

Application of Different Median Filter Algorithms for Welding Defects Clarification in Radiographic Images

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Abstract

The main aim of the inspections is to ensure that the quality of the welds meets the design requirements and operating conditions, as well as meeting safety and reliability requirements in many industrial sectors. There are many different ways of non-destructive testing NDT are employed for checking welds. The radiographic testing RT is one of the most prevalent and widely used processes in the industry to detect both surface and subsurface defects. In recent years, industrial radiography has been well developed to be used alongside with the combination of techniques of image processing to enhance both the process of inspection and the time of operation. The RT images are often affected by some external surroundings and degraded by noises during the process of acquisition of them. The filtering process is intended to recover the original image from the corrupted one. Median filtering can be considered as an appropriate procedure since it is used by many researchers. In this paper, a comparison among four types of median filter is used to get the best one, to adopting it in welding inspection images. The peak signal to noise ratio (PSNR) and root means square error (RMSE) indexes are used to perform the quality of image filtering techniques. The results shown that the median filter is a good tool for clarification of welding defects and both adaptive median filter (AMF) and decision based median filter (DBMF) gives the best results respectively. The results obtained were consistent with the results of the engineering examination for qualified and certified welding defects inspectors.

Keywords: welding defects, Median filter, radiographic images, salt & pepper.

1. Introduction

The process of joining metals permanently is called welding. Where heat or/and pressure are both used. The welding industry is considered a key role in any country's economy, since it has been widely utilized in several fields including aviation, chemical industries, railways, petroleum, etc. It enters all industrial details, where, there is no structure in any industry without the welding process is used [1].

During welding, the materials are subjected to a process of heating and then cooling, where the material is fused and then solidifies, this process is accompanied by metallurgical changes, and may result in the appearance of defects. The defects of welding are differences between them according to their severity. Some of them are very serious and others are considered less serious. For example, porosity is less severity in the joint of welding if it is compared with cracks, lack of fusion and underfill which are very dangerous, since they occur at the plane above the direction of stresses and are sharp and likely to cause fatigue or failure [2].

The main welding defects which are; porosity, concavity, crack, inclusion, burn-through and lack of penetration. Porosity is small linear or cluster spherical cavities on the weld surface. Concavity or suck back is occurred as grooves in joints due to exclusive root bead grinding and excessive purge pressure. Cracks are discontinuities caused by the metal rupture when it is in its plastic state (hot cracking) or by fracture during the cooling process (cold crack). Inclusions defects occurred when some material such as a slag presence in the weld metal.

There are three types of inclusions; slag Inclusions, tungsten Inclusions, and oxide Inclusions. Burn-through is the defect of the molten pool collapsing when the welding arc blasts through the joint. Many parameters are leading to increase the burn-through such as high voltage, high current, low welding speed, and small root face. When the root of the weld groove does not fill perfectly, a welding defect called incomplete penetration [3].

Based on traditional standards the welds are inspected to preserve the required level of structural integrity. A non-destructive test NDT is a very important factor to identify defects of weld in its early stages to improve its forecast and to enhance the welding process. Among the non-destructive tests, Radiography Testing RT is one of the most prevalent and widely used processes in the industry since it is used to estimate the welded joints' quality by assessing the radiographs of them. Using a computer-aided system for weld inspection can be of great benefit for an inspector, and with his knowledge and experience, it can give out a better result in the detection of any flaws and be able to make a consistent decision about the weldment accepting [4].

The quality of the image for NDT is influenced by noise, as in all imaging systems. Noise is an arbitrary signal usually attends during acquisition of image, coding, transmission, and processing steps. This noise attendance disorganizes the main data in the image. The most common sources of noise in digital images are defective devices and problems during the data acquisition process [5].

The filtering process is a significant technique usually used in the preprocessing of images and the result of it will

influence the quality of images and related processes. The filtering process is intended to restore the original image composition from the image distorted by noise. The methods used for noise filtering are either linear or nonlinear. In the linear methods, the algorithms are implemented to every pixel of an image in a linear manner lacking to set the pixels as valid or invalid and this can result to manipulate the valid pixel in the filtering process leading to blurring the image and hence these techniques are inefficient to attenuation/elimination of noises [6]. On the other hand, the non-linear filtering is characterized by two steps which firstly the pixels are specified as valid and invalid pixels and secondly a specified algorithm is applied to the invalid pixel only, whereas the valid pixels are preserved [7].

The median filter is a non-linear spatial filter that replaces the values of the pixels in question with the median value. It works to allow spatial frequencies to pass through and block other frequencies, to eliminate noise and to save the edges from blurring. This technique is very suitable for suppressing impulse noise, or what is termed as salt and pepper noise. So, it is used by many researchers [4], [8]. Four types of median filters are used; Standard Median Filter, Center-Weighted Median Filter, Adaptive Median Filter and Decision Based Median Filtering.

1. Standard Median Filter (SMF)

It is a plain non-linear spatial filter and is commonly used to reduce/suppress noise in radiographic images. In this filter, pixels value of the close neighborhood to the pixel of interest are ordered in an ascending or descending arrangement. After that, changing the pixel of the center position in a moving window of finite length with the median value. Usually, a slithering window of size $2k + 1$, is utilized to treat the center pixel in this square moving window [9].

2. Center-Weighted Median Filter (CWMF)

It is identical to the primary median filter technique except that the pixel in question at the center of the nucleus to be filtered is given more weight. The two parameters that specified the CWM filters are the window size $\{(2L+1) \times (2L+1)\}$ which is denoted as M , and the center weight $w(0,0)$. The largest weight is given to the center sample, i.e. $w(0,0) = 2K + 1$ where K is a non-negative integer, and all other weights are set equal to one provided that they are not zero, i.e. $w(i,j) = 1$ for $i \neq 0$, and $j \neq 0$. [10]

3. Adaptive Median Filter (AMF)

This filter applies a dynamic slithering kernel whose dimension depends on the local density of noise. In core, they can be considered as a self-modifying digital filter that adjusts its parameters for the contrast minimizing to between the reference image and the resulted one of the adaptive filters [11].

4. Decision Based Median Filtering (DBMF)

This algorithm is firstly detecting whether the pixel is noisy or not to manipulate the damaged image pixels. That is, whether the processed pixel value takes place between the

maximum and the minimum gray level values. The value of the pixel replaces with the median pixel value of the window or the neighborhood else the pixel is adjusted as a noise-free pixel and left unaltered when it is located in the range between the maximum and the minimum values [10]. Recently, there are many algorithms applied for salt and pepper noise filtering such as: weighted median filtering [11], the central weighted median filtering [12-14], and adaptive median filter [15-17].

Finally, this study will be focused on the ability of using several algorithms of median filters for welding defects images denoising and checked the best one using RMSE and PSNR.

2 Experimental Work

In this paper, the database is randomly selected to include 28 actual images of welding operations. These images contained different welding defects which are explained in Table 1. The required radiographic images were made in Ibn Majid state company in Basrah-Iraq. The resulted radiographic images transferred to computer using NIKON D7000 digital camera to obtain the best contrast properties. The total images are 28 divided into several types of welding defects.

Table 1 Database of radiographic images.

Category	Defect	Number
Porosity	distribution	2
	clustering	2
Crack	longitude	2
	transverse	2
Fusion	lack	4
Concavity	internal	2
	external	2
Inclusion	slug	4
Penetration	incomplete	4
Burn Through	Burn Through	4

The images are cropped automatically and individually for each image, as this cropping method helps to standardize the image quality and extract the target Region of Interest (ROI). This ROI, included the welding area and its surrounding area with only a limited area (label 3), in this case, the cognitive symbols and numbers that often accompany the welding films (label 1), as well as the extra background (label 2), are eliminated which in turn reduces the complexity computations and time required. Fig. (1) shows the original image where the size (728x1972) pixels and the cropped one where the size is reduced to (298x1972) pixels.

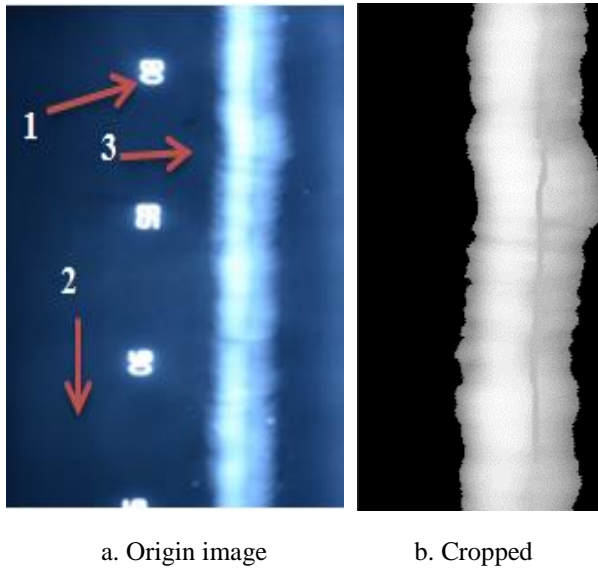


Fig.1 Original image and cropped images

3 Experimental Results

Radiographic welding images containing various defects are considered, including Porosity, lack of penetration, slag inclusion, concavity, burn through, and cracks. During the acquisition process, different types of noises affect the images, especially salt and pepper type. The evaluation of the performance of the simulated results is validated in both objective and subjective ways.

Objectively, two parameters have been counted which are Root Means Squared Error RMSE and the criterion of Peak Signal to Noise Ratio PSNR to compare representative algorithms with each other to obtain answer of image denoising in welding.

RMSE: A mathematical representation of the difference between the original image and the filtered image, in other words, is a measure of the loss of image quality. A low RMSE value means better filtering process.

$$RMSE = \sqrt{\frac{1}{MN} \sum_{i,j=0}^{l-1} (F(i,j) - G(i,j))^2} \quad \dots 1$$

PSNR is evaluated in decibels and represents the inverted MSE. This parameter is usually adopted to measure the quality between the processed image and the original one. The high value of PSNR is an indicator of a good filtering process.

$$PSNR = 10 \log_{10} \frac{(2^n - 1)^2}{MSE} = 10 \log_{10} \frac{255}{RMSE} \quad \dots 2$$

The PSNR and RMSE criteria for the mentioned filters are calculated according to equations 1 and 2 respectively, as these two parameters can measure image quality. It turns out that the combination of high PSNR and low RSME indicates the best noise removal filter. Tables (2-7) show the values of PSNR and RMSE for the filtered images having different defects. The best values indicated in yellow background cells in the table (Minimum for RMSE and maximum for PSNR).

Table 2 PSNR &RMSE values for image having longitudinal crack

Crack	[3x3]	[5x5]	DBM	AMF	CWM
RMSE	2.20	3.64	0.50	1.64	5.89
PSNR	49.69	47.40	52.00	50.90	45.41

Table 3 PSNR &RMSE values for image having inclusion

Inclusion	[3x3]	[5x5]	DBM	AMF	CWM
RMSE	2.99	3.78	2.35	1.39	4.71
PSNR	45.80	44.57	46.29	47.57	42.06

Table 4 PSNR &RMSE values for image having porosity defect

Porosity	[3x3]	[5x5]	DBM	AMF	CWM
RMSE	1.57	2.61	2.90	0.78	4.31
PSNR	47.07	44.86	44.24	50.00	42.37

Table 5 PSNR &RMSE values for image having burn through

Burn through	[3x3]	[5x5]	DBM	AMF	CWM
RMSE	1.75	2.41	1.79	1.12	15.79
PSNR	46.52	45.14	49.42	48.45	37.05

Table 6 PSNR &RMSE values for image having concavity

Concavity	[3x3]	[5x5]	DBM	AMF	CWM
RMSE	1.27	2.18	0.10	0.84	15.74
PSNR	65.84	63.49	67.96	67.62	38.31

Table 7 PSNR &RMSE values for image having incomplete penetration

Penetration	[3x3]	[5x5]	DBM	AMF	CWM
RMSE	1.77	2.20	1.20	1.18	2.24
PSNR	46.50	45.58	47.92	48.29	45.17

The resulting filtered images are also sent to four certified welding defects inspectors to assign any filters that give more accurate results to identify the best algorithms subjectively, according to the indexes, including clarity, contrast, contour of the objects in the image and convenience.

There are agreements between the certified welding inspectors that the images of AMF and also DBMF satisfied the best results as compared with other filter types. Fig. (2-7) shown selected welding radiographic images for crack, inclusions, porosity, burn-through, concavity and lack of penetration respectively.

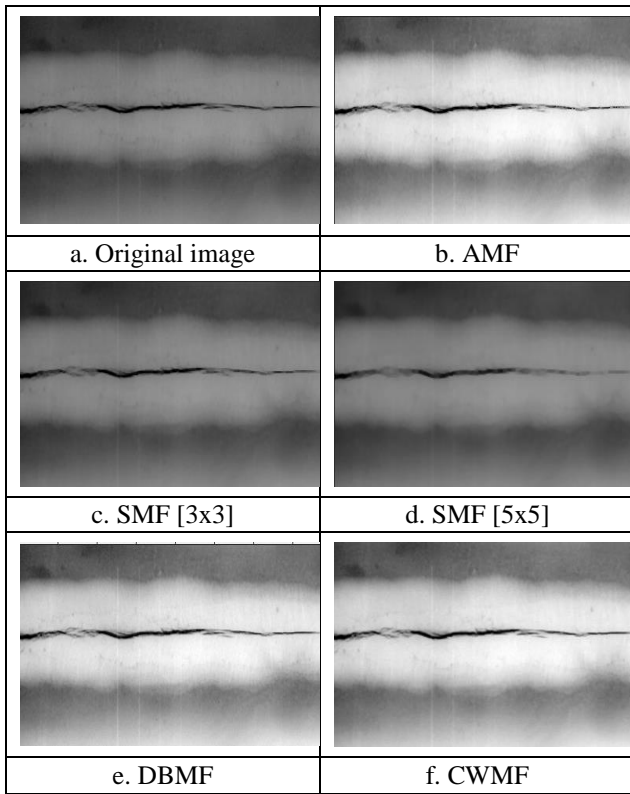


Fig. 2 Crack defect processing using different median filters.

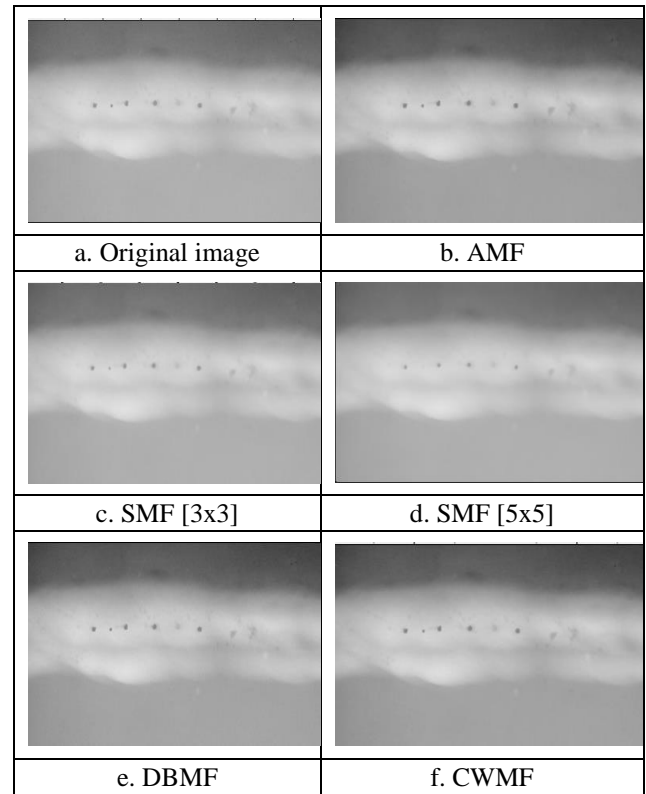


Fig. 4 Porosity defect processing using different median filters.

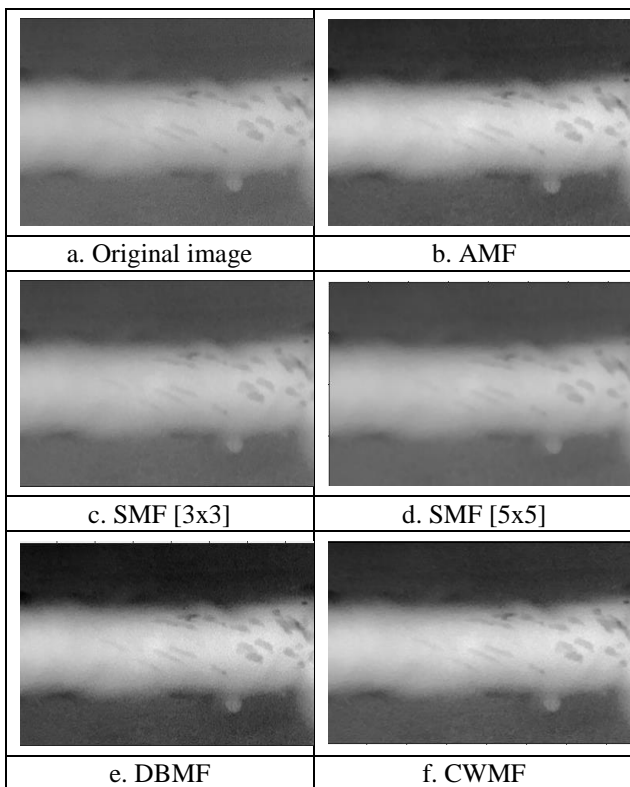


Fig. 3 Inclusion defect processing using different median filters.

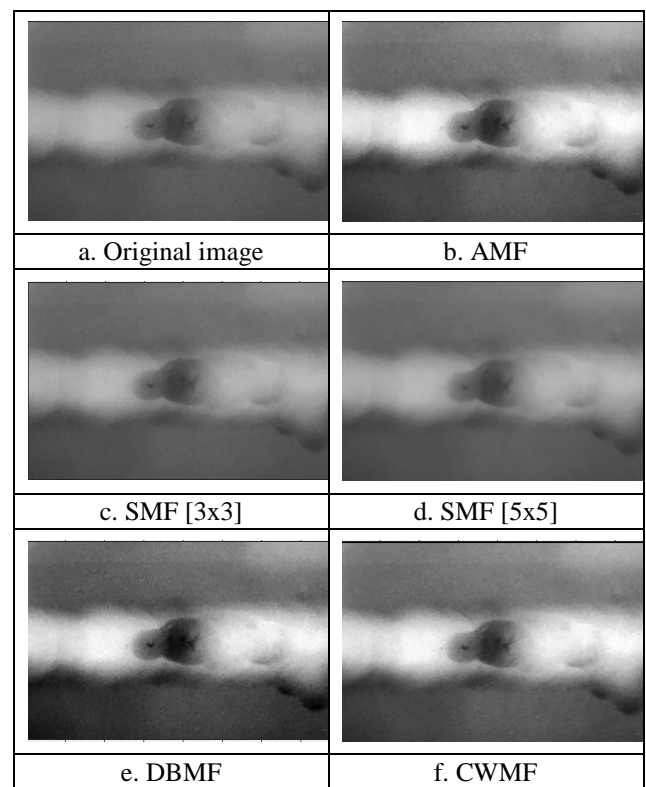


Fig. 5 Burn through defect processing using different median filters.

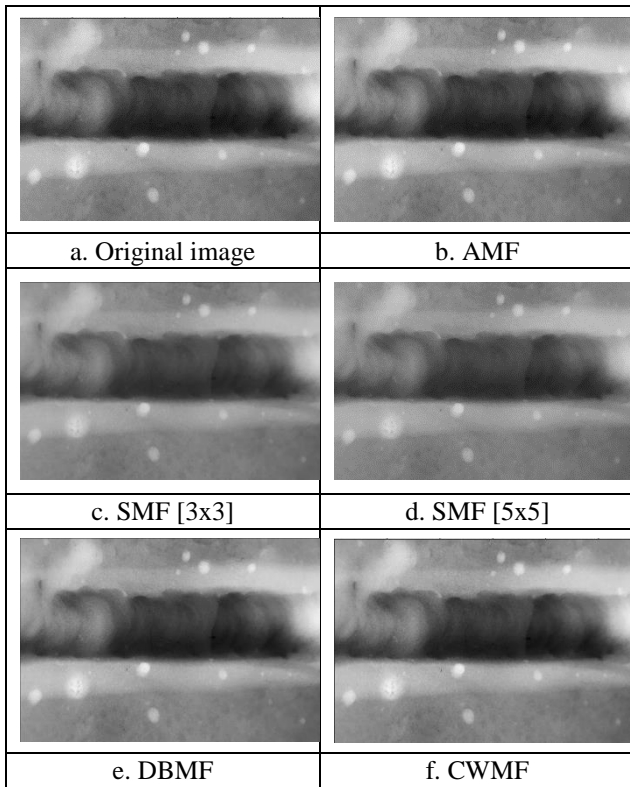


Fig. 6 Concavity defect processing using different median filters

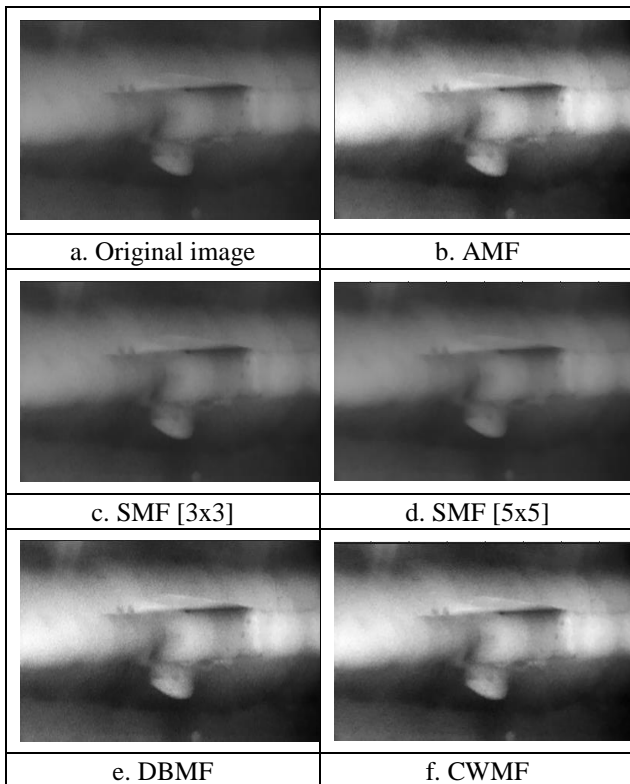


Fig. 7 Incomplete penetration defect processing using different median filters.

The indexes of PSNR and RMSE are calculated for the different types of median filters to study the effect of salt & pepper noise removal. The study does for different levels of noise for incomplete penetration as a sample of welding defect. The value of PSNR and RMSE also indicated that DBMF and AMF give the best results respectively at all salt and pepper noise ratios as shown in Fig. (8) and table (8).

Table 8 RMSE value for incomplete penetration image at different percentage of impulse noise

%	CWM	AMF	[3x3]	[5x5]	DBM
10%	45.33	41.21	42.38	42.55	41.89
20%	67.37	57.57	59.40	59.63	59.31
30%	85.76	70.08	72.55	73.00	72.64
40%	102.39	80.44	84.21	84.51	83.96
50%	117.71	88.63	94.77	94.78	93.84
60%	132.09	95.60	105.32	104.40	103.0
70%	145.14	101.35	116.09	114.81	111.42
80%	157.46	108.39	127.89	128.30	119.19
90%	168.95	119.90	140.43	145.34	126.73

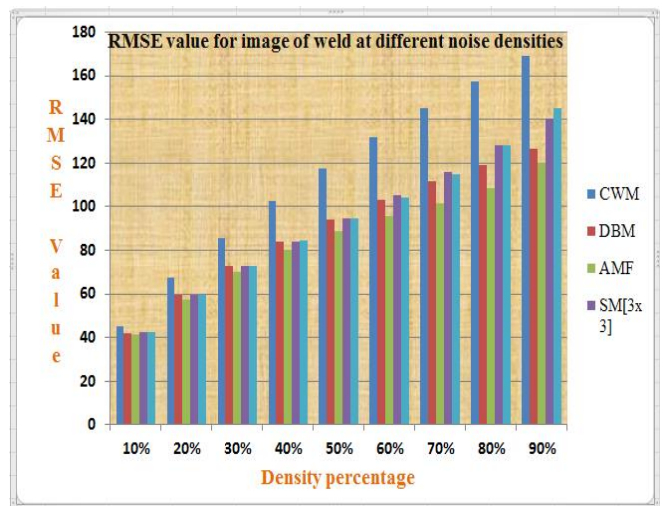


Fig. 8 RMSE value graph of different percentage salt & pepper noise.

4. Conclusion

Noise is one of the drawbacks that affect the automatic understanding of images and the process of eliminating or reducing it is very important to improve the results of additional processing. In this paper, various types of median filtering techniques have been discussed on the radiographic images of weld to produce a suitable filter among them to remove different types of noise in this field. Through the results obtained, whether using the qualitative comparison methods represented by the PSNR and RMSE indexes or quantitative comparison methods represented by visual clarity. In general,

1. The median filter is a good algorithm to clarify the radiographic images of the welding defects. On the other hand, the adaptive median filter and decision based median filter have impressive activity as compared to other filters.
2. Center Weight Median Filter (CWMF) considers as the worst technique.
3. The obtained results were consistent with certified welding defects inspectors.

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