approx 1; \text{ when } \hat{\eta}(m, n) > 1; \text{ AND}$$

$$\hat{\eta}(m, n) = \max[\hat{\eta}(m,$$

$$n)] \approx 0; \text{ when } \hat{\eta}(m, n) < 0; \text{ when } \hat{\eta}(m, n) < 0;$$

#### d) Edge image thresholding

After the edge image is produced through the edge detector, simple thresholding is required to binaries it according to a certain threshold level. An optimum threshold level  $\lambda$  is determined through experiments to be in the range of 0.7 to 0.9, where

$$\hat{\eta}(m, n) = \begin{cases} 1 & \lambda \geq 0.7 \rightarrow 0.9 \\ 0 & \lambda \geq 0.7 \rightarrow 0.9 \end{cases}$$

## IV. FUZZY-CANNY EDGE DETECTION

Now after fuzzifying the image we can simply apply canny operator to the resultant image. the simple algorithm for Canny edge detection is given below:

1. Minimum number of false negatives and false positives.
2. Good localization, report edge location at correct position.
3. Single response to single edge.

Solving an optimization problem using variational calculus and the criteria specified above he arrived at an optimal edge enhancing filter, the derivative of a Gaussian

$$G(x, y) = e^{-x^2+y^2/2\sigma^2} \quad (22)$$

$$\frac{\partial G}{\partial x} = -\frac{x}{\sigma^2} G \quad (23)$$

$$\frac{\partial G}{\partial y} = -\frac{y}{\sigma^2} G \quad (24)$$

#### Steps of Canny edge detection algorithm:

1. Convolve the image with the derivative of a Gaussian.
2. Apply non maxima suppression to the gradient magnitude image.
3. Use two thresholds  $T_1 > T_2$ :

- a) Class = {edge if magnitude > T1 Candidate  
if magnitude > T2}
- b) Hysteresis: Any candidate which is a neighbor, in the gradient direction, of an edge is reclassified as an edge.

## V. RESULTS AND DISCUSSIONS



Fig 5.1 : Original low contrast noisy image



Fig 5.2 : Detection of edges using Canny edge detection



Fig 5.3 : Detection of edges Using Fuzzy edge detector



Fig 5.4 : Detection of edges using Fuzzy-Canny edge detector

The Fuzzy-Canny detector algorithm is implemented on low contrast noisy image and prior to the application of this algorithm, no pre-processing was done on the image. As the algorithm has two phases – fuzzy based detection and then implementing Canny edge detector, we present the results of implementation on these images separately.

For noisy low contrast images Fussy is a good approach because it involves the enhancement of an image before filtering the edges in which Canny failed to provide acceptable results. This can be explained by the fig. 5.2 and 5.3 given above. The resultant image can be further improved by using Canny operator which will help in linking the edges and enhancing the edge pixels as given by fig. 5.4.

## VI. CONCLUSION

The fuzzy –Canny edge detector presented in this paper uses both global (histogram of gray levels) and local (membership function in a window) information and finally edge linking which is one of the step of Canny. The local information is fuzzified using a modified Gaussian membership function. Using the

contrast intensification operator, the image is enhanced to the required level of visual quality by the entropy optimization of parameters  $fh$  and  $xc$ . Then, the local edge detection operator is applied on the enhanced image using parameters  $\alpha$  and  $\beta$ , which are again obtained from entropy optimization. Simple edge thresholding is applied and finally canny edge detection is performed. Results show that this edge detector is immensely suitable for applications such as face recognition and fingerprint identification, as it does not distort the shape and is able to retain the important edges and continuous edges unlike the Canny and fuzzy-Canny edge detector. Choice of some of the parameters  $t$ ,  $\alpha$  and  $\beta$  is crucial for the success of this algorithm.

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# Identification of Early Osteoporosis Using Intensity Slicing method

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**Abstract** - Osteoporosis is a disease characterized by low bone mass and deterioration of bone tissues, leading to bone fragility and, consequently, an increase in fracture risk [2-6]. Loss of bone mass occurs as part of the natural process of aging [4]. Bones naturally become thinner (called osteopenia) as one grows older, because existing bone is broken down faster than new bone is made. As this occurs, the bones lose minerals, heaviness (mass), and structure, making them weaker. With further bone loss, osteopenia develops into osteoporosis. The thicker bones are, the longer it takes to develop osteoporosis. Although osteoporosis can occur in men, it is most common in women older than age 65. Since osteoporosis can develop undetected for decades until a fracture occurs, early diagnosis is important [2].

*GJRE- J Classification : FOR Code: 090399*



*Strictly as per the compliance and regulations of:*



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# Identification of Early Osteoporosis Using Intensity Slicing method

R. Sivakumar

## I. INTRODUCTION

Osteoporosis is a disease characterized by low bone mass and deterioration of bone tissues, leading to bone fragility and, consequently, an increase in fracture risk [2-6]. Loss of bone mass occurs as part of the natural process of aging [4]. Bones naturally become thinner (called osteopenia) as one grows older, because existing bone is broken down faster than new bone is made. As this occurs, the bones lose minerals, heaviness (mass), and structure, making them weaker. With further bone loss, osteopenia develops into osteoporosis. The thicker bones are, the longer it takes to develop osteoporosis. Although osteoporosis can occur in men, it is most common in women older than age 65. Since osteoporosis can develop undetected for decades until a fracture occurs, early diagnosis is important [2].

A BMD test is the only way to diagnose osteoporosis and determine risk for future fracture[5]. The painless, noninvasive test measures bone density and helps determine whether medication is needed to help maintain bone mass, prevent further bone loss, and reduce fracture risk. Several different machines measure bone density. Central machines, such as the dual energy x-ray absorptiometry (DXA or DEXA), measure density in the hip, spine and total body. Peripheral machines, such as radiographic absorptiometry (RA)[1], peripheral dual energy x-ray absorptiometry (pDXA). Dual X-ray absorptiometry (DXA) uses two different X-ray beams, due to which there is an increase in exposure to radiation causing harmful side effects. Special types of x-ray machines, are used. These machines are costlier. pDEXA also uses very low doses of radiation, and the results are faster than conventional DEXA measurements. pDEXA has limited usefulness (compared to DEXA) for monitoring the effect of medication used to treat osteoporosis[2]. The PDEXA equipment is much costlier than ordinary X-ray equipment. This method is not recommended for pregnant women because of the radiation exposure to the baby (fetus). Intensity slicing method is proposed to highlight the affected regions in osteoporotic x-ray images in order to assist the doctors in the identification of osteoporosis affected regions which cannot be visually identified.

## II. MATERIAL AND METHOD

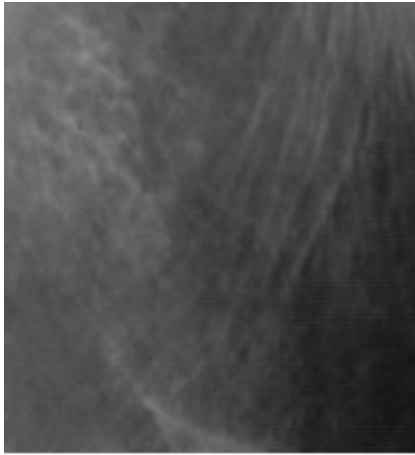
We have made use of X – rays of osteoporotic and non osteoporotic patients at different locations of the body collected from hospitals and processed it using image processing tools of MATLAB.

This method for the detection of osteoporosis consists of two modules.

### a) *Intensity Slicing for Bone Structures*

This module is used to highlight pores and the regions that have low Bone Mineral Density, which could be of very great use to the doctors in identifying the affected areas which are otherwise not visually detectable. In this method the radiograph is loaded as bitmap image and converted into gray scale. Then the region of interest in gray scale image is chosen, in order to neglect the black background of the radiograph, the mean is computed for the region of interest omitting the pixel intensities that are less than a scale of 5. This ensures that there is no interference due to the black even if it is accidentally chosen in the region of interest.

The histogram (Histogram plot the pixel intensities in x-axis and the corresponding number of pixels in the y-axis) of the image is computed and stored in a variable, and then the index value of the histogram that has the maximum number of pixels is noted. The size of the region of interest is stored in a variable. Let the index value of the histogram that has the maximum number of pixels be L. Then the pixels with the intensity lesser than the mean value and lie within the range L-10 & L-30 are displayed as red pixels that visually highlight the affected regions. From experimentation it was learnt that the range L-10 & L-30 covers the pixels with intensities which are more prominent in osteoporotic radiographs. The comparison between the histogram of osteoporotic and non osteoporotic radiographs clearly show the reason for the selection of the range in the figures 2.1. -2.4. & Flow Chart 2.5.



OSTEOPOROTIC X-RAY

Figure: 2.1

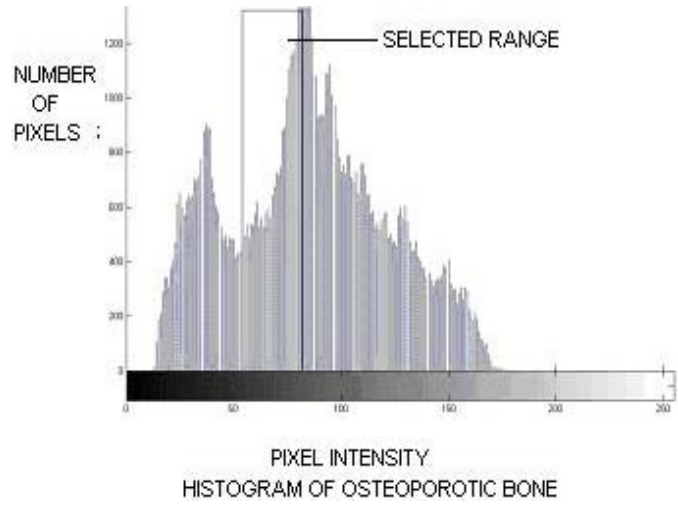


Figure: 2.2



NON OSTEOPOROTIC X-RAY

Figure: 2.3

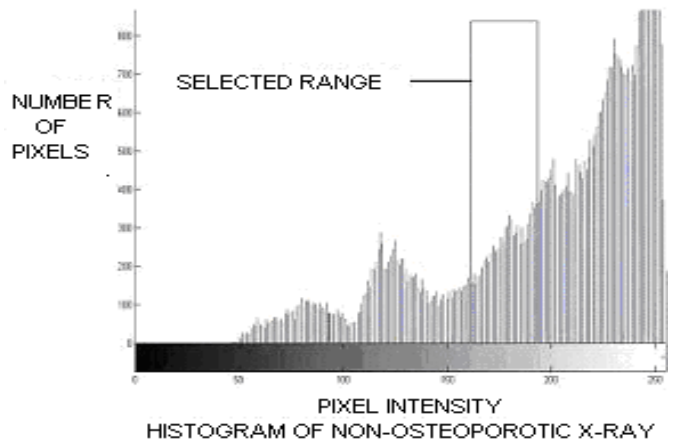


Figure: 2.4



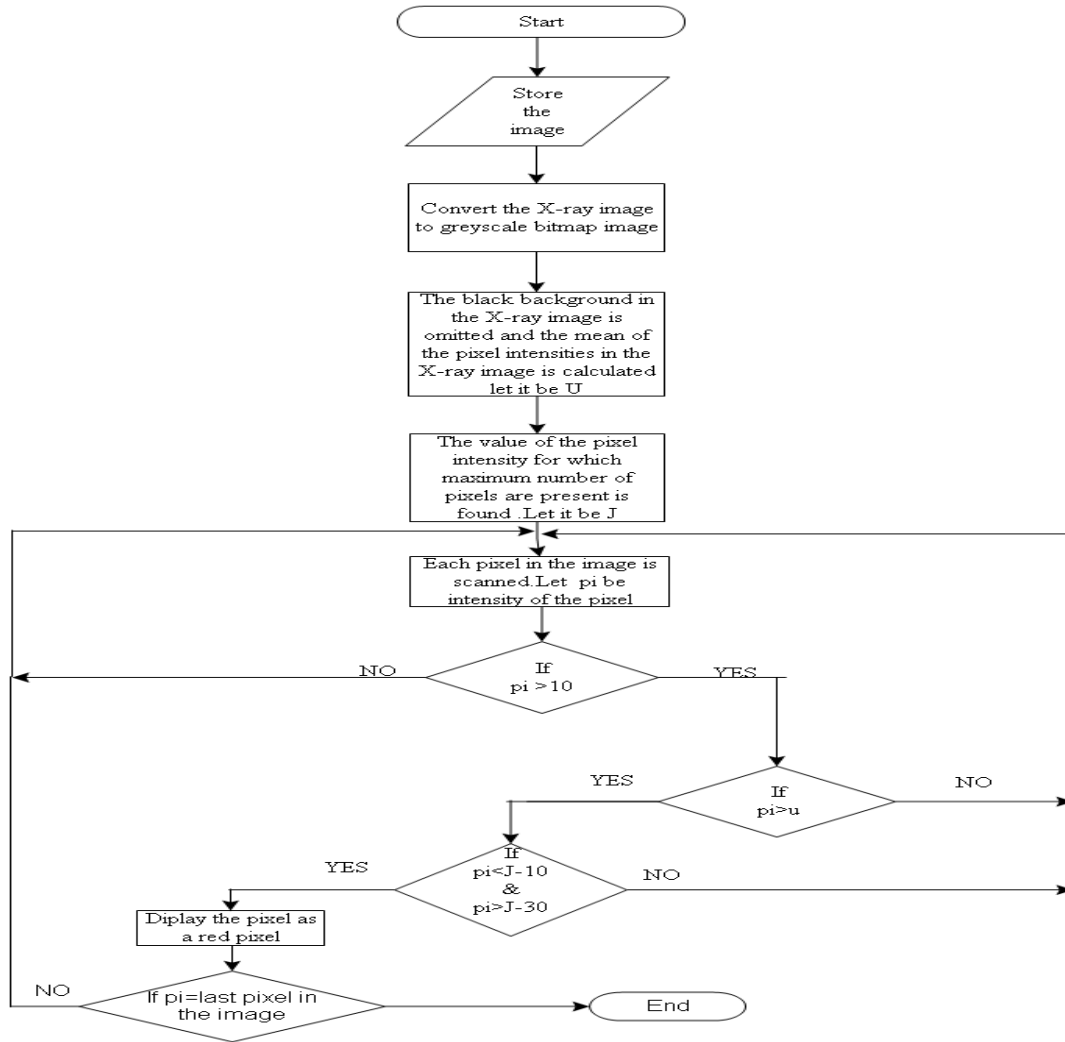


Figure 2.5 : Flow chart for Intensity Slicing for bone structures

b) Intensity Slicing for Tracing Striations

This module is used to highlight striations within the bone structures that have very low calcium deposits, striations are caused due to drastic reduction of Bone Mineral Density. This method for detecting the striations will be of very great use to detect striations which are not visible to the naked eye. In this method the radiograph is loaded as bitmap image and converted into gray scale. Then the region of interest in gray scale image is chosen, in order to neglect the black background of the radiograph, the mean is computed

for the region of interest omitting the pixel intensities that are less than a scale of 5. This ensures that there is no interference due to the black even if it is accidentally chosen in the region of interest. Then the region of interest is fully scanned for intensity variations, this can be done by monitoring the variation of intensities from pixel to pixel. If the variation of pixel intensity is over the threshold value then the pixel with lesser intensity is displayed as red pixel. Consider the following figures 2.6 & 2.7.

145	145	144	140	146	132	160
144	143	141	144	130	145	142
143	144	65	143	125	142	135
142	143	146	130	125	142	146
141	140	126	140	120	143	145
141	143	120	139	142	139	143
142	143	119	141	142	138	142

Figure 2.6 : Pixels before highlighting

145	145	144	140	146	132	160
144	143	141	144	130	145	142
143	144	65	143	125	142	135
142	143	146	130	125	142	146
141	140	126	140	120	143	145
141	143	120	139	142	139	143
142	143	119	141	142	138	142

Figure 2.7 : Pixels after highlighting

If the threshold value is set as 5, then all the pixels which have intensities 5 greater than that of the previous pixel in the same row and pixels which have intensities 5 greater than that of the next pixel in the same row will be highlighted as shown in figure.

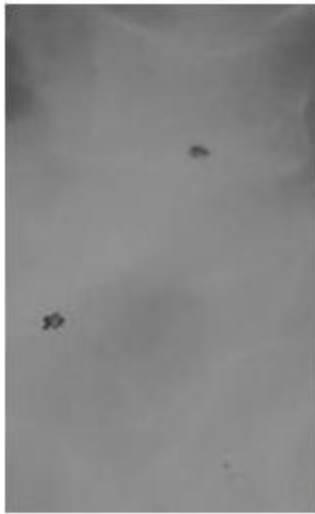
### III. RESULTS AND DISCUSSION

#### a) Results Of Intensity Slicing for Bones

The results of intensity slicing for bone structures are displayed in the following page, figures

3.1, and 3.3,3.5 display the image of the osteoporotic bone and the corresponding outputs of intensity slicing method for bone structures are displayed in the figures 3.2, 3.4, and 3.6 respectively. By examining the osteoporotic images and their corresponding output for intensity slicing method for bone structures it would be clear that, the regions that have low calcium deposits are highlighted clearly. The pores within the bone structures which are hardly visible to the naked eye are clearly highlighted in the outputs

#### OUTPUTS OF INTENSITY SLICING FOR VARIOUS IMAGES



OSTEOPOROTIC IMAGE

Figure : 3.1



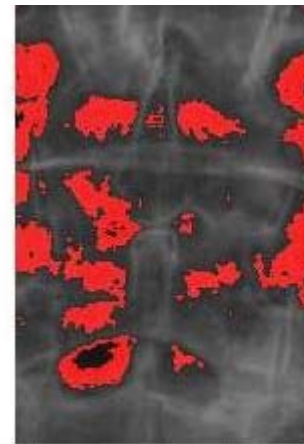
OUTPUT OF INTENSITY SLICING FOR  
OSTEOPOROTIC RADIOGRAPH

Figure : 3.2



OSTEOPOROTIC IMAGE

Figure : 3.3



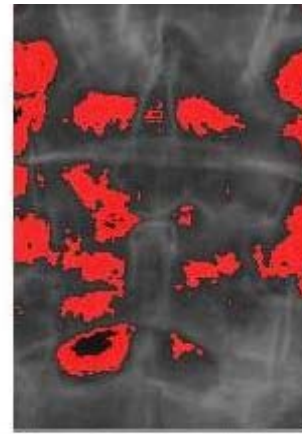
OUTPUT OF INTENSITY SLICING FOR  
OSTEOPOROTIC RADIOGRAPH

Figure : 3.4



OSTEOPOROTIC IMAGE

Figure : 3.5



OUTPUT OF INTENSITY SLICING FOR OSTEOPOROTIC RADIOGRAPH

Figure : 3.6

*b) Results of Intensity Slicing for Tracing Striations*

The results of intensity slicing for tracing striations are displayed in the following page, figures 3.7,3.9,3.11 display the image of the osteoporotic bone with striations, the corresponding outputs of intensity slicing method for tracing striations are displayed in the figures 3.8,3.10,3.12 respectively. By examining the

osteoporotic images and their corresponding output for intensity slicing method for tracing striations, it would be clear that, the regions having low calcium deposits are highlighted clearly .The striations within the bone structures which are hardly visible to the naked eye are clearly highlighted in the outputs .

OUTPUTS OF INTENSITY SLICING FOR VARIOUS IMAGES



Figure 3.7 : Osteoporotic X-ray 1

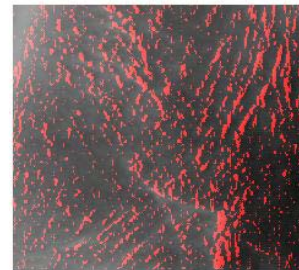


Figure 3.8 : Osteoporotic X-ray image 1 with striations highlighted



Figure 3.9 : Osteoporotic X-ray 2



Figure 3.10 : Osteoporotic X-ray image 2 with striations highlighted





Figure 3.11 : Osteoporotic X-ray 3

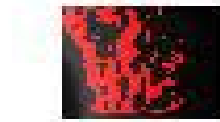


Figure 3.12 : Osteoporotic X-ray image 3 with striations highlighted.

From the analysis of various radiographs using Intensity Slicing method produce accurate results. Thus using this method, detection of osteoporosis can be done with a minimum exposure to radiations and it can be of very great use to the doctors in the analysis of x-ray images for detecting osteoporosis.

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# Cumulative Production Forecast of An Oil Well Using Simplified “Hyperbolic-Exponential” Decline Models

By Makinde F. A, Orodu O. D. , Ladipo A. O. & Anawe P. A. L.

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**Abstract** - Decline Curves are important tools employed in the petroleum production industry to establish a good production performance forecast of production wells. Studies have shown that neither hyperbolic nor exponential decline could accurately produce dependable forecast results, which in turn affects the various economic decisions being made on both investment and future production processes. New simplified models for decline curve analysis are developed. The models are applicable to naturally producing wells that have not been secondarily enhanced. These models use exponential decline to extrapolate hyperbolic decline behaviour in making future production performance forecasts. Estimating different needed parameters and engaging some assumptions, the forecasted cumulative production increment using the model is . This compares favourably with the existing models.

**Keywords** : *Production forecast, Reserves, Decline curve, Exponential, Hyperbolic.*

**GJRE- J Classification** : *FOR Code: 090999*



*Strictly as per the compliance and regulations of:*



# Cumulative Production Forecast of An Oil Well Using Simplified “Hyperbolic-Exponential” Decline Models

Makinde F. A<sup>α</sup>, Orodu O. D.<sup>σ</sup>, Ladipo A. O.<sup>σ</sup> & Anawe P. A. L.<sup>σ</sup>

**Abstract** - Decline Curves are important tools employed in the petroleum production industry to establish a good production performance forecast of production wells. Studies have shown that neither hyperbolic nor exponential decline could accurately produce dependable forecast results, which in turn affects the various economic decisions being made on both investment and future production processes. New simplified models for decline curve analysis are developed. The models are applicable to naturally producing wells that have not been secondarily enhanced. These models use exponential decline to extrapolate hyperbolic decline behaviour in making future production performance forecasts. Estimating different needed parameters and engaging some assumptions, the forecasted cumulative production increment using the model is  $Q_{el} \approx 20,705 \text{ bbls}$ . This compares favourably with the existing models.

**Keywords** : Production forecast, Reserves, Decline curve, Exponential, Hyperbolic.

## I. INTRODUCTION

The petroleum industry is summarily driven by profit. This is the topmost factor to consider in the development of petroleum fields. Reserves have to be well estimated before the company's limited available resource is expended on a given project.

One of the most important tasks of a petroleum engineer is estimating, by factual prediction, the amount of oil and gas that could be recovered from a reservoir. Choosing the methodology is critical for accurate forecasts that are, in turn, vital for sound managerial planning<sup>5</sup>. Risks have to be minimized in the process of making decisions based on the recoverable percentage of the original hydrocarbon in place, as well as the residual amount of this oil when the economic limit is reached before the need for any secondary recovery mechanism is involved, for the case of a naturally producing reservoir-well relationship.

Extrapolation of production history has long been considered the most accurate and defensible method of estimating the remaining recoverable reserve from a well and, in turn, a reservoir<sup>5</sup>. Various methods have been developed so far, ranging from the most commonly used Decline Curve Analysis (DCA), to the Type Curve Matching (TCM) method based on the well

or reservoir production history. While Decline Curve Analysis is independent of any reservoir characteristics, Type Curve Matching is a very subjective procedure.

DCA is a method used for the prediction of future hydrocarbon production by analyzing past production. A decline curve of a well is simply a plot of the well's production rates against the respective times of recording. It was recognized early in the history of petroleum engineering that calculating reserves and production forecasts were possible by studying past production trends.

Upon all the various works done in the past on forecasting the recoverable amount of hydrocarbons from an oilfield, the problem has been how to forecast with decline curves (production history) without over-estimating or under-estimating cumulative production/reserves, most especially with Arps's Decline Curve Analysis.

This study combines hyperbolic and exponential declines in developing simplified empirical decline curve models (hyperbolic-exponential models), to forecast the oil production performance of a primarily flowing well till economic limit. The production performance includes **predicting future production rates, cumulative production increments, production time or period, ultimate recovery and the residual reserves**<sup>6</sup> but this paper presents only the models for predicting the cumulative production.

Arps<sup>1</sup> published several excellent papers in 1944 and 1945. These papers contained several excellent equations which have essentially remained unchanged and are still referred to as the “Arps” equations.

Arps categorized decline curves into exponential, hyperbolic and harmonic declines. The hyperbolic equation is the universal equation upon which the exponential and harmonic declines are special cases of. The difference is just the changes in the hyperbolic constant used for the two cases. The hyperbolic constant determines the degree of change of each decline. The hyperbolic constant “b” equals 0 for exponential declines, 1 for harmonic declines, and ranges from 0 to 1 for hyperbolic declines.

Arps in his document, coupled with the work of Curtler showed that approximately two-third of the various cases of declines studied have a hyperbolic constant between 0.1 and 0.4, suggesting a log normal distribution.

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Arps was able to derive and establish the various basic equations for Decline Curve Analysis, but unfortunately, he could not establish this transition point from hyperbolic to exponential decline.

To tackle this problem, in early 1980s, Fetkovich<sup>2</sup> designed Type Curve models from different studied wells and fields based on Arps' empirical equations and known reservoir flow properties from which the decline curve derived from the production data of analysis is compared to look for a perfect match of which the well automatically assumes the Type Curve properties, whose values are then used for the forecasting of the well of interest.

Long and Davis<sup>3</sup> (1988) further added to the work of Arps. They tried to look at how the problem of the transition point could be surmounted. In their pursuits, they developed a log-rate-versus-time overlay to cope with this problem. They introduced the use of Type Curve Matching method, where the curve from a well production history is matched with already developed curves from different wells based on different reservoir-well properties for correlation.

Robertson<sup>4</sup> (1988) also developed a production rate equation that is hyperbolic initially but asymptotically exponential with time. He introduced a dimensionless constant; its value ranges from 0 to 1 and is related to the abandonment pressure, and the rock and fluid properties.

Long and Davis, and Robertson ignored determining the precise transition point between the hyperbolic and exponential declines, they assumed the exponential decline rate was known based on experience with analogous wells or experience with particular reservoirs. This method proposed by them is limited in application because:

- Different wells situated in the same reservoir at times exhibit different reservoir-well properties such as the skin effect along their production history, thus, making them to exhibit different productivity indices, effective permeabilities etc,

thereby drastically varying their production decline rates. This limits the dependability on the value.

- Also, in a situation when the well to be analyzed is the first producing well on the field or probably the other wells on the field are in a hyperbolic decline state, a dependable exponential decline rate (constant) that could have served as a reference for comparison with the decline rate value of the well-in-question is no more readily available.

Due to the fact that the hyperbolic decline rate at which exponential decline starts is the rate that is used to forecast the various production rates and cumulative production at any time or point after this transition point, conciseness is necessary in determining this value for improved accuracy in any estimated forecast made after this point (that is in the exponential decline state of the well productions).

Khaled<sup>5</sup> from King Saud University, Saudi Arabia, in his publication "Predicting Production Performance using a Simplified Model", looked at combining hyperbolic and exponential decline models empirically together to predict production performance using the available well production history data. In his method, he stated that at a point in the production life of a well, the rate of decline of the decline rates,  $D$  with production time will behave as a constant (that is  $\frac{dD}{dt} = C$ ). The time, at which this occurs, he described as the transition point from hyperbolic to exponential declines, from where production forecast can now be made exponentially. In that publication, Khaled assumed the value of this constant, based on the behaviour of the curve gotten from the constant-time graph he plotted. Thus, he employed a deterministic approach in estimating the transition time.

## II. METHODOLOGY

In this work, a set of empirical models are developed for estimating the cumulative production at the economic limit as follows:

### Model for Cumulative Production Forecast

*Cumulative Production,  $Q_{cum}$  till any production rate,  $q_o$  in the exponential decline period:*

$$Q_{cum} = Q_{hyp} + Q_{exp} \dots \dots \dots (2.0)$$

*From the general hyperbolic decline equation for cumulative production,*

$$Q_{hyp} = \frac{q_{oi}^b * (q_{oi}^{(1-b)} - q_{iexp}^{(1-b)})}{D_i(1-b)} \dots \dots \dots (2.1)$$

$$\text{but } q_{iexp} = q_{oi} (1 + bD_i t_{exp})^{-\frac{1}{b}} \dots\dots\dots(\text{xx})$$

$$t_{exp} = b^{-1} (D_{exp}^{-1} - D_i^{-1}) \dots\dots\dots(\text{xxx})$$

Therefore:

$$Q_{hyp} = \frac{q_{oi}^b * \left( q_{oi}^{(1-b)} - q_{oi}^{(1-b)} (1 + bD_i t_{exp})^{-\frac{1}{b}(1-b)} \right)}{D_i(1-b)}$$

$$Q_{hyp} = \frac{q_{oi}^b * \left( q_{oi}^{(1-b)} - q_{oi}^{(1-b)} (1 + bD_i t_{exp})^{\frac{b-1}{b}} \right)}{D_i(1-b)}$$

$$Q_{hyp} = \frac{q_{oi}^b * q_{oi}^{(1-b)} \left[ 1 - (1 + bD_i t_{exp})^{\frac{b-1}{b}} \right]}{D_i(1-b)}$$

$$Q_{hyp} = \frac{q_{oi} * \left[ 1 - (1 + bD_i t_{exp})^{\frac{b-1}{b}} \right]}{D_i(1-b)} \dots\dots\dots(2.2)$$

From the general exponential equation for cumulative production, the cumulative production (from the beginning of the exponential decline model,  $t_{exp}$  to any production time with a production rate,  $q_o$ ),  $Q_{exp}$  in the exponential decline period is:

$$Q_{exp} = \frac{q_{iexp} - q_o}{D_{exp}} \dots\dots\dots(2.3)$$

$$\text{Where } D_{exp} = \frac{D_i}{1 + bD_i t_{exp}}$$

Therefore:

$$Q_{exp} = \frac{(q_{iexp} - q_o)(1 + bD_i t_{exp})}{D_i} \dots\dots\dots(2.4)$$

$$Q_{exp} = \frac{\left( q_{oi} (1 + bD_i t_{exp})^{-\frac{1}{b}} - q_o \right) (1 + bD_i t_{exp})}{D_i}$$



$$Q_{exp} = \frac{\left[ q_{oi}(1 + bD_i t_{exp})^{\frac{b-1}{b}} \right] - q_o(1 + bD_i t_{exp})}{D_i} \dots \dots \dots (2.5)$$

Substituting (2.2) and (2.5) into (2.0),

$$Q_{cum} = \frac{q_{oi} * \left[ 1 - (1 + bD_i t_{exp})^{\frac{b-1}{b}} \right]}{D_i(1 - b)} + \frac{\left[ q_{oi}(1 + bD_i t_{exp})^{\frac{b-1}{b}} \right] - q_o(1 + bD_i t_{exp})}{D_i}$$

Therefore:

$$Q_{cum} = \frac{q_{oi} * \left[ 1 - (1 + bD_i t_{exp})^{\frac{b-1}{b}} \right] + \left[ \left( q_{oi}(1 + bD_i t_{exp})^{\frac{b-1}{b}} \right) - q_o(1 + bD_i t_{exp}) \right] (1 - b)}{D_i(1 - b)}$$

The Cumulative production to the economic limit production rate ( $q_{el}$ ),  $Q_{el}$  is:

$$Q_{el} = \frac{q_{oi} * \left[ 1 - (1 + bD_i t_{exp})^{\frac{b-1}{b}} \right] + \left[ \left( q_{oi}(1 + bD_i t_{exp})^{\frac{b-1}{b}} \right) - q_{el}(1 + bD_i t_{exp}) \right] (1 - b)}{D_i(1 - b)}$$

In terms of a constant  $\beta$ , Cumulative Production,  $Q_{cum}$  till any production rate ( $q_o$ ) in the exponential decline period can be expressed as:

$$Q_{cum} = \frac{q_{oi} * \left[ 1 - \beta^{\frac{b-1}{b}} \right] + \left[ \left( q_{oi} \beta^{\frac{b-1}{b}} \right) - q_o \beta \right] (1 - b)}{D_i(1 - b)} \dots \dots \dots (2.6)$$

while Cumulative production to the economic limit production rate ( $q_{el}$ ),  $Q_{el}$  is

$$Q_{el} = \frac{q_{oi} * \left[ 1 - \beta^{\frac{b-1}{b}} \right] + \left[ \left( q_{oi} \beta^{\frac{b-1}{b}} \right) - q_{el} \beta \right] (1 - b)}{D_i(1 - b)} \dots \dots \dots (2.7)$$

where:  $\beta = 1 + bD_i t_{exp} \dots \dots \dots (2.8)$

Hence, the residual oil reserve in the reservoir at the point of economic limit assuming  $q_{oi}$  is the first production rate in the production history of the producing

well,  $Q_{residual,el}$  is:

$$Q_{residual,el} = OIIP - Q_{el} \dots \dots \dots (2.9)$$

*If the well has produced certain amount of oil,  $Q_{oi}$  before the analysed production decline period begins, either as a result of well's transient production period, production downtime, or any other reasons, the residual oil reserve,  $Q_{residual,el}$  is:*

$$Q_{residual,el} = OIIP - (Q_{oi} + Q_{el}) \dots \dots \dots (2.10)$$

*In addition, the ultimate recovery through the producing well concerned, from the onset of the production decline period to the economic limit (that is within the analysed production decline period),  $E_R$  is:*

$$E_R = \frac{Q_{el}}{OIIP} \dots \dots \dots (2.11)$$

*While the ultimate recovery through the producing well assuming there has been a period of production prior to the production decline period being analysed,  $E_R$  is given as:*

$$E_R = \frac{Q_{oi} + Q_{el}}{OIIP} \dots \dots \dots (3.12)$$

*NOTE: For all the cumulative production models above, if any of the decline rates,  $D, D_i$  or  $D_{exp}$  is in per year ( $yr^{-1}$ ), and the associated production rate,  $q_0$  is in  $\frac{STB}{day}$ , the respective cumulative production expression must be multiplied by a factor of 365 to express it in STB.*

*Also, if  $D$  is expressed in  $month^{-1}$ , and  $q_0$  is in  $\frac{STB}{day}$ , the cumulative production expression must be multiplied by a factor of 30.4 to express it in STB. The cumulative production models stand the way they are expressed ONLY if the involved declines,  $D$  are in  $day^{-1}$ , and production rates,  $q_0$  are in  $\frac{STB}{day}$ , or the declines,  $D$  are in  $month^{-1}$ , and production rates,  $q_0$  are in  $\frac{STB}{month}$ , or the declines,  $D$  are in  $yr^{-1}$ , and production rates,  $q_0$  are in  $\frac{STB}{yr}$ .*

*All these are just to correct for the varying units of the decline rate,  $D$ .*



a) Estimation of Required Parameters

From the developed models, the required parameters for forecasting the performance of a well in a reservoir, and subsequently estimating the cumulative production and residual reserve at a set or predetermined economic limit production rate are:

- $t_{exp}$  , the time at which the hyperbolic decline models turn to exponential decline models along the production history of the well,
- $D_i$  , the initial decline rate at the onset of the hyperbolic decline behavior of the well's production rates, and
- $b$  , the hyperbolic decline constant or exponent.

b) Estimation of  $t_{exp}$

$t_{exp}$  is an important parameter needed for forecasting a well's production and residual reserve using a combination of hyperbolic and exponential decline models.

There are three methods which could be used in the estimation of  $t_{exp}$  . Each method has its own applicability and conditions of usage. They include:

- Graphical method,
- Comparison with already producing well in the same field, and
- Company's Production Policy.

c) Solving For the Hyperbolic Decline Constant/ Exponent,  $b$

The value of the hyperbolic constant  $b$  is very crucial in any hyperbolic DCA forecast. The shape of the hyperbolic curve is controlled by both the hyperbolic constant  $b$  , and the initial decline  $D_i$  . The higher the  $b$  factor, the lower the decline in production rate, the longer the life of the well to the economic limit and the higher the ultimate recovery is.

Over the years, engineers calculate the hyperbolic constant using simple and approximate methods. Apart from the various empirical methods developed for calculating the various parameters needed in hyperbolic decline models, various DCA softwares such as the Oilfield Manager (OFM) are available in the industry for estimating them.

Empirically, the following methods can be employed in solving for the hyperbolic decline constant,  $b$ .

They are:

- The three-point method, and
- The initial rate and decline method.

d) Calculation Of The Initial Decline Rate,  $D_i$

The initial decline rate  $D_i$  plays an important role in a hyperbolic-exponential decline models as seen

above. Apart from the widespread DCA computer softwares available presently in the oil and gas industry for estimating the various hyperbolic decline constants, this paper identifies two simplified and empirical methods for achieving the task of calculating  $D_i$ . These are:

- The tangential method, and
- The two-rate method.

### III. MODEL VALIDATION AND DISCUSSION OF RESULTS

There are various methods of estimating the forecast parameters as highlighted above but for the sake of simplicity and time, quite a number of computer softwares have been developed nowadays to ease seemingly complex calculations such as estimation of the hyperbolic decline exponent, the hyperbolic initial decline rate, and the initial decline rate.

In this work, the Schlumberger Oilfield Manager (OFM) was used in carrying out the various estimations. Shown in Figure 1 in the Appendix A is a Microsoft Excel format of the semi-log plot obtained from the OFM software showing both hyperbolic and exponential decline models fit for the region of best historical decline behaviour and their respective decline parameters as well as their regression coefficients.

It is understood that most naturally-producing wells start their production history with a hyperbolic decline behaviour, which does occur for just some periods after production commences, before finally exponential decline behaviour sets in. This understanding aided the development of the models in this paper. The result of the decline rates,  $D_i$  above clearly shows that the hyperbolic initial decline rate is higher than that of the exponential decline rate, therefore permitting the hyperbolic initial decline to reduce to the exponential decline rate, from where the decline rate remains constant till the end of the forecast. This is a good pointer to establishing the intent of this work.

The forecast starts with a hyperbolic rate, then the time at which this rate declines to the exponential rate is calculated from one of the models (equation xxx), hence, from this time, the exponential decline is employed to forecast the remaining future production time behaviour of the well till the economic limit is reached assuming no work-over activities are being carried out on the well.

After estimating all these parameters (for Hyperbolic Decline):

$$D_i = 0.129655 \text{ month}^{-1}$$

$$b = 0.192333$$

$$D_{exp} = 0.101351 \text{ month}^{-1}$$

Then, estimating the time at which the

hyperbolic behaviour changes to the exponential behaviour:

From Equation (XX) :  $T_{exp} = b^{-1}(D_{exp}^{-1} - D_i^{-1})$

Therefore :  $t_{exp} \approx 11.2$  months

Note that this parameter  $t_{exp}$  is the most important tool in forecasting using combined models of two decline behaviours. Its value is what mostly determines how valid our forecast result is and this is not known to have been determined with any known software yet. It is best solved empirically by analyzing the historical production decline behaviour of the well. The method used here in calculating it is employed because we have a well that is showing a decline behaviour that is very close to both hyperbolic and exponential declines. The graphical method cited under the methodology would have been the only applicable method assuming there is a great difference between the hyperbolic and exponential decline fits.

Having estimated  $t_{exp}$  and the other required parameters for forecast with the developed models, the cumulative production forecast is done using the developed models.

The validity of the models developed and used here is authenticated with the data set analyzed.

a) Cumulative Production Forecast

Setting the last historical oil production rate (Table 1) of the well as the initial production rate for the forecast:

$q_{last\ historical} = q_{oi} = 77.667$  bbls/day

Assuming that no work-over activities like perforation interval plugging, pressure build-up and drawdown tests etc, as well as no secondary or enhanced recovery mechanisms are to be employed on the field till the bench-marked economic limit rate is reached, then the developed models for cumulative forecast could be used in forecasting the cumulative production increments through the well from the field, from the last historical date/rate to any forecasted production rate,  $q_o$  at various production times. For this forecast, the minimum forecasted production rate is set at:  $q_o = 0.1$  bbl/day.

For the cumulative production forecast,

equation(2.2):  $Q_{hyp} = \frac{q_{oi} \left[ 1 - \left( 1 + b D_i t_{exp} \right)^{\frac{b-1}{b}} \right]}{D_i (1-b)}$  is used

to estimate the cumulative production increments at different forecasted production times ranging from the last historical date where  $t=0$  to when  $t = t_{exp}$ , and

equation(2.6):  $Q_{cum} = \frac{q_{oi} \left[ 1 - \beta^{\frac{b-1}{b}} \right] + \left[ \left( q_{oi} \beta^{\frac{b-1}{b}} \right) - q_o \beta \right] (1-b)}{D_i (1-b)}$

is used to estimate the cumulative production increments from  $t_{exp}$  to  $t_o$  where  $q_o = 0.1$  bbl/day.

Also, the constant  $\beta \approx 1.279294$ , estimated from equation (2.8):  $\beta = 1 + b D_i t_{exp}$

Calculating the various cumulative production increments at the various forecasted times using the above models at designated regions would generate Table 2 in Appendix A.

A normal plot of these forecasted cumulative production increments against the respective production times is shown in Figure 2.

The forecast in Figure 2 is very useful in analyzing at what production time a particular cumulative production increment will be achieved in the future production of the well. It is also applicable when determining the total recovery from a well at any forecasted production time in future.

On the other hand, the relationship between the forecasted rates and the forecasted cumulative production increments can be studied. This is very important in analyzing how the decrease in production rate with time is affecting the cumulative increments in production. It could also be used in predicting the forecasted production rate at which no economically viable increase in cumulative production will be experienced. This helps in using the forecast to decide when there will be need for a production-enhancement programme or a post-primary recovery mechanism (secondary or enhanced) to be adopted for further oil recovery from the field. This is based on the estimated reserves remaining in the field at this forecasted production rate.

The forecasted rate-cumulative production increment data are graphically shown in Figure 3:

ANOTHER POSSIBLE FORECAST

Forecasting Total Cumulative Production Increment Till Economic Limit

To forecast the total possible cumulative incremental production till economic production rate, i.e till  $q_{ei}$  is reached,

equation (3.7):  $Q_{ei} = \frac{q_{oi} \left[ 1 - \beta^{\frac{b-1}{b}} \right] + \left[ \left( q_{oi} \beta^{\frac{b-1}{b}} \right) - q_{ei} \beta \right] (1-b)}{D_i (1-b)}$

is used.

In this forecast, setting the economic limit production rate at  $q_{ei} = 1.0$  bbl/day, and already estimated  $\beta \approx 1.279294$  above, the forecasted cumulative production increment, is  $Q_{ei} \approx 20,705$  bbls.

b) Model Validation

Here comparison is done between the use of a hyperbolic-exponential combined model in predicting or forecasting the performance of a naturally-depleted well, and that of using either a full hyperbolic decline model

or an exponential model.

In doing this, the essential forecast done so far with the developed models is carried out again using a full hyperbolic decline model as well as a full exponential model.

Now, forecasting the cumulative production increment using the three models and creating a comparison between them shows how valid the developed models in this work in predicting a well's performance, as well as the lapses involved in using either a hyperbolic or exponential decline type for the full forecast.

A comparison using a normal plot of each model's forecasted cumulative production increment results against time is presented in Figure 4.

In addition, results obtained from the other forecasts (like cumulative production) when compared with the ones that hyperbolic and exponential declines would have generated if they were to be separately used to forecast these parameters also show that neither hyperbolic nor exponential decline alone could adequately forecast the performance of a naturally-flowing well, hence the need for a combined model as the one developed, analyzed and used in this work. It is either one decline model over-estimates the reserves and the other under-estimates the reserves or vice versa. But in most cases, the hyperbolic over-estimates while the exponential model under-estimates. This is as a result of the hyperbolic decline having its decline rate reducing with time, thereby experiencing a decreasing rate of production decline with time. Exponential decline in its own case has a constant decline rate with time, thereby making the production decline with time to be constant throughout the forecast.

The forecast results have satisfactorily validated the reason for the development of the models in this paper, which is showing that in most well performance prediction or forecast involving the use of Decline Curve Analysis (DCA), only one model cannot just be employed for the forecast because most naturally producing wells exhibit mostly the combination of two models. Despite that the hyperbolic decline behaviour that they display at the onset of their production history does not really last for long before exponential decline sets in, still if this period of hyperbolic decline is not considered (or probably taken as exponential), or the remaining exponential decline period is taken to be

hyperbolic, it seriously affects the forecast results as shown above with feasible space or shift between the different models' results.

Table 3 in Appendix A shows in summary the effectiveness of the developed model on cumulative production increment forecast. This is done by applying the developed model in making a cumulative production forecast using an already-established set of production data employed by Long and Davis<sup>3</sup> and Khaled<sup>5</sup> in their works. This is just to show the level of deviation of the developed model's result from the results estimated by Long and Davis<sup>3</sup>, as well as Khaled<sup>5</sup>. It significantly shows that the result generated by the developed model (for total cumulative production forecast) in this paper correlates well with the results from the works of Long and Davis<sup>3</sup> and Khaled<sup>5</sup>.

#### IV. CONCLUSION AND RECOMMENDATION

##### a) Conclusions

The use of either hyperbolic or exponential decline model has been discovered to produce unrealistic results in predicting or forecasting the production performance of a naturally-flowing well. This serves as the platform on which this work was based.

New models are developed to forecast the production performance of a well in terms of cumulative production increment. These new models combined the conventional hyperbolic and exponential decline models. The transition time from hyperbolic to exponential decline along the production life of such well was estimated by a deterministic approach.

It indeed showed in the results generated from the analysis of the data used in this study that neither the hyperbolic nor the exponential decline model could predict or forecast the performance of a naturally-flowing well accurately. The results obtained vividly showed that the two models, (hyperbolic and exponential) either over-estimate the forecasted performance (rate, time and cumulative production increment) or under-estimate it.

##### b) Acknowledgments

The authors appreciate and acknowledge the faculty and staff of the Department of Petroleum Engineering, Covenant University for the conducive atmosphere provided for this study.

##### c) Nomenclature

$$q_o - \text{oil production rate at any point in time, } \frac{STB}{\text{day}}$$

$$q_{oi} - \text{initial oil production rate at the onset of production decline, } \frac{STB}{\text{day}}$$

$q_{iexp}$  – oil production rate at the end of the hyperbolic decline model or onset,  $\frac{STB}{day}$

$q_{e1}$  – set oil production rate at the economic limit,  $\frac{STB}{day}$

$q_1$  – oil production rate at the end of the first year of hyperbolic decline behaviour,  $\frac{STB}{day}$

$q_{01}$  – selected oil production rate at time  $t_1$  during the hyperbolic decline behaviour,  $\frac{STB}{day}$

$q_{02}$  – selected oil production rate at time  $t_2$  during the hyperbolic decline model,  $\frac{STB}{day}$

$q_{03}$  – selected oil production rate at time  $t_3$  during the hyperbolic decline model,  $\frac{STB}{day}$

$b$  – hyperbolic decline constant or exponent

$D_i$  – initial decline rate, in  $yr^{-1}$ ,  $month^{-1}$ , or  $day^{-1}$

$t$  – any time along the production history of the well, in years, months or days

$t_{exp}$  or  $t_0$  – time along the production history at which exponential decline model sets in

$t_{e1}$  – forecasted production period of the well from  $q_{oi}$  till economic limit rate,  $q_{e1}$

$t'$  – a defined production time parameter, in years, months or days

$D$  – decline rate at any production time in the hyperbolic model, in  $yr^{-1}$ ,  $month^{-1}$ , or  $day^{-1}$

$C$  – a defined constant

$D_{exp}$  = constant exponential decline rate, in  $yr^{-1}$ ,  $month^{-1}$ , or  $day^{-1}$

$\beta$  = a defined constant

$Q_{hyp}$  – cumulative oil production till the end of the hyperbolic decline behaviour,  $STB$

$Q_{exp}$  – cumulative production from the onset of the exponential model to any time,  $STB$

$Q_{cum}$  – cumulative production till any time in the exponential model,  $STB$

$Q_{residual,e1}$  – residual oil in the reservoir at the economic limit of production,  $STB$



$Q_{e1}$  – cumulative production till economic limit, STB

$Q_{oi}$  – cumulative production from the producing well prior to  $q_{oi}$ , STB

$Q_{23}$  – cumulative production from time,  $t_2$  to  $t_3$  along the hyperbolic decline period, STB

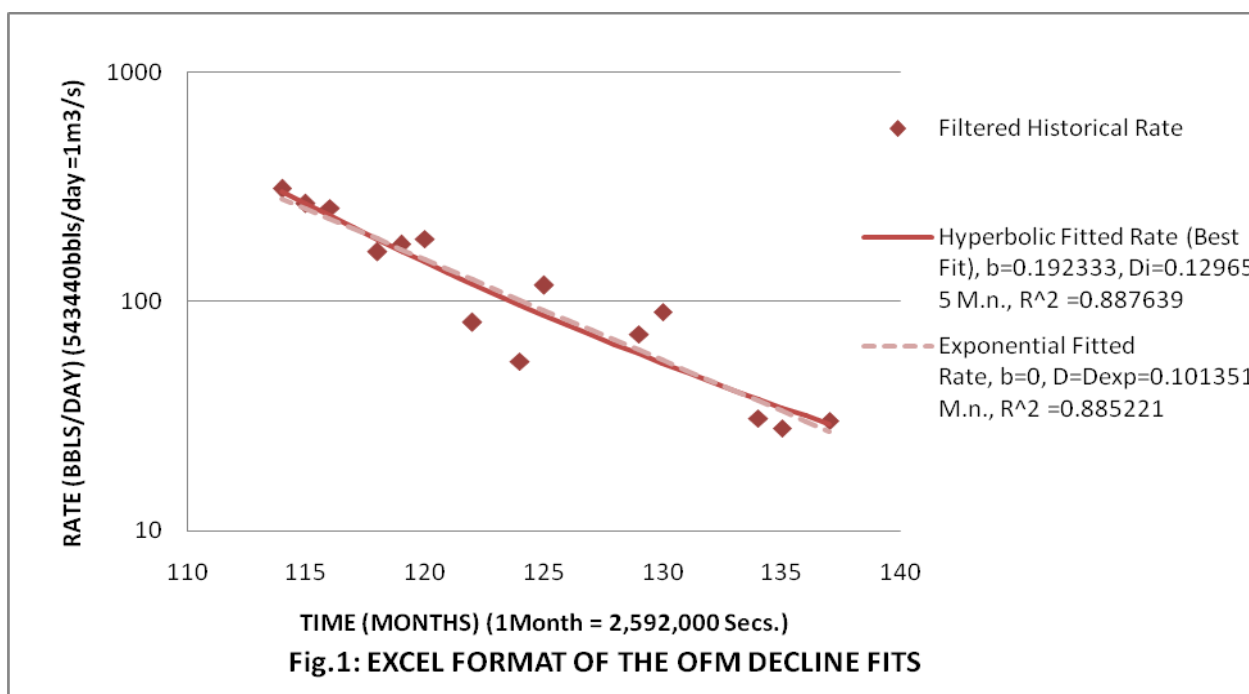
OIIP – Oil Initially In Place, STB

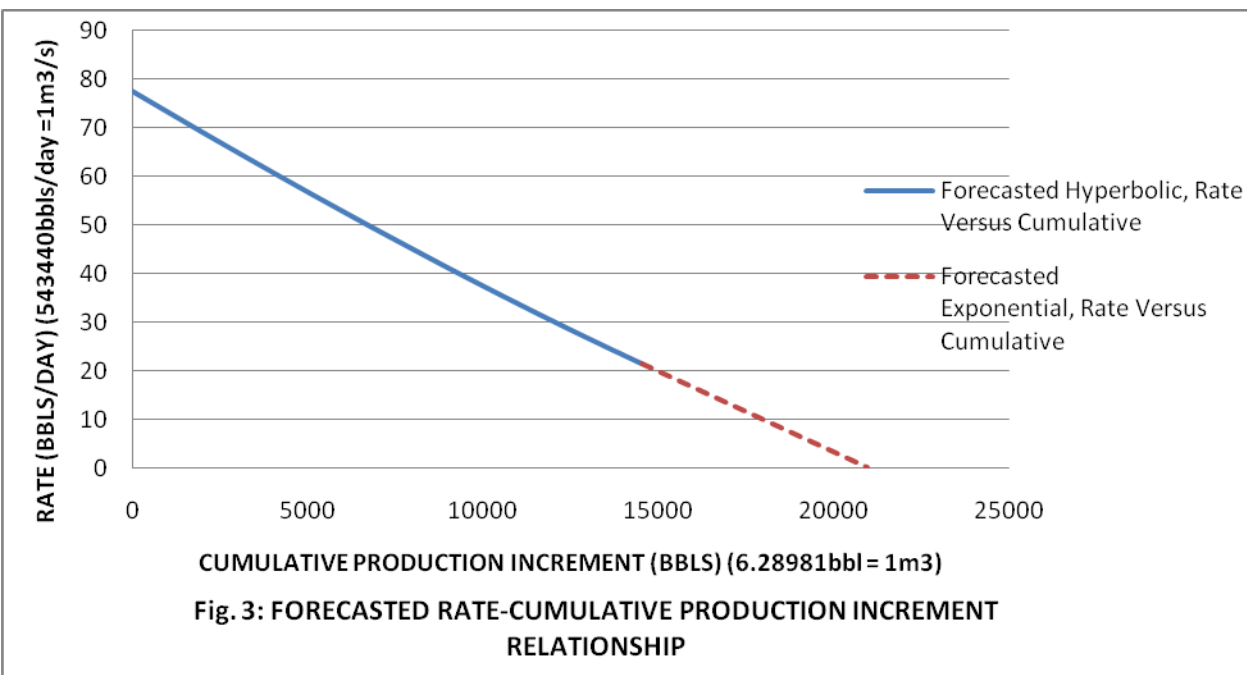
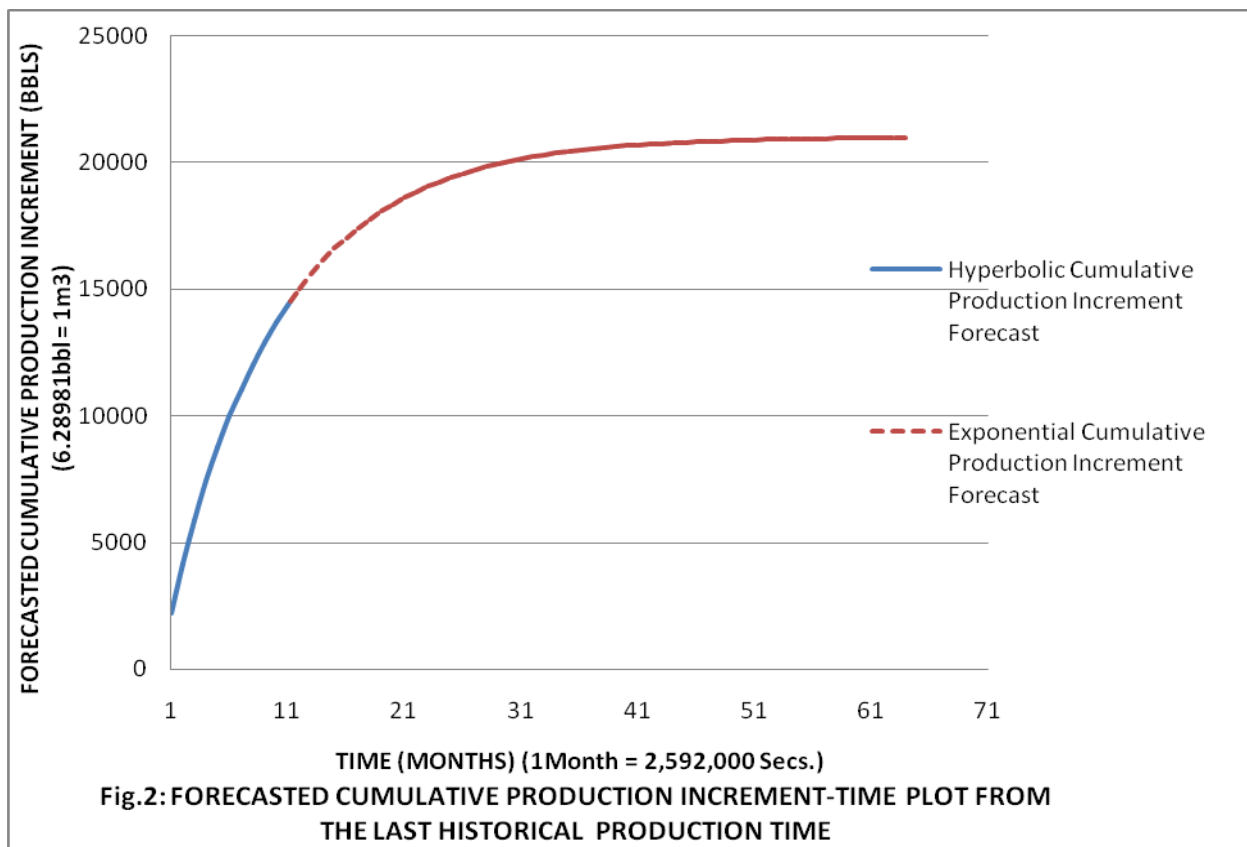
$E_R$  – Ultimate Recovery, %

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APPENDIX





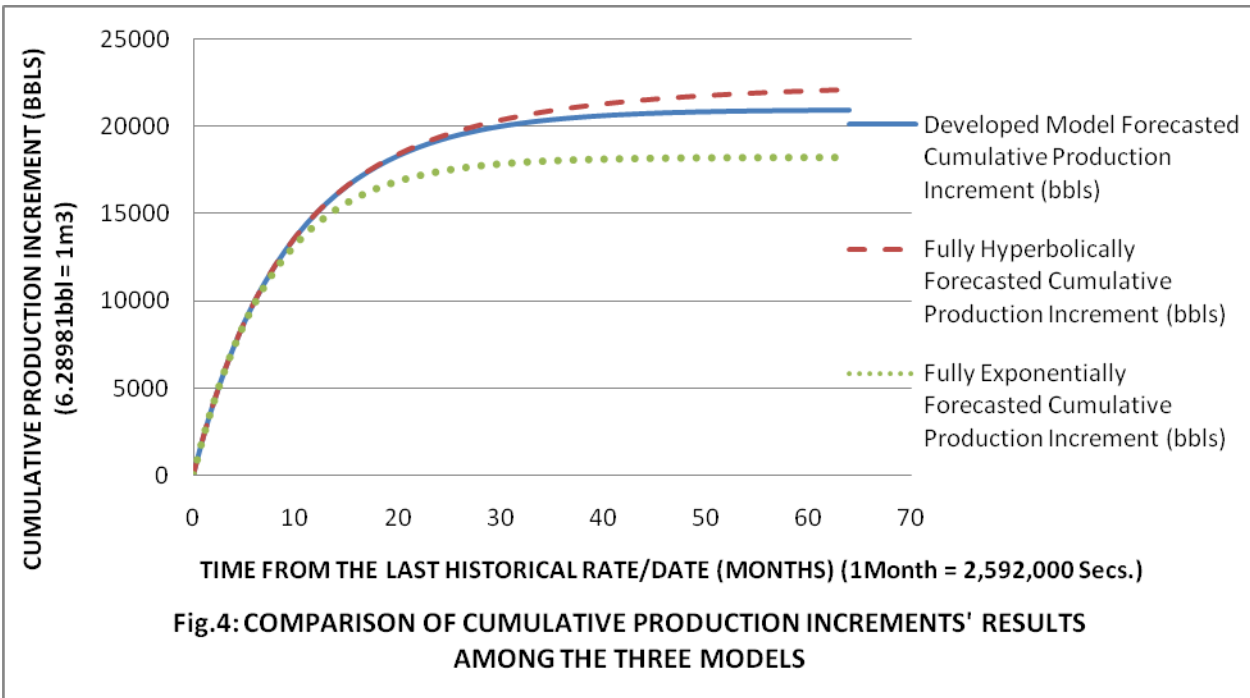


Table 1 : Well's Historical Production Data

DATE	TIME (MONTHS) (1month = 2,592,000secs)	HISTORICAL CUMULATIVE PRODUCTION (BBLS) (6.28981bbbl = 1m <sup>3</sup> )	HISTORICAL PRODUCTION RATE (BBLS/DAY) (1m <sup>3</sup> /s=543440bbbls/day)
7/15/1975	0	5.09	164.19
8/15/1975	1	24.09	612.9
9/15/1975	2	47.6	783.67
9/15/1976	14	314.54	620.33
10/15/1976	15	333.84	622.58
11/15/1976	16	350.83	566.33
7/15/1977	24	449.82	310.97
8/15/1977	25	459.04	297.42
2/14/1978	31	509.88	257.5
3/15/1978	32	517.69	251.94
4/15/1979	45	616.02	232
6/15/1979	47	631.67	249.33
7/15/1980	60	728.55	174.84
8/15/1980	61	729.88	42.9
3/15/1981	68	736.4	210.32
4/15/1981	69	746.34	331.33
6/15/1982	83	777.74	10
7/15/1982	84	778.03	9.35
1/15/1985	90	778.19	5.16
8/15/1985	97	820.13	122.9

1/15/1986	102	821.35	39.35
2/14/1986	103	827.92	234.64
12/15/1987	125	905.36	117.74
12/15/1988	137	916.05	30.32
1/15/1989	138	916.56	16.45
5/15/1990	142	918.19	52.58
6/15/1990	143	920.04	61.67
1/15/1991	150	949.59	126.77
2/14/1994	175	1016.13	210
12/15/1994	185	1073.15	215.81
1/15/1995	186	1080.29	230.32
7/15/1996	192	1106.02	133.55
8/15/1996	193	1110.5	144.52
9/15/1996	194	1115	150
10/15/1996	195	1119.99	160.97
11/15/1996	196	1122.32	77.67

Table 2 : Forecasted Cumulative Production Data from the Last Historical Rate

<b>FORECASTED TIME (MONTHS AFTER LAST HISTORICAL RATE) (1month = 2,592,000secs)</b>	<b>FORECASTED CUMULATIVE PRODUCTION (BBLs) (6.28981bbbls = 1m<sup>3</sup>)</b>
0	0
1	2215.552893
2	4167.752185
3	5893.083292
4	7422.290562
5	8781.38399
6	9992.452056
7	11074.3212
8	12043.09341
9	12912.58633
10	13694.69521
11	14399.69167
11.2	14532.24207
12	15036.25694
13	15611.58971
14	16131.46949
15	16601.24108

Table 3 : Comparison of the Developed Model with Long and Davis<sup>3</sup> and Khaled<sup>5</sup> Data Results for Total Cumulative Production Increment

ESTIMATED PARAMETER $q_{el} = 100 \text{ bbls / month}$ @ $= 6.13377e^{-6} \text{ m / s}$	LONG AND DAVIS <sup>3</sup>	DEVELOPED MODEL USING LONG AND DAVIS <sup>3</sup> DATA	KHALED <sup>5</sup>	DEVELOPED MODEL USING KHALED'S DATA
FORECASTED CUMULATIVE PRODUCTION INCREMENT, $Q_{el}$ (BBLs) ( <b>6.28981bbbls = 1m<sup>3</sup></b> )	142,010 22,577.8m <sup>3</sup>	142,014 22,578.4m <sup>3</sup>	142,014 22,578.4m <sup>3</sup>	142,224 22,611.8m <sup>3</sup>





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# Strength Development Models of Concrete with Silica Fume As Fine Aggregate Replacement Material

By Ahmed M. Ashteyat , Muhannad Ismeik & Khaled Z. Ramadan

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**Abstract** - An extensive experimentation was performed to study the strength development of concrete in which fine aggregate was partially replaced with silica fume. Mathematical models were developed using statistical techniques to predict the compressive strength of such concrete. Water-to-cement ratio was varied from 0.50 to 0.60 and fine aggregate replacement level ranged from 0 to 15%. Compressive strength testing was conducted at age of 7, 28, and 56 days. Results showed that compressive strength of concrete, made with silica fume as fine aggregate replacement material, was higher than the control concrete. The developed models provided a closed form estimate of compressive strength of concrete. The models would serve as useful guidelines for proportioning concrete mixes incorporating silica fume as fine aggregate replacement material. Such concrete could be used successfully in structural applications with economic and environmental advantages.

**Keywords** : Concrete, fine aggregate replacement, predication models, compressive strength, silica fume.

**GJRE- J Classification** : FOR Code: 090599



*Strictly as per the compliance and regulations of:*



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**Keywords** : Concrete, fine aggregate replacement, predication models, compressive strength, silica fume.

## I. INTRODUCTION

Silica Fume (SF) is generally used as a replacement of cement, as an admixture in concrete, and in manufacturing of cement. Economic and environmental considerations played a great role in advancing its usage. SF, composed of submicron particles of silicon dioxide, is produced by electric arc furnaces as a by-product waste of the production of metallic silicon or ferrosilicon alloys. SF incorporation could enhance the concrete basic properties in both the fresh and hardened states. It improves compressive strength, durability, depletion of cement alkalis, resistance to chloride and sulphate penetration, and continued micro structural development through a long-term hydration and pozzolanic reaction (Lam et al., 1998; Zain et al., 1999; Nassif et al., 2003; Demirboga and Gul, 2006; Gonen and Yazicioglu, 2007; Sata et al., 2007; Yazici, 2008).

The literature is rich with standard codes of practice, guidelines, and predication models to estimate the compressive strength of SF concrete. The majority used SF as a mineral admixture or as a cement

replacement material (Slanicka, 1991; Babu and Prakash, 1995; Gutierrez and Canovas, 1996; Duval and Kadri, 1998; Papadakis et al., 2002; Bhanja and Sengupta, 2003; Zelic et al., 2004; Holland, 2005; Bhikshma et al., 2009).

In spite of the wealth of information available in the existing literature on compressive strength predication of SF concrete, no studies have reported on the direct role of SF as fine aggregate (sand) replacement material, and guidelines to predict the compressive strength of such concrete at any replacement level are not yet available. This aspect has been investigated in this research based on work conducted by Ismeik [2010]. Statistical techniques were used to provide mathematical models to estimate the compressive strength of concrete when fine aggregate was replaced partially by SF.

## II. EXPERIMENTAL PROCEDURE

### a) Materials

Ordinary Portland cement (C) type I, conforming to ASTM C150, was used with properties listed in Table 1. Properties of SF, conforming to ASTM C1240, are shown in Table 2. Aggregate conforming to ASTM C33 was used. Fine aggregate (FA) with a 4.75-mm maximum size was used while the coarse aggregate (CA) used had a 16.6 mm nominal size. Physical properties of aggregate are listed in Table 3 with grading shown in Figure 1. Absorption and specific gravity tests were performed for fine and coarse aggregate according to ASTM C127 and ASTM C128 specifications, respectively. Tap water (W) needed for the mix design was adjusted based on the absorption of aggregate.

Table 1 : Properties of ordinary Portland cement

Property	Value
Fineness (90- $\mu$ m sieve)	8.3
Specific surface (m <sup>2</sup> /kg)	281
Normal consistency (%)	28
Vicat setting time (min)	
Initial	145
Final	260
Specific gravity	3.15

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Table 2 : Properties of silica fume

Property	Value
SiO <sub>2</sub> Content (%)	90
Surface Area (m <sup>2</sup> /kg)	20,000
Specific gravity	2.2
Unit weight (kg/m <sup>3</sup> )	245
Fineness (45-µm sieve)	5.1

Table 3 : Physical properties of aggregate

Property	Fine aggregate	Coarse aggregate
Specific gravity	2.46	2.75
Specific gravity (SSD)	2.50	2.78
Apparent relative density	2.56	2.83
Los Angeles abrasion (%)	N/A	20.50
Absorption (%)	1.62	1.05
Fineness modulus	2.73	6.53
Voids (%)	36.7	38.1
Unit weight (kg/m <sup>3</sup> )	1705	1617

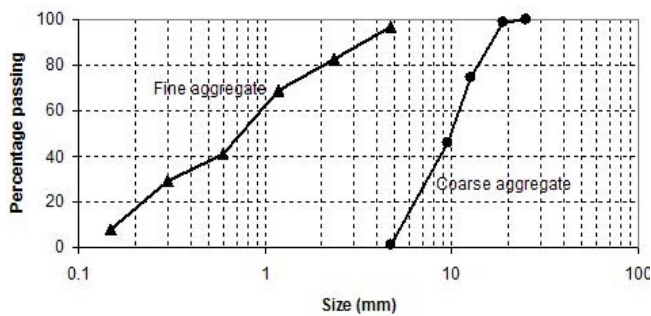


Figure 1 : Grain size distribution of aggregates

Table 4 : Concrete mix proportions and experimental results

Series	Mix	W/C	R	P	W/CM	Weight (kg/m <sup>3</sup> )					Compressive strength (MPa)			
						SF	C	CM	W	FA	CA	$f_{sf}^7$	$f_{sf}^{28}$	$f_{sf}^{56}$
I	A	0.50	0	0.000	0.50	0	400	400	200	340	1360	19.67	31.95	33.81
	B		5	0.041	0.48	17	400	417	200	323	1359	27.04	35.11	39.62
	C		10	0.078	0.46	34	400	433	200	306	1358	25.56	34.92	39.52
	D		15	0.113	0.44	51	399	450	200	288	1357	25.38	34.46	37.49
II	E	0.55	0	0.000	0.55	0	392	392	216	333	1334	17.84	26.39	30.04
	F		5	0.041	0.53	17	391	409	216	317	1333	21.97	32.88	37.21
	G		10	0.078	0.51	33	391	425	215	300	1332	21.50	32.60	38.18
	H		15	0.113	0.49	50	391	441	215	283	1331	21.23	30.46	33.71
III	I	0.60	0	0.000	0.60	0	385	385	231	327	1308	14.37	21.88	27.13
	J		5	0.041	0.58	16	384	401	231	310	1307	17.02	27.31	30.37
	K		10	0.078	0.55	31	384	417	231	294	1306	19.03	28.89	32.46
	L		15	0.113	0.53	49	384	433	230	277	1305	18.57	27.14	31.49

W/C = water-to-cement ratio, R = silica fume replacement level of fine aggregate, P = silica fume-to-cementitious materials ratio (SF/CM), W/CM = water-to-cementitious materials ratio, SF = silica fume, C = cement, CM = cementitious materials (SF+C), W = water, FA = fine aggregate, CA = coarse aggregate.  $f_{sf}^7$ ,  $f_{sf}^{28}$  and  $f_{sf}^{56}$  = compressive strengths of concrete at 7, 28, and 56 day, respectively.

b) Mix proportions

Concrete mix proportions are summarized in Table 4. Three series of tests designated as series I (mix A, B, C, and D), series II (mix E, F, G, and H), and series III (mix I, J, K, and L) were prepared with three water-to-cement (W/C) ratios of 0.50, 0.55, and 0.60, respectively. In each series, the replacement level (R) of fine aggregate with silica fume, was 0, 5, 10, and 15% by weight. The cement content (C) varied from 384 to 400 kg/m<sup>3</sup>. The cementitious materials content (CM = C + SF) varied between 385 and 450 kg/m<sup>3</sup> resulting in four water-to-cementitious materials (W/CM) ratios of 0.50, 0.48, 0.46, and 0.44 for test series I, of 0.55, 0.53, 0.51, and 0.49 for test series II, and of 0.60, 0.58, 0.55, and 0.53 for test series III.

c) Preparation and casting of test specimens

All experiments were conducted in a laboratory under a controlled environment and were properly monitored. Specimens used were standard cylinders of 150 x 300 mm. Concrete mixes were made in a power-driven 90-liter revolving type drum mixer conforming to ASTM C192. The dry constituents were mixed in the rotating mixer with a speed of 40 rpm. The standardized mixing procedure was as follows: cement, fine aggregate and SF were mixed first; then water and coarse aggregate were added. The overall mixing time was about 4 minutes. The time, sequence, and method of adding the aggregate and SF for each batch remained unchanged and simulated good field practice. Concrete casting was performed according to ASTM C192.

Molds were covered to prevent loss of water from evaporation. Specimens were kept for 24 hours in molds at a temperature of 23° C in the casting room; and then cured in a water tank for the specified time at a temperature of 23° ± 1° C.

#### d) Testing of the specimens

Compressive strength tests were performed at age of 7, 28, and 56 days. The specimens were tested in a dry state following the moist curing. Prior to compression testing, the top and bottom ends of the each specimen were capped with sulfur mortar conforming to the requirements of ASTM C617. A compression machine, conforming to ASTM C39, was used for all compression strength testing at a load rate of 0.15 MPa/s. The compressive strength of specimens was recorded as load was gradually applied until failure. The average of 3 specimens was used to report the compressive strength of each mix. High quality control requirements in terms of mixing, curing, and testing of specimens were strictly followed during the experimental phase. Tests not adhering to such requirements were rejected and repeated.

### III. RESULTS AND DISCUSSION

#### a) Compressive strength

Compressive strength for all concrete mixes was determined at 7, 28, and 56 days of curing as shown in Table 4. Figures 2, 3, and 4 show the variation of compressive strength with SF replacement levels for test series I (W/C = 0.50), II (W/C = 0.55), and III (W/C = 0.60), respectively. Test results show that the compressive strength of concrete mixes with 5, 10, and 15% replacement levels (mix B, C, and D), (mix F, G, and H), (mix J, K, and L), were higher than their corresponding control concretes, (mix A, E, and I), respectively.

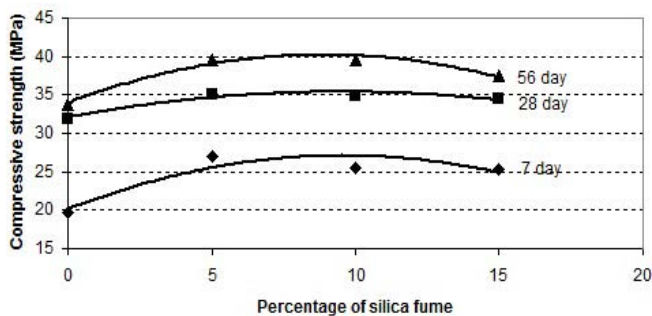


Figure 2 : Concrete compressive strength development of test series I (W/C = 0.50)

The maximum value of 28-day compressive strength was obtained as 35.11 MPa at 5% replacement level with a W/C ratio of 0.50 and W/CM ratio of 0.48 (mix B), and the minimum was obtained for the control specimens at a W/C ratio of 0.60 and W/CM ratio of 0.60 as 21.88 MPa (mix I). The maximum value of 56 - day

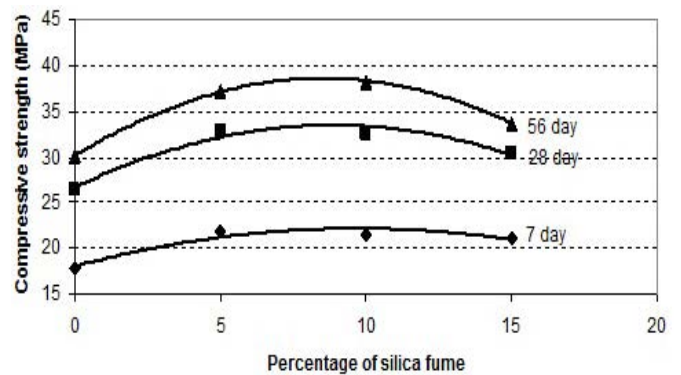


Figure 3 : Concrete compressive strength development of test series II (W/C = 0.55)

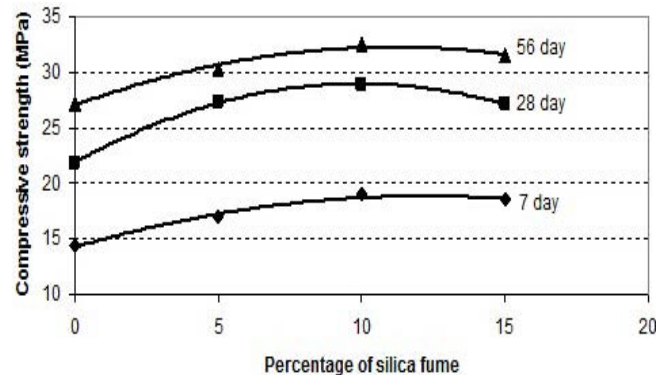


Figure 4 : Concrete compressive strength development of test series III (W/C = 0.60)

compressive strength was obtained as 39.62 MPa at 5% replacement level with a W/C ratio of 0.50 and W/CM ratio of 0.48 (mix B), while the minimum value was 27.13 MPa obtained at the control specimens at a W/C ratio of 0.60 and W/CM ratio of 0.60 (mix I). When the W/CM ratio decreased, the compressive strength of concrete increased for all ages and replacement levels compared to the corresponding control mix. The results indicated that the strength benefits were increased as the age increased.

It was observed that SF incorporation in concrete, as fine aggregate replacement material, increased the strength. A close observation of Figures 2, 3, and 4 illustrated that benefits gradually decreased after about 10% level. At higher replacement levels of SF, no further increase in the compressive strength was dedicated. Generally, for all W/C ratios, 5 to 15% replacements improved the compressive strength with respect to control concrete.

#### b) Models development

It is considered useful to derive compressive strength development models of concrete made with SF as fine aggregate replacement material. Regression analysis was used to quantitatively correlate the compressive strength of SF fume concrete  $f_{sf}$  to a selected range of variables. The method of least

squares that leads to the best fitting line of a postulated form to a set of data was used to form regression models between the dependent variable and independent variables. SPSS software was utilized to develop the strength prediction models based on the available data. Stepwise calibration procedure was then used to form the multiple linear regression models and to determine the critical and non critical influencing variables. F-test and t-test were used to verify the choice of models and critical variables with a significant level of 5%.

Statistical analysis of the results of the three series of tests produced the following 3 models with their corresponding coefficient of determination ( $R^2$ ). The compressive strength of SF concrete  $f_{sf}^7$ ,  $f_{sf}^{28}$  and  $f_{sf}^{56}$  at 7, 28, and 56 day, respectively, was determined as:

$$f_{sf}^7 = -71.650(W/C) - 6.073R + 841.128P + 56.892 \quad (1)$$

$$(R^2 = 0.938)$$

$$f_{sf}^{28} = -78.075(W/C) - 7.897R + 1080.187P + 69.796 \quad (2)$$

$$(R^2 = 0.959)$$

$$f_{sf}^{56} = -72.475(W/C) - 9.629R + 1311.367P + 70.210 \quad (3)$$

$$(R^2 = 0.946)$$

where

W/C : water-to-cement ratio by weight

R : silica fume replacement level of fine aggregate

P : silica fume-to-cementitious materials ratio by weight (SF/CM)

A more general prediction model that incorporates the testing age T, in days, could also be proposed as shown in model 4:

$$f_{sf} = -74.067(W/C) - 7.866R + 1077.561P + 0.268T + 57.505 \quad (4)$$

$$(R^2 = 0.914)$$

In developing the above models the W/C ratio was used instead of W/CM ratio since most of control mixes (without silica fume) are defined with W/C ratio during the initial design stage. The effect of the addition of the silica fume to the mix is accounted for by the term silica fume-to-cementitious materials ratio  $P = SF/CM = SF/(C+SF)$ . As shown in Table 4, when the cementitious materials content CM increases, the P term increases from 0 to 0.113 for each test series accounting for the silica fume contribution to strength enhancement.

Table 5 : Statistical comparison between actual and predicated strength values

	$f_{sf}$	Model 4	Deviation
Unit	MPa	MPa	%
Min	14.370	14.941	-4.0
Max	39.620	41.237	-4.1
Median	29.465	28.088	4.7
Mean	28.449	28.452	0.0
Range	25.250	26.296	-4.1
Std. Deviation	6.935	6.630	4.4
Coef. of Variation	0.243	0.233	4.1
R <sup>2</sup>	1.000	0.914	-4.0

To have a more precise investigation of model 4, a comparison between the actual and predicated compressive strength values was plotted. As seen in Figure 5, there existed an excellent agreement between the actual and predicted compressive strength values. This demonstrated that model 4 could be used reliably to predicate the compressive strength of concrete made with silica fume as a partial replacement of fine aggregate.

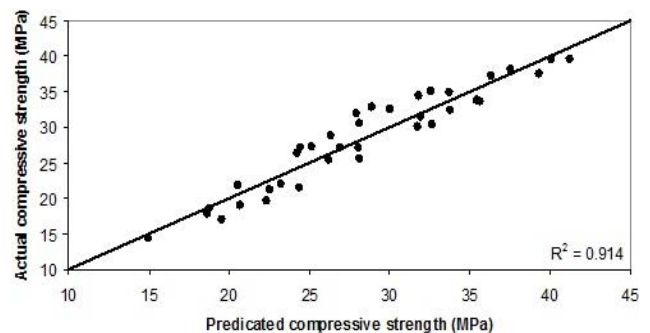


Figure 5 : Comparison between actual and predicated compressive strength values

A comparison in terms of the statistical parameters (Min, Max, Median, Mean, Range, Standard Deviation, and Coefficient of Variation) of the actual and predicated compressive strength results is believed to be useful. As seen in Table 5, the statistical parameters of model 4 are relatively close to the distribution parameters of actual strength values within a 5% deviation. Thus, model 4 produces reliable and accurate predication values and could be used conveniently to estimate the compressive strength of concrete with silica fume used as fine aggregate replacement material.

### c) Applications

The strength of conventional concrete can generally be estimated with good accuracy based on strength charts or by experience if mix proportions, age, and curing conditions are known. However, when SF is used as fine aggregate replacement material the exact nature of strength development becomes complicated as such charts or experience would be no longer applicable.

The proposed four models are capable to provide a quick solution for strength estimation of mixes where fine aggregate is partially replaced with SF. With these models, strength of silica fume concrete at a particular age can be estimated over a range of replacement levels and W/C ratios. The suggested models would be of value in the design process of such concrete mixes where specific target strength needs to be achieved at a certain age or can be used to modify any basic concrete mix so that the concretes with and without silica fume have similar strengths.

#### IV. CONCLUSIONS

Extensive experimentation was performed to study the strength development of concrete made with silica fume as fine aggregate replacement material over a range of W/C ratios varying from 0.50 to 0.60, silica fume replacement levels ranging from 0 to 15%, and testing age of 7, 28, and 56 days.

Compressive strength of concrete, made with silica fume as fine aggregate replacement material, was higher than the control concrete at all ages. Compressive strength continued to increase with age for all silica fume replacement levels. The compressive strength increased as fine aggregate replacement level increased. This increase was maximum at a replacement level of about 10%.

On the basis of regression analysis of the experimental results, statistical models were developed to estimate the 7, 28, and 56 day compressive strength of concrete. The proposed models could serve as a useful tool for optimizing and predicting the strength of silica fume concrete over a range of replacement levels and W/C ratios. The suggested prediction models could be used to modify any basic concrete mix so that the concretes with and without silica fume would have similar strengths.

Silica fume can be used as a partial fine aggregate replacement material in concrete and such concrete can be used conveniently in structural applications with economical and environmental benefits. Short term economical advantages lie in the fact that utilization of waste product and saving of fine aggregate resources would reduce the cost of concrete production. Long term environmental advantages would be a reduction of environmental problems and hazards related to improper disposal of silica fume.

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- Numbering of Second Main Headings (Heading 2) must be in Alphabets, Italic, and Font Size of 10.

**You can use your own standard format also.**

### Author Guidelines:

1. General,
2. Ethical Guidelines,
3. Submission of Manuscripts,
4. Manuscript's Category,
5. Structure and Format of Manuscript,
6. After Acceptance.

### 1. GENERAL

Before submitting your research paper, one is advised to go through the details as mentioned in following heads. It will be beneficial, while peer reviewer justify your paper for publication.

### Scope

The Global Journals Inc. (US) welcome the submission of original paper, review paper, survey article relevant to the all the streams of Philosophy and knowledge. The Global Journals Inc. (US) is parental platform for Global Journal of Computer Science and Technology, Researches in Engineering, Medical Research, Science Frontier Research, Human Social Science, Management, and Business organization. The choice of specific field can be done otherwise as following in Abstracting and Indexing Page on this Website. As the all Global

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- 2) Drafting the paper and revising it critically regarding important academic content.
- 3) Final approval of the version of the paper to be published.

All authors should have been credited according to their appropriate contribution in research activity and preparing paper. Contributors who do not match the criteria as authors may be mentioned under Acknowledgement.

Acknowledgements: Contributors to the research other than authors credited should be mentioned under acknowledgement. The specifications of the source of funding for the research if appropriate can be included. Suppliers of resources may be mentioned along with address.

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## 3. SUBMISSION OF MANUSCRIPTS

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Complete support for both authors and co-author is provided.

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Based on potential and nature, the manuscript can be categorized under the following heads:

Original research paper: Such papers are reports of high-level significant original research work.

Review papers: These are concise, significant but helpful and decisive topics for young researchers.

Research articles: These are handled with small investigation and applications

Research letters: The letters are small and concise comments on previously published matters.

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The recommended size of original research paper is less than seven thousand words, review papers fewer than seven thousands words also. Preparation of research paper or how to write research paper, are major hurdle, while writing manuscript. The research articles and research letters should be fewer than three thousand words, the structure original research paper; sometime review paper should be as follows:

**Papers:** These are reports of significant research (typically less than 7000 words equivalent, including tables, figures, references), and comprise:

- (a) Title should be relevant and commensurate with the theme of the paper.
- (b) A brief Summary, "Abstract" (less than 150 words) containing the major results and conclusions.
- (c) Up to ten keywords, that precisely identifies the paper's subject, purpose, and focus.
- (d) An Introduction, giving necessary background excluding subheadings; objectives must be clearly declared.
- (e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition; sources of information must be given and numerical methods must be specified by reference, unless non-standard.
- (f) Results should be presented concisely, by well-designed tables and/or figures; the same data may not be used in both; suitable statistical data should be given. All data must be obtained with attention to numerical detail in the planning stage. As reproduced design has been recognized to be important to experiments for a considerable time, the Editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned un-refereed;
- (g) Discussion should cover the implications and consequences, not just recapitulating the results; conclusions should be summarizing.
- (h) Brief Acknowledgements.
- (i) References in the proper form.

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Choice of key words is first tool of tips to write research paper. Research paper writing is an art. A few tips for deciding as strategically as possible about keyword search:



- One should start brainstorming lists of possible keywords before even begin searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in research paper?" Then consider synonyms for the important words.
- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

*Acknowledgements: Please make these as concise as possible.*

#### References

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**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.

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**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.

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**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.

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## 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.

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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.

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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

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- Use past tense to describe specific results
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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.

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- Reason of the study - theory, overall issue, purpose
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- Significant conclusions or questions that track from the research(es)

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- 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.
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- 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.

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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



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#### Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
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- 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.

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- 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.

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<i>References</i>	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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