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# An Experimental Investigation on Health Monitoring of Cement Mortar Deterioration using Image Processing

**N Rajeswari[1], E. Arunakanthi[2]**

M. Tech Student, Department of Civil Engineering, JNTUA College of Engineering, Anantapur, AP, India[1]

Professor, Department of Civil Engineering, JNTUA College of Engineering, Anantapur, AP, India[2]

**ABSTRACT:** The condition of a structure can be predicted well by analyzing the response received from the structure under test signals. Structures like bridges, dams, towers, and spacecraft parts are some of the most complex designs for which advancement in the SHM method is essential. In order to assess the Conventional mortar structures on the structure is first chemical attacking area, so there is a need for the development of reference charts and baseline images for condition monitoring through Image processing Software. In the present study conventional mortar is casted and cured in water for 28 days then exposed to the chemicals $CH_3COOH$, NaCl, HCl, and $H_2SO_4$ for the duration of 7, 14, 28, and 56 days. The paper proposes a new color image processing system that is based on the human visual system, where the brightness and chromaticity are processed independently. Consequently, this research facilitates image-based detection of damage, a systematic and objective assessment of the degree of deterioration, and offers insights into how the severity of deterioration correlates with strength and durability performance.

**KEYWORDS:** Conventional Mortar, Image Processing, Monitoring, Deterioration, Baseline.

## I. INTRODUCTION

**General:**

Image processing refers to the techniques and methods used to analyze and manipulate images of concrete surfaces or structures. This field can involve various applications, such as assessing the quality of concrete, detecting cracks or defects, and monitoring the condition of concrete overtime. The paper proposes a new color image processing system which is based on colors that are absolutely depend on normal human visual system, where brightness and chromaticity are processed independently. In this system, the color signal is first divided into brightness and chromaticity, and then both components are processed simultaneously. The system allows for the application of various color image processing methods, and it demonstrates specific processing procedures based on color constancy and brightness constancy, resulting in high-quality color enhancement images.

In the field of image processing, chromaticity is typically defined by two key parameters: hue (h) and colourfulness (s), which is also referred to as saturation, chroma, intensity, or excitation purity. These parameters are derived from the trichromatic nature of human vision, a principle that underlies many colour science models. Chromaticity diagrams serve as tools for visualizing colour relationships and demonstrating the mixing of colours to achieve a specific perceived hue. For instance, chromaticity diagrams can be employed to delineate colour spaces like CIE XYZ or CIE 1931, which are based on human colour perception as represented by the CIE parameters x and y.

## II. OBJECTIVES

The primary goal of image processing is to convert an image into a digital format and execute specific operations to derive particular models or extract valuable information from the image.

Common applications of image processing include:

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Visualization: This means capturing the picture of the cube and analysing the image to get the required results. In this method it also includes some techniques such as zoom out, zoom in, adjusting the colours, edge detection, image recognition and retrieval.

## III. LITERATURE REVIEW

The sustainability of civil infrastructure can be enhanced through regular evaluations that require efficient structural health monitoring (SHM) tools and techniques. Traditional SHM methods tend to be time-intensive and laborious.
Yue et al. (1996) utilized digital image processing techniques on asphalt concrete to analyse the orientation of coarse aggregate particles. It was presumed that the concrete mixture exhibited homogeneity and isotropy. The findings indicated that specimens compacted using a gyratory compactor tended to have a horizontal orientation, whereas those compacted with a Marshall Compactor displayed a random orientation.

A research study by O'Broyne et al. (2012) focused on the detection of damage in offshore infrastructure elements through image processing techniques that utilize textural information. This investigation employed textural analysis and image segmentation in conjunction with Support Vector Machine (SVM) classification to identify and quantify damaged areas. The study especially tested the images showing a fully eroded surface of the cubes by the surrounding environment. The author assessed the Grey-Level Co-occurrence Matrix to perform the texture analysis. The findings indicated that this method successfully identified seven distinct textures: contrast, correlation, homogeneity, skewness, angular second moment, entropy, and kurtosis. These textures proved effective in determining the presence of damage within the structure.

## IV. MATERIALS AND METHODOLOGY

**CEMENT:**
The cement used in this process is the ordinary Portland cement which is of class 53 from JSW company that is confirmed with IS:12269. To keep it safe from moisture, the cement is stored in an atmosphere with controlled humidity in an airtight container. The Specific gravity and Normal consistency of cement is 31% and 2.65

**FINE AGGREGATE:**
The fine aggregate conforms to IS 383- 1970. Fine aggregate going through an IS sieve measuring 4.75 mm and retained on a 75-micron IS sieve is employed. It belongs to Zone II from sieve analysis. The fineness modulus, specific gravity and bulk density of cement are 2.51, 2.65 and 1481kg/$m^3$

**Methodology:**
The Raw Materials are taken in the ratio of 1:3 mix ratio and they are mixed uniformly to fill the cubes of size 70.6*70.6*70.6 mortar cubes and to cast them perfectly. The cubes which are casted are then cured for 28 days and they have under gone the compressive strength test for duration of 7,14 and 28 days.

Mortar cubes which are cured in normal water are then removed and again cured in chemicals such as $CH_3COOH$, NaCl, HCl & $H_2SO_4$.Each chemical is added with 5% of concentration with normal water and added for curing of cubes in chemical. Weight and diagonal dimensions of each cube should be noted before and after curing of cubes in chemicals. The cubes are cured in each chemical for the duration of 7,14,28 and 56days. After removing cubes from chemical curing they are dried and each face of the cube is being photographed along with lux meter, we have captured a total of 6 images, one for each face of the cube.

Lux meter is an instrument that is used to calculate the light density with in a particular area and its measuring unit is lx. It is a measurement of the intensity of light that navigates a surface that is observed by the human eye and is used in photometry.

By using Image j software, we have to analyze each picture to know the values of R, G, B which are primary colors and are responsible for the color chromaticity that shows the intensity of each color and this also provides different color spaces like chromaticity, Lab and HSI. Image J software is a tool that allows you to work with images and extract color

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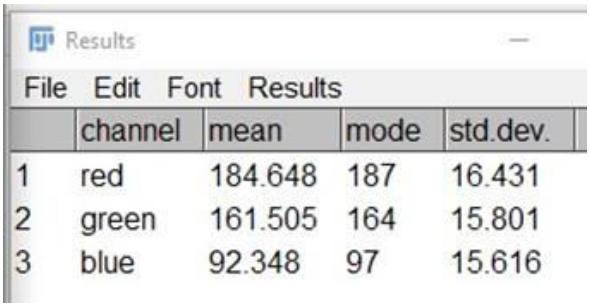
information. You can use this software to analyze images and obtain the color values in terms of primary colors such as red, blue and green. The values which obtained here shows us the intensity of each color.

Color Spaces:
Chromaticity: Chromaticity refers to the quality of a color, independent of its brightness. The colors position on the chromaticity diagram is defined by its two coordinate values x & y.

The RGB values are noted from the color histogram through the image processing values as follows:




| | channel | mean | mode | std.dev. |
|---|---|---|---|---|
| 1 | red | 184.648 | 187 | 16.431 |
| 2 | green | 161.505 | 164 | 15.801 |
| 3 | blue | 92.348 | 97 | 15.616 |

**Durability assessment:**
The ability of mortar cubes to endure chemical attacks was tested by immersing each one of them for 7,14,28 and 56 days in solutions containing 5% of each chemical. Three components are used to value the factor, according to Venkateshwara Rao etal (2012). The acid mass loss factor, acid attacking factor, acid durability factor and acid strength loss factor.

The AMLF considers the ratio of mass change to beginning mass when calculating mass changes.
1: AMLF = M1 - M2 /M1 * 100
Mass at initial stage= M1, Mass at final stage = M2
The ratio of the diagonal dimension's growth or reduction to its initial value prior to immersion loss is how the AAF measure changes in dimension loss

2: AAF = d1 - d2 / d1 * 100
where, d1 is the final dimension following immersion & d2 is the initial dimension prior to immersion.
The ASLF indicates the compressive strength decrease following N days, and the immersion ends after M days.

3: ASLF = Sr N/M
Here M represents number of days at which the exposure is to end, N is the durability factor required for number of days.
Sr is the ratio of the control cubes compressive strength of the cube after N days.
The Acid durability loss factor is the product of the three factors such as AAF, AMLF, ASLF.
ADLF = AAF * AMLF * ASLF

## V. ANALYSIS AND DISCUSSION

Applying "ImageJ" software, aligned pictures have been studied. The Java based, open-source image processing has gained significant popularity in health care imaging procedures, ranging from three-dimensional live cell monitoring to radiological information processing, it is a commonly used tool in civil engineering research for digital image processing. After 7,14, 28 and 56 days, the amount of degradation for each immersion may be seen by examining the appropriate calibrated photos and creating the corresponding 3D surface models.

Every sample concrete cube's six faces' images were calibrated and examined. The concrete sample cube's most deteriorated faces for a certain acid exposure are displayed in Figures after a predetermined amount of immersion time.

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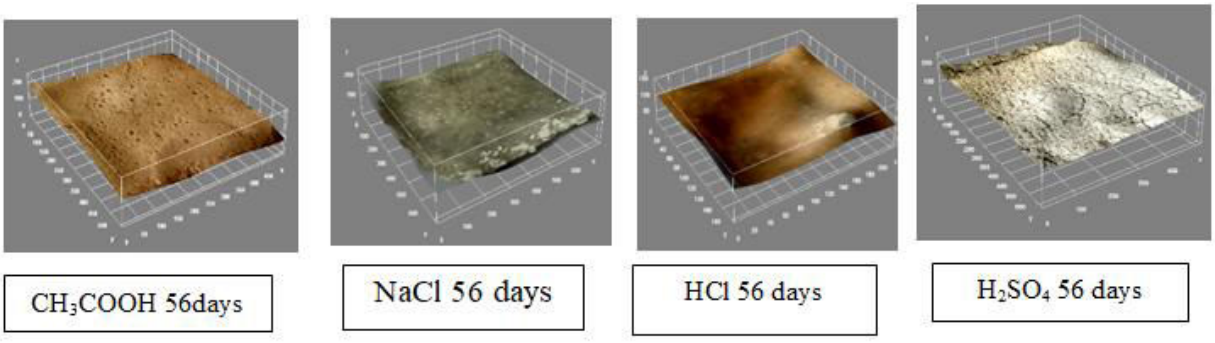
The above-mentioned pictures represent the cubes immersed in each chemical for duration of 56 days and then the images are captured along with lux meter.

The 3D surface plots are also visualized in the color histogram which shows variation between the cubes when they are immersed in different chemicals for different duration which normally shows the color variation in the surface whether in chromaticity these are internally varied with colors by representing the intensities.
The following surface plots represents the surface plot of each chemical for 56 days of duration.




**Evolution of the chromaticity graph:**
To explain the visual qualitative color change in mathematical numbers, the associated RGB values for the regions reflecting the reduction must be transformed to CIE XYZ values. Component Z has no effect on the color information, it only modifies the brightness of the image when converted to the CIE-XYZ color space. In order to mathematically characterize the color visible in the picture, the color information may thus be displayed on the XY axis with and Z axis have 0 values. Wei et al.(2019) states that changes in light intensity will change the planes level but not the data inside. The color information can be quantitatively represented by plotting the X,Y coordinates on a 2D graph that are produced from the translated XYZ values. Following the choice of the concrete face demonstrating a substantial decrease in RGB shade, data should be gathered and utilized to execute polynomial operations that will transform the RGB intensities of each region to match their corresponding values. Plotting the chromaticity diagram and using CIE-XYZ values are both feasible

CIE-XYZ values, and plotting the chromaticity diagram is possible. The below represents the how the chromaticity diagram shows the colour variations according to CIE-XYZ values.

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The following are the stages involved in creating a chromaticity diagram:
(a) Using the calibrated picture of the deteriorating concrete surface, determine the RGB color information. To achieve this, a selection of pixels' RGB values are averaged that can most accurately depict the image's color profile.
(b) Polynomial is used to convert to XYZ color space modifications described by:
X = 0.41245R + 0.35758G + 0.18042B
Y = 0.21267R + 0.71516G + 0.07217B
Z = 0.01933R+0.11919G+0.95023B
where the matching color is represented by R, G, and B values in the RGB color space.

(c) The aforementioned settings will eliminate the impact of light intensity are projected into the X-Y plane after being normalized (Z = 0).
The following may be used to calculate the x, y coordinates.
x = X/(X+Y+Z)
y = Y/(X+Y+Z)

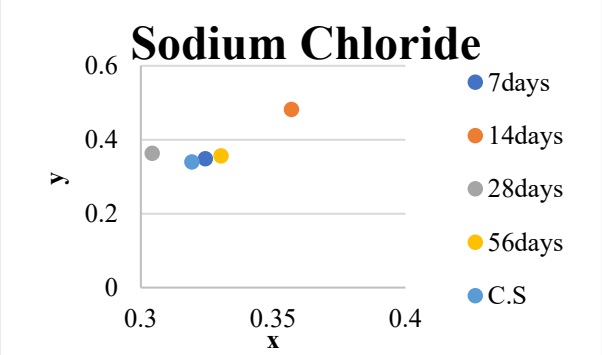


Figure 1: Diagram of chromaticity along with control sample which is immersed in 5% of NaCl for the duration of 7, 14, 28, and 56 days.

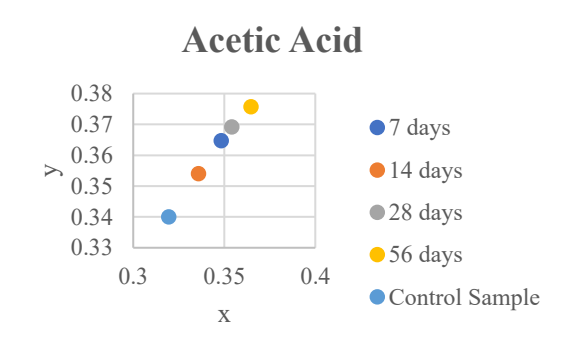


Figure 2: Diagram of chromaticity along with control sample which is immersed in 5% of NaCl for the duration of 7, 14, 28, and 56 days.

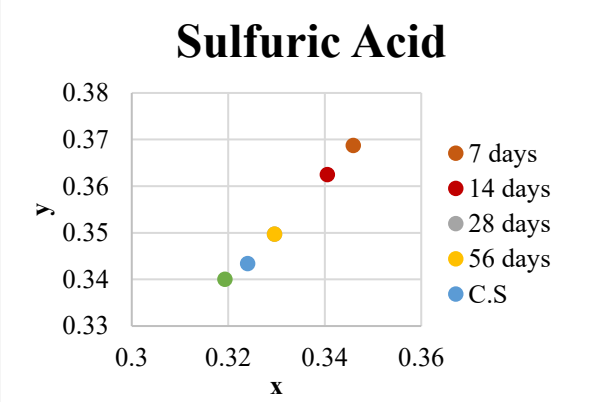


Figure 3: Diagram of chromaticity along with control sample which is immersed in 5% of $H_2SO_4$ for the duration of 7, 14, 28, and 56 days.

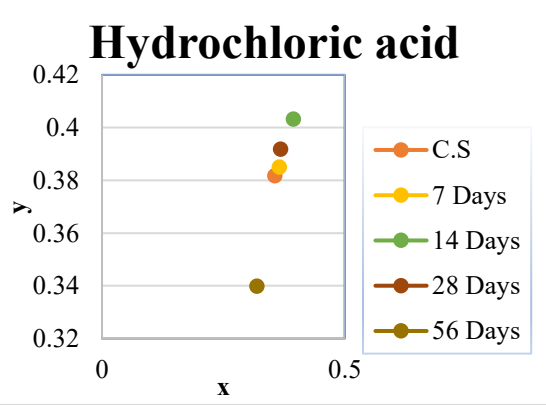


Figure 4: Diagram of chromaticity along with control sample which is immersed in 5% of HCl for the duration of 7, 14, 28, and 56 days.

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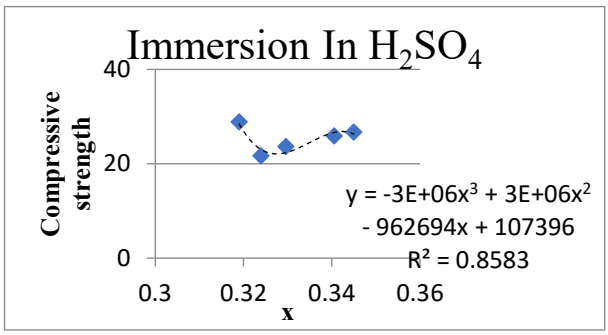
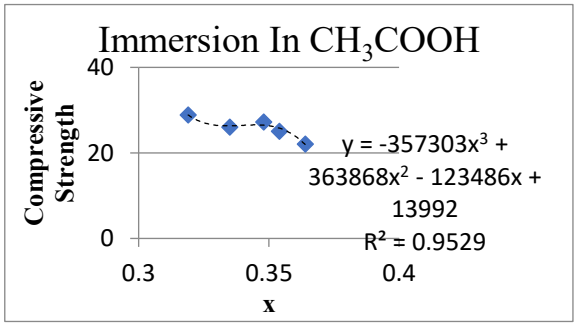
In the above represented figures, the fig 1 shows the chromaticity diagram of sample that is subjected to sodium chloride this diagram has more variations than the other chromaticity diagrams as it is base solution that is used for cubes curing. Then for Fig 2&4 are the acids here the chromaticity diagrams are similar as the color intensity and the cube appearance after curing in chemicals some what looks similar for our eye vision also. . Then for fig 3 it is $H_2So_4$ chromaticity diagram after the curing of chemicals for 56 days duration the upper layer of the cubes was completely damages and here the mortar is completely deteriorated its dimensions but this has less color intensity than the other acids.

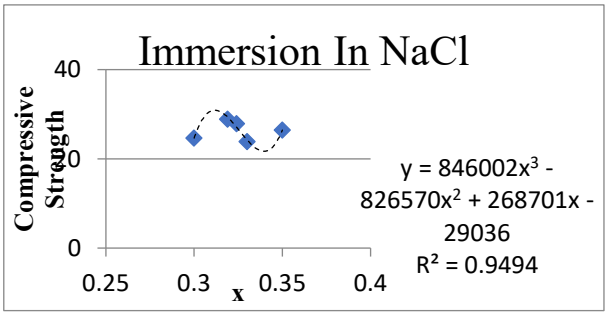
## VI. RESULTS AND DISCUSSIONS

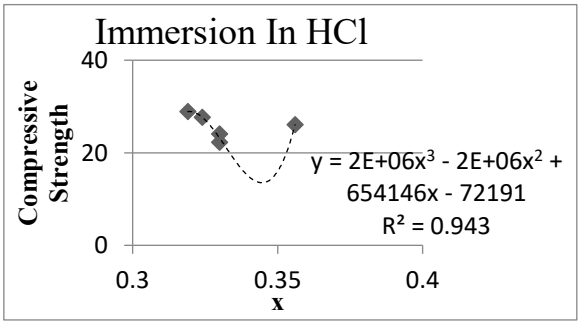
An investigation was conducted to determine the link within the samples final compressive strength and their associated acid durability loss factors after different times of immersion in their corresponding solutions using the chromaticity data points.

The following describes the relationship between the chromaticity x values and the residual compressive strength at different immersion times for 7, 14, 28 and 56 days. Using the correlations between the X and Y coordinates of the chromaticity sample data points under specified immersion conditions and durations. performance and deterioration as reflected in changes to the respective colour profiles



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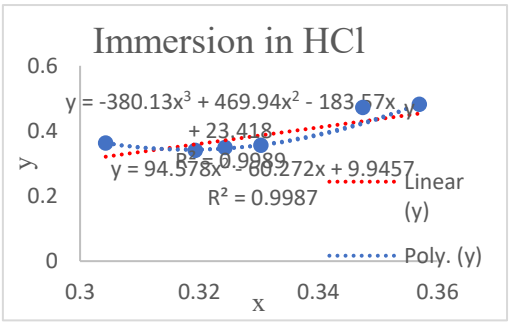


Fig 5: Polynomial curve fitting with $R^2$ Values for hydrochloric acid solution for the duration of 7,14,28 and 56 days

In order to determine the association that was previously described , both the X and Y Coordinates of the specimens that were immersed in particular chemicals for predetermined periods of time had to be analysed (refer to Figure 5).

This study sheds light on the relationship between mechanical performance and deterioration, as seen in variations in the corresponding color profiles. The comparison between the residual strength and the chromaticity 'x' values for samples submerged in sodium chloride and hydrochloric acid is quite similar, the differences arise from the samples varying reactivity rates. To assess durability, acid durability loss factors were calculated for each sample after immersion in the respective solutions for the specified durations.

## VII. CONCLUSION

The results that follow may be made in the context of the chromaticity method and research study on Conventional mortar degradation & by choosing the spot of interest. The sample's surface damage was best represented by color information, and the mean values of RGB color histograms determined using the random pixel-based region of interest approach were utilized for validation.

The surfaces that were damaged by immersion in acetic acid, sulfuric acid, hydrochloric acid and sodium chloride for durations 7, 14, 28 and 56 days were compared using chromaticity diagrams and 3D surface plots. Consequently, it can be said that the qualitative description of the damaged surface color. It is acceptable to translate knowledge into quantitative data in order to perform a numerical analysis of the color shift.

Based on the chromaticity diagrams produced for each form of immersion acid such as Hydrochloric Acid, Acetic Acid are mainly gone through the redshift from the initial stage of duration till the final stage of duration. When coming to the Sulfuric acid and Sodium Chloride these are completely observed in white patches and in sulfuric acid layer which is eroded because of its high concentration is also found in white patches but the primary colour values are obtained through Image j software from its colour histogram option only.

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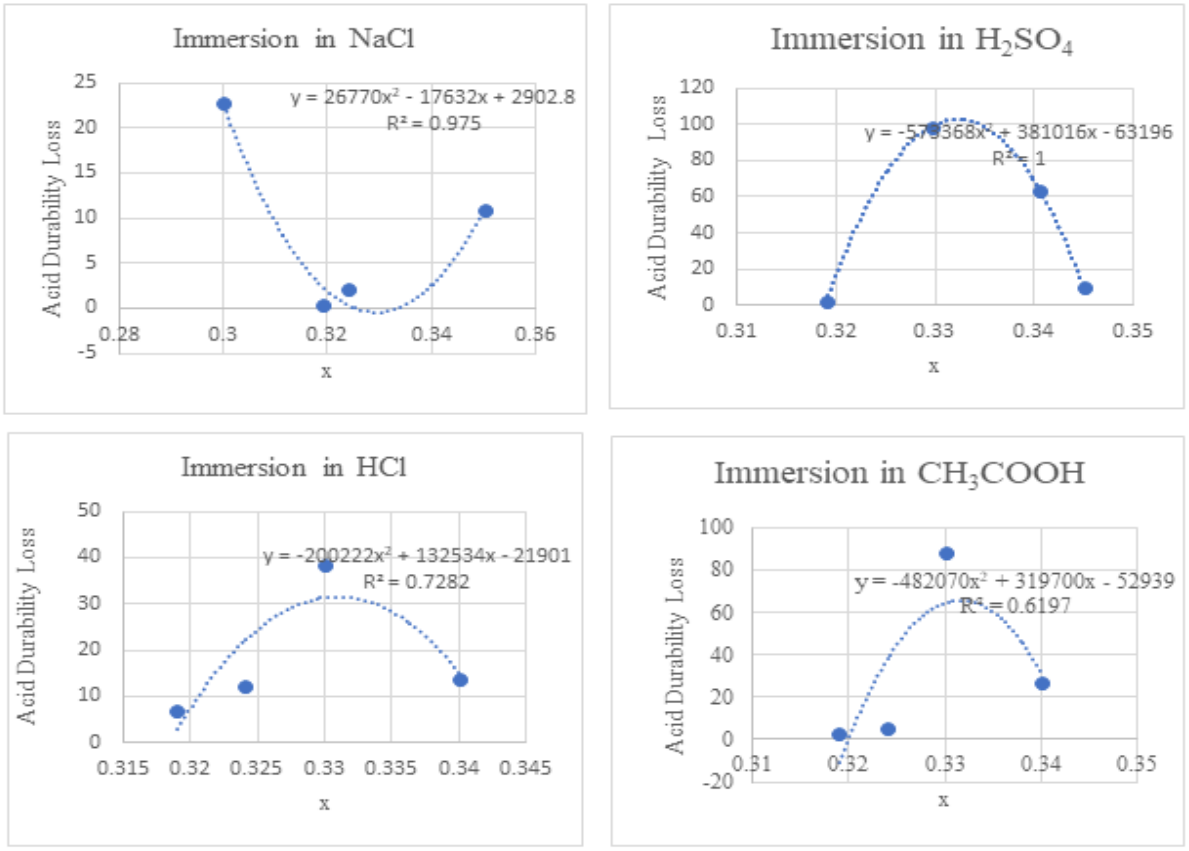


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