Preliminary development of conductivity based test method for industrial radiography film developer solution

Pembangunan kaedah ujian berasaskan kekonduksian untuk larutan pencuci filem radiografi industri yang pertama

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Abstract

The strength of industrial radiography film developer solution is one of the most important aspects in radiography film processing. The developer solution reacts with the exposed film to visualize the latent image through chemical-film reaction. As the developer is repeatedly used, the strength decreases until a point where it cannot yield the required film optical density value. This work attempts to investigate the developer solution strength through its conductivity. Obtained data are cross correlated to the required industrial radiography optical density range. Through the experiment, the conductivity of the developer solution decreased as the number of the film processed increase. Thus, the desired optical density of the film cannot be achieved. The conductivity of developer is measured and recorded at interval of six films developed. The optical density of every film is recorded to analyze the change in optical density as the conductivity decreases. Through the procedure, it is suggested that as the conductivity decreases, the optical density of film decreased. Ultimately, the strength level of the developer solution can be determined.

Abstrak

Kekuatan larutan pencuci filem industri merupakan salah satu aspek terpenting didalam kerja pemprosesan filem. Pencuci tersebut bertindak balas dengan filem yang terdedah untuk mengambarkan imej pendam melalui proses pengurangan pencuci. Kekuatan larutan pencuci menurun setelah pencuci digunakan berulang kali, sehingga tahap dimana ia tidak memberikan nilai piawai ketumpatan optik yang dikehendaki. Kertas kerja ini menerangkan percubaan untuk mencari tahap kerberkesanan larutan pencuci dalam industri filem dengan mengukur kekonduksiannya. Hasil ukuran kekonduksian tersebut dirujuk silang kepada ketumpatan optik filem radiografi yang telah diproses. Konduktiviti larutan pencuci menurun dengan meningkatnya bilangan filem yang diproses. Oleh itu, ketumpatan optik filem yang dikehendaki tidak dapat dicapai. Konduktiviti pencuci diukur dan direkodkan pada selang 6 filem dicuci. Ketumpatan optik setiap filem direkodkan untuk menganalisis perubahan dalam ketumpatan optik apabila konduktiviti menurun. Melalui prosedur ini, dicadangkan bahawa koduktiviti menurun apabila ketumpatan optik filem menurun. Oleh itu, tahap kekuatan larutan pencuci boleh ditentukan.

Keywords: Non Destructive Testing (NDT), industrial film developer solution, conductivity measurement, industrial film radiography

INTRODUCTION

Non-Destructive Testing (NDT) is a process of testing and examining material without destroying the serviceability of the part or system. It is often used to determine the usability, and the physical properties of the materials such as resistance, ductility, strength, and fracture. NDT has several testing methods which are Radiographic Testing (RT), Liquid penetrant Testing (PT), Magnetic Particle Testing (MT), Ultrasonic Testing (UT), and Electromagnetic Testing (ET).

Radiographic testing is one of the methods that is commonly used in NDT where internal image of a test object is recorded to identify the internal defect. This method is carried out by exposing the test object to radiation source. For a less dense material, electrically generated X-ray is used while for a denser material, gamma (γ) radiation is generally used (Fa Mendelu, 2015). These processes depends on several factors such as penetrating power, exposure time, and the intensity of the radiation results in a radiographic image of the sample (Mark & George, 2003).

There are two techniques in radiography testing; conventional radiography and digital radiography. Conventional radiography uses thin transparent plastic coated film with silver bromide. When the film is exposed to the radiation, it undergoes reaction and latent image is formed on the film. According to The American Society for Non Destructive Testing Section V Article 2 in order the film to be useable, the area of interest on the film must be within standard optical density which is 2 until 4 (Ibrahim, Hamzah and Muhammad 1992). If this parameter is below the standard, another exposure must be made until the film achieved standard optical density. Digital radiography eliminates the use of film while the radiography task is performed.

Conventional radiography film processing

There are two important parts in conventional radiographic film processing; film exposure and film processing. Film processing is where the exposed radiographic film is immersed in a series of chemical solutions. The process caused the latent image contained in the sensitized film emulsion to be visible and permanent (Brothers, 2006). There are five steps involve in film processing procedures i.e. development, stop bath, fixing, washing, and drying.

Each solution used in film processing composed of several chemicals responsible for different function in chemical-film interaction .The film is immersed in a developer solution for a specific time and temperature. The developer solution initiates a chemical reaction that reduce the exposed silver halide crystal. The result is precipitation of metallic silver which create dark areas on radiography film. Following the developing process is stop bath which removes any remaining developer solution. Acidic fixer solution will remove the unexposed silver halide crystal to create a white or clear area on the film. The film is then washed in running water to remove any remaining traces of chemical solutions. After washing, the film is dipped in a solution called ‘photo-flo’ before it is left to dry in the dryer (Brothers, 2006).

Development process is the most critical phase in film processing. It is greatly affected by the development time, solution temperature, and chemical concentration (Marchiori, 2014). As the number of film developed increased, the level of exhaustion of developer solution increased which also affects the image quality (Jenkins, 2012). Adjustments are made in development technique to compensate for changes in the activity of developer in order to achieve the same development as would be obtained in fresh developer. Thus, the image quality obtained will be essentially unaffected (Kodak, 2008).

The activity of developer deteriorated throughout the film processing. The bromide ions from the films being developed adds to the restrainers content resulting a high bromide concentration in developer (Jenkins, 2012). Moreover, during the development of the film, developer donates electron which represent oxidation of developer. When oxidation occurs the preservative content will slowly depleted and slow down the activity of developer (Jenkins, 2012).

Until now, replenishment method is used to maintain the activity of developer (Sprawls 2008). This work suggests to determine the developer strength by measuring and observing the trend of conductivity of the developer solution. The conductivity is a measure of the ability of the solution to carry a current. In this work, electrolysis process is used to calculate the conductivity of the developer solution.

The electrolysis describes the process which takes place when an ionic solution (developer) has electricity passed through it. The process completes an electric circuit between two electrode called cathode and anode. The positive ions in the developer solution will move toward the cathode and the negatively charged ion toward the anode. The flow of ions through the developer constitutes the electric current in that part of circuit. The electrons flow along the wire and through the voltmeter from cathode to anode. Thus, multi-meter measures the current that pass through the wire and the conductivity of the developer solution can be calculated. Figure 1 illustrates the electrolysis process.

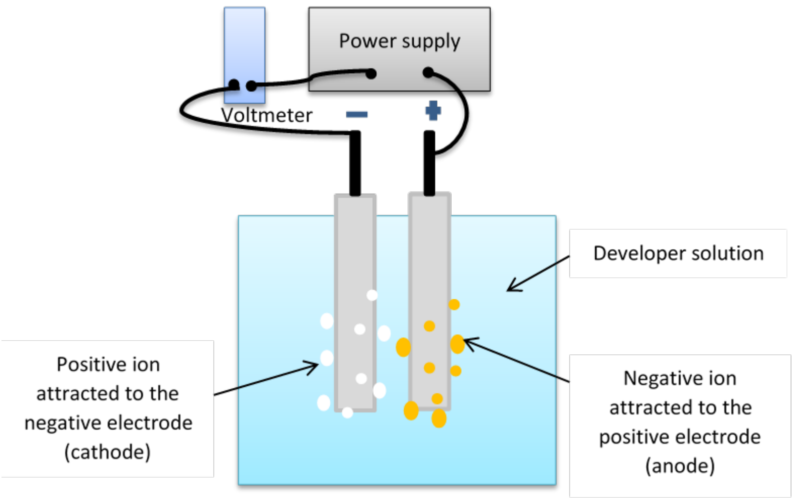


Figure 1: Electrolysis process in a chemical solution.

The specific objectives of this are too experimentally: (a) Design a prototype of a conductivity meter that enable conductivity measurement (b) Measure the conductivity of a developer solution after films are developed (c) Investigate the relationship between the conductivity of a developer and optical density of the film.

RESEARCH APPROACH

In this experiment, industrial X-ray film AGFA Structurix D7 is used. The film is packed in lead screen cassette with thickness of 0.125mm. For the first part of radiography processing, the film is exposed to X-ray radiation with a rectangular test piece with thickness of 9.1mm. Based on the thickness of test piece, the exposure details are determined according to the exposure diagram as listed in Table 1.

Table 1: Exposure details

Exposure Details	
X-ray	Isovolt Titan E
Kilovoltage	160 Kv_p
Tube current	3.0 mA
Exposure time	1.6 minutes

Source to film distance (SFD) is set to 700mm to avoid geometrical unsharpness. The radiographic arrangement is illustrated in the Figure 2.

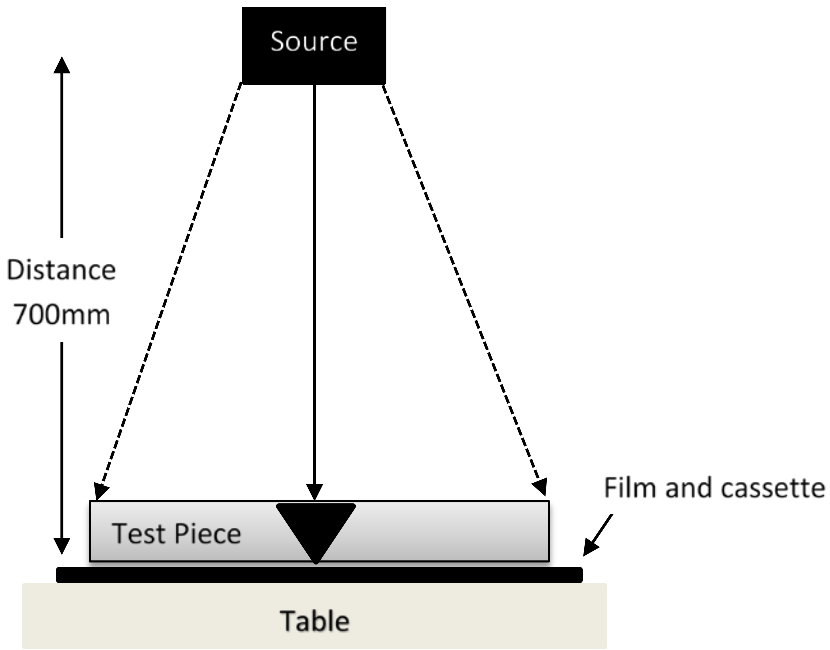


Figure 2: Radiography technique for film exposure.

After each exposure, the film went through chemical processes where it is immersed into several type of chemical solution as previously discussed. In this work, developer used is Structurix G-138 from AGFA. Factors like temperature of developer solution and development time are controlled and kept constant to avoid errors during the conductivity measurement. The illustration of film processing is shown in Figure **3**.

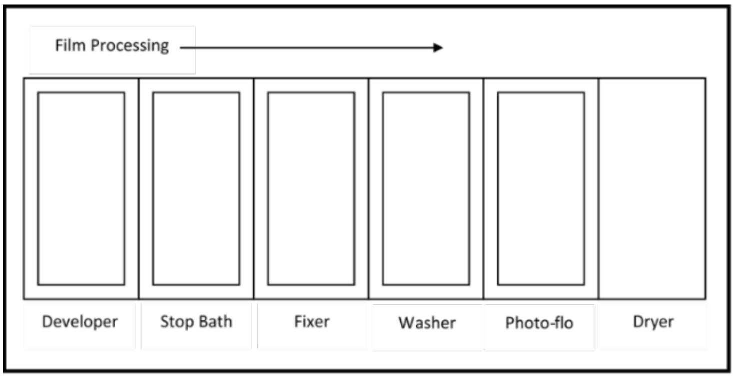


Figure 3: Film processing stages

The conductivity of developer is measured at every interval of six films developed using electrolysis method. A prototype conductivity meter is constructed as shown in Figure 4 for this propose.

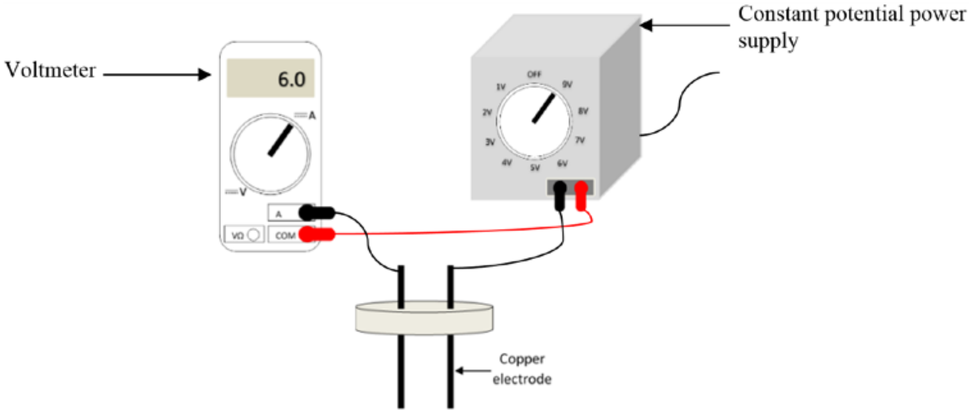


Figure 4: The illustration of conductivity meter that was built to measure the conductivity of developer solution

Using electrolysis method, the current reading is obtained by using a voltmeter. The power supply is set to nine volts for a sufficient flow of electric current during electrolysis process. The reading was done repeatedly for four times at every 10 seconds after the electrode is immersed into the developer solution. The pH value of the developer is measured using pH meter. The current average is calculated and conductivity of developer (σ) is determined using Equation (1).

$$\sigma = \frac{R\, l}{A} \tag{1}$$

where *R* is the resistance, *l* is the length of electrode between two electrodes, *A* is area of electrode.

The optical density at three different spots on the film marked as A, B and C are measured and recorded using a densitometer. The measurement of six films are tabulated and analyzed. Figure 5 illustrates the overall approach used in this experiment.

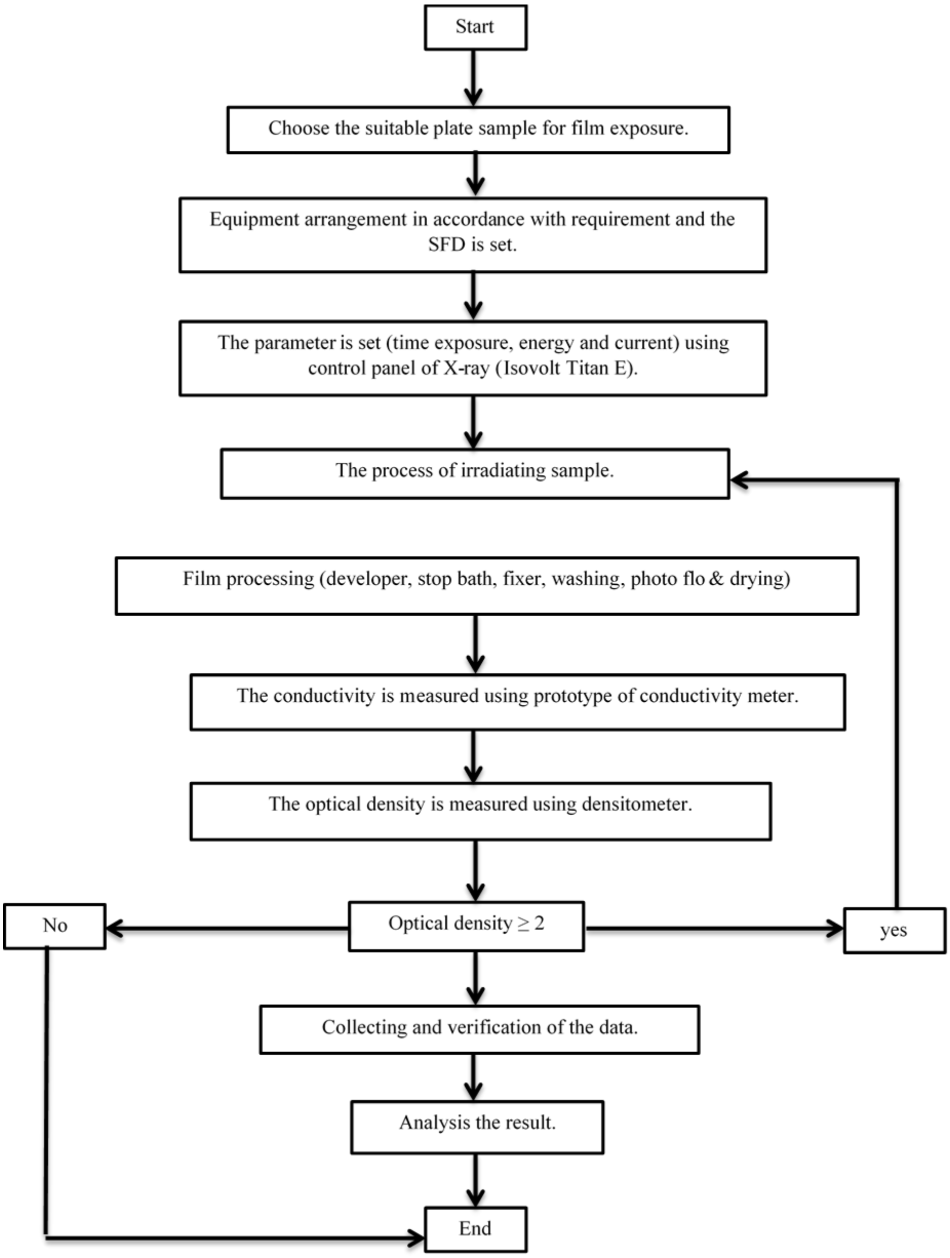


Figure 5: Research approach steps

RESULT AND DISCUSSION

The data obtained is analyzed and a graph showing the relationship between numbers of films developed and conductivity is plotted. Figure 6 shows the graph for number of films developed versus developer solution conductivity. The graph suggests that the conductivity of developer decreases as the number of film developed increases. Even so, there are fluctuations in conductivity of developer throughout the experiment. This may cause by some parameters such as temperature or the precipitation formed during electrolysis process. During the experiment, the temperature was kept constant to 25°c using thermometer. However, it is hard to get the exact value for temperature as the experiment consume a lot of time and the air-conditioner in the dark room cannot be fixed to 25°c at all time. There are also precipitation from copper electrode formed during electrolysis that may contaminate the developer solution and cause instability in the measurement of conductivity.

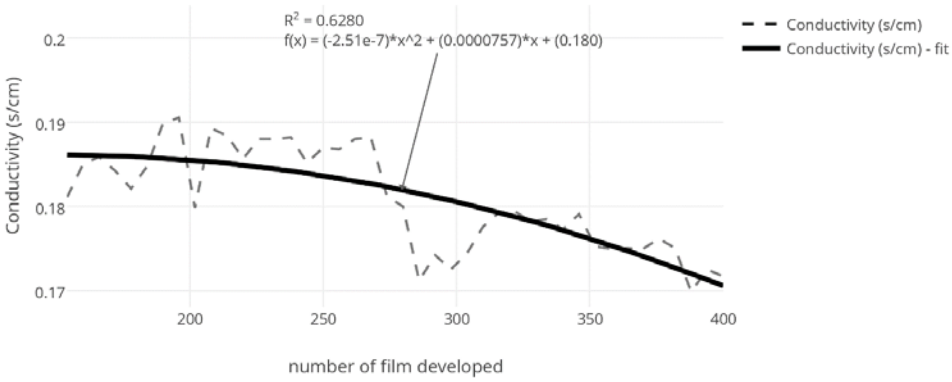


Figure 6: Number of film developed against conductivity

A graph number of film developed versus pH also generated to study the pattern of pH value when the number of film developed increases. Figure 7 shows the graph for number of films developed versus pH value.

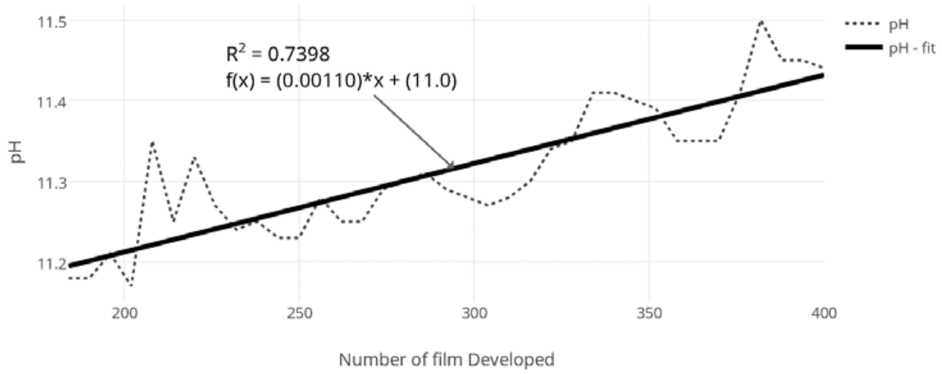


Figure 7: Number of film developed VS pH value

It is found that the pH value increases throughout the experiment. The result obtained contradicted to what is stated by Jenkins, 2012 that the alkalinities of the developer decrease during the use of developer. It is believed that the increased in are resulted from the contamination of copper precipitation. The optical density is measured and recorded as a reference to analyze the change conductivity. The optical density is measured at three different points as previously mentioned. Figure 8 shows the sample of the film with 3 marked points; A, B and C to measure the optical density. The 3 points are selected because it shows significance welding thickness.

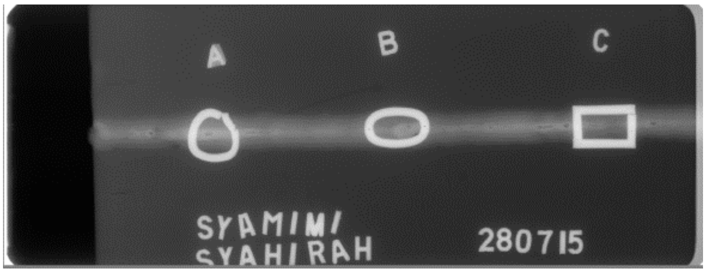


Figure 8: The processed film sample with three marked spot; A, B, and C for optical density measurement

The optical density of the film was found to be decreasing as the number of film developed is increased. The optical density for point A is the lowest followed by point B and the highest value is point C as shown in Figure 9. This result is caused by the irregular thickness of the welded test piece. The thickness of welded test piece at point A, B, and C are 3.02mm, 2.45mm, and 1.21mm, respectively. Besides that, the experiment was stopped at 400 pieces of film developed because optical density obtained is below the required standard.

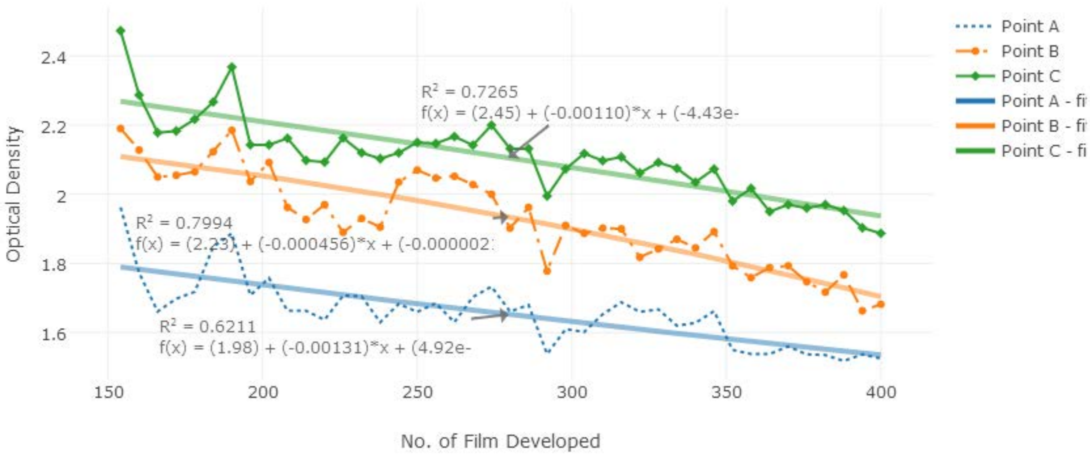
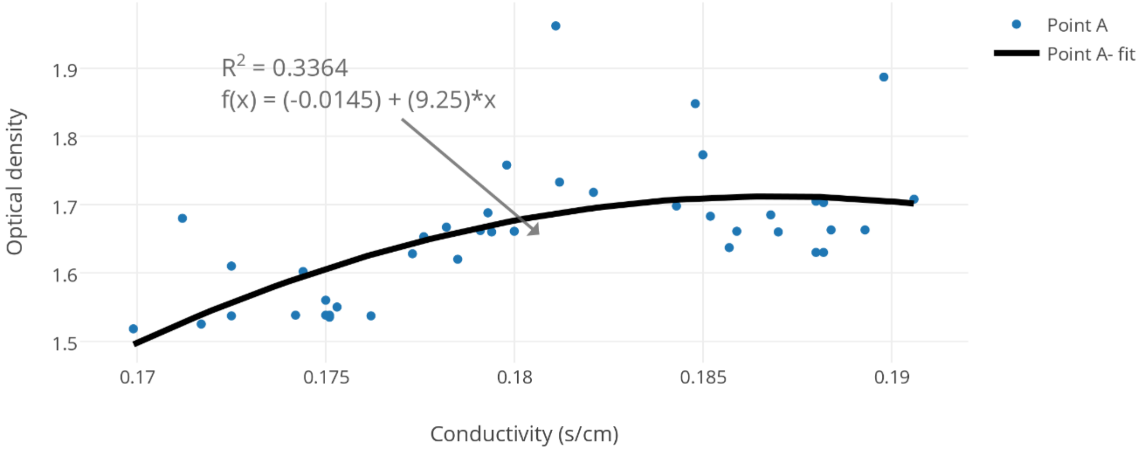
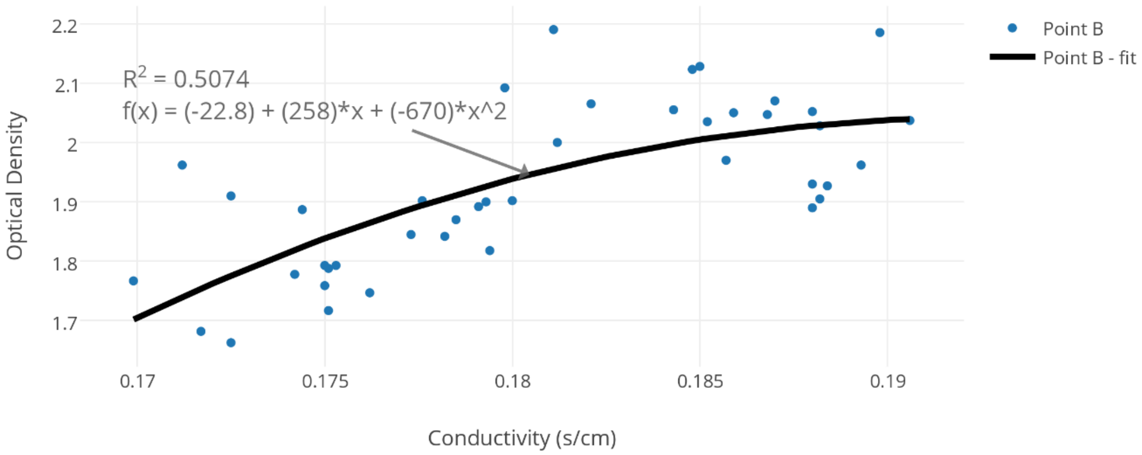


Figure 9: Graph of optical density against number of film developed.

Correlation graphs between optical density for point A, B, and C versus conductivity are generated to show how these variables related. The result for the graph is shown in Figure 10 (a), (b) and (c), respectively. Based on the graphs in Figure 10, the result is as expected where the optical density of all point for processed film increase if the conductivity increase. This result proves that the optical density depends on the conductivity of developer. It is important to keep the conductivity of developer constant throughout the processing in order to obtain image quality as required by the standard.



(a)



(b)

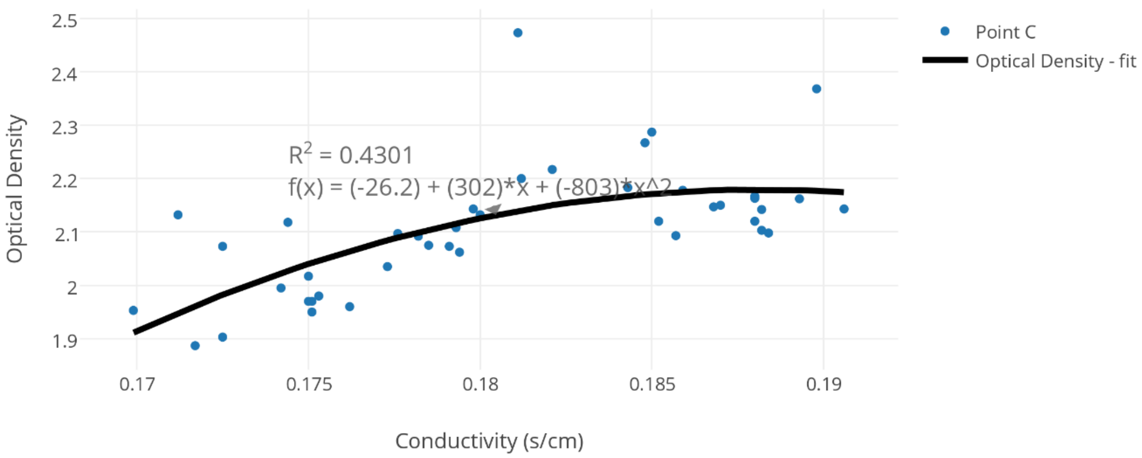


Figure 10: Cross correlation between the radiographic film optical density and conductivity between points (a) A, (b) B, and (c) C

Figure 11 illustrates the relationship between optical density, conductivity, and number of film developed.

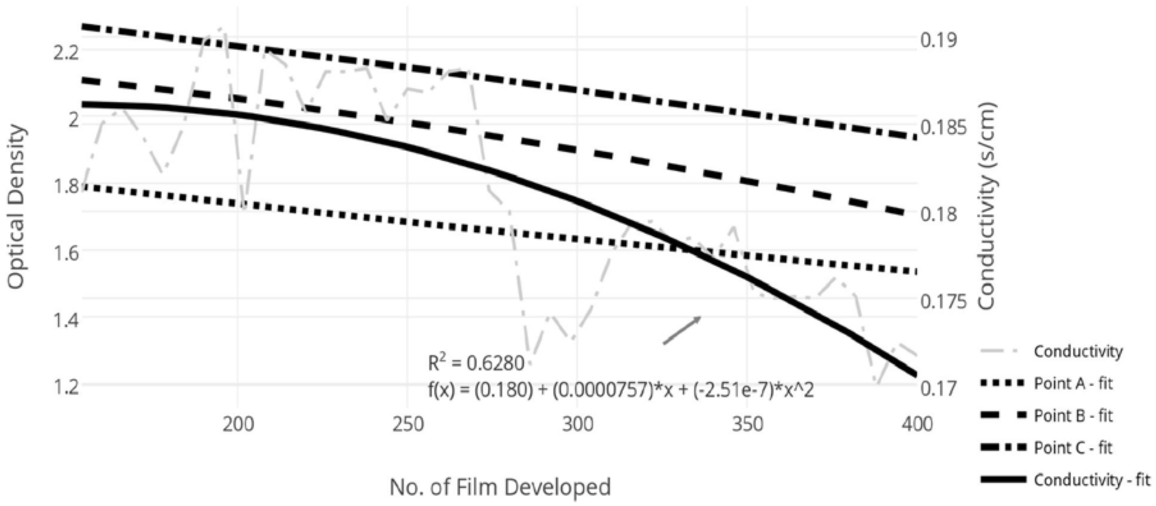


Figure 11: Relationship between optical density and conductivity.

As predicted, as more number of film developed, both optical density and conductivity decreased. The optical density declines due to deteriorating activity of developer as the number of film developed incline. Hence, the conductivity of developer solution become weak. Referring to the conductivity line, at conductivity equal to 0.17 when the number of developer reached 400, the average optical density is 0.5 which is lower than required by standard. This result suggest that when the conductivity of developer is 0.17 s/cm, the developer should be replaced as it cannot yield the required optical density.

CONCLUSION

This study highlights the ability to measure the industrial film developer solution strength through its conductivity. The method to measure conductivity of developer solution is presented by using electrolysis method. This study attempts to provide the value conductivity of developer solution with standard optical density based on ASME Section V Article 2. The consequence from this study shows that the conductivity of developer and optical density decreases as the number of film developed increases. The experiment stops when optical density is less than two at a measurement conductivity of 0.17s/cm. Although the study has successfully measured the conductivity of developed solution, it has some deficiency during experiment due to precipitation of the electrode and temperature which can affect the efficiency of the result. This study is important to develop a prototype to measure the developer conductivity. Future research should be done to obtain the supported result for conductivity of developer accurately. It is also recommended to make a further research focusing on the pH of developer solution due to the aforementioned contradiction.

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