Seam welds quality control improvement using method of pseudo-color coding images

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Abstract: The method of seam welds quality control using X-ray is considered. The X-ray methods of control are based on the capability of gamma radiation to penetrate through a metal including welded areas. Regions having defects - pores, faulty welds, cracks, scale inclusions - look darker on images. Appearance, linear dimensions and depths of the defects usually are determined by a visual examination comparing the X-ray image with standard defects images. It is known that a human eye can distinguish not more than 12-15 shades on a black and white image but more than a hundred on a colored image. The paper considers possibilities of the developed method by the author and based on the optical mixing of two or three complementary colors - red, blue and green. The method can use only one pair of the colors at a time, i.e. it is possible to have three various pairs for a pseudo-color image. The obtained pseudo-color image has the same informational capacity as the original black and white image. But the greater fraction of the saved information becomes available for visual examination of the X-ray image. In the end the efficiency of the seam weld quality control increases.

1. Introduction
The check of the welded joints is a mandatory stage of any weld process. In that case revealing obvious and hidden defects is important. Some defects can be observed by visual examination. That is why the quality of welds is at first examined visually. Then various methods can be utilized – ultrasonic, magnetic, capillary or X-ray. Each method has its advantages and disadvantages. The paper considers the method ensuring the increase of the quality control in revealing welded joints defects of various pipe-lines (further the method is addressed as the method for revealing defects). The method is based on optical mixing of two complementary colors being on the edges of the spectral range, in particular, mixing the blue and the red colors.

The original image of the seam weld is shown in figure 1. Figure 2 represents the pseudo-color copy of the image – the result of application of the method for revealing defects. It is known that an average human eye can distinguish not more than 10-12 black and white shades whereas more than 100 color tints. The method for revealing defects is based on the theory of the pseudo-color conversion [1, 2], which, in turn, is based on a wide range of theoretical grounds. The essence of the method is that according to the Young-Helmholtz color vision theory the whole color spectrum is formed in a human brain. The receptors feel only the colors corresponding to the wave-lengths 430, 543 and 564.
nanometers. In the additive theory of color of slightly different wave-lengths are adopted – 440, 520 and 700 nanometers that comply with requirements of the International Commission on Illumination.

Figure 1. Half-tone X-ray image of the weld joint.

Figure 2. Pseudo-color X-ray image of the weld joint in violet-red tints.

The authors briefly describe physical principles governing the proposed method. In a weld quality diagnostics, firstly, the half-tone X-ray image is taken. Then the analysis of the X-ray image is conducted using illumination with two complementary colors at two different angles – at the normal and at the angle corresponding to diffuse scattering of the photo-material. For the majority of photo-layers the angle is around 30 degrees. When the X-ray image is illuminated at the normal angle the direct image is observed, under the diffuse light the complementary image is observed. In the latter case the light and dark areas interchange their locations. In addition color filters are placed on the ways of the illuminating rays, red on the way of one ray, and blue - on another. By mixing the direct red and complementary blue images the original X-ray image is converter to the pseudo-color image. Depending on the intensity of the mixing rays the image can be shifted to one ore another part of the spectrum. The represented on the figure 2 pseudo-color image, used for illustration of the method, is shifted to the violet part of the spectrum. The idea of the proposed method has emerged because the black and white photo-materials are still used for X-ray imaging. Besides, up to now no algorithms has been made capable of reliable
separation of defect and defectless areas. If the image is clear and contrast it can be analyzed immediately without need for the image quality improving operations. However often, when thick materials are analyzed, the image has low contrast. In the latter case the image is usually converted into pseudo-color, or in 3D image, and then the converted image is analyzed. The conversion is required because an average human eye can reliably distinguish less than 10-12 shades of black and white. In order to improve recognition by the human eye the two known methods are combined – the method of computer analysis using Femtoscan software and the patented by the authored method for optic analysis of images in diffuse light.

2. Research methods

It is necessary to mention the methods being the prototypes of the proposed method in order to understand the essence of the proposed approach. The clusterization method is well described in [3, 4]. The clusterization method is well known among optic researchers dealing with images processing of any dynamic objects, including changing in time X-ray images. In the beginning of a clusterization process an image is made segmented into set of pixels. Then the original objects are separated into several non-intersecting groups. The separation is conducted by similarity of characteristics: the objects of a group significantly differ from the objects of the other groups. In order to evaluate the similarity the original values are estimated by 5-component vector consisting of coordinates x, y and a parameter which are valuable for image understanding by a human. Let us briefly describe the physical essence of the method [8, 9]. An exposed and developed photo-layer plane direction an image is direct radiating. If the image is observed at the normal to the photo-layer plane direction an image is direct black and white. In the scattered light the image inversion takes place. The blue light filter is placed on the way of the scattered (diffuse) radiation. Then the images are superimposed and obtain a pseudo-color image. The original image is shown on figure 1, the pseudo-color image is presented in figure 2.

In the review [7–10] several modern approaches to images processing are considered. The informational-measurement complexes of three levels are considered: low, medium and high. The noise reduction and contrast improving are the operations of the low level. The segmenting and compression can be attributed, on authored opinion, to the middle level operations. The operations of the high level include understanding of the processed images, in other words the primitive modeling of human brain operation. Some operations of the low and middle levels are required for improving those image parameters which are valuable for image understanding by a human. Let us briefly describe the physical essence of the method [8, 9]. An exposed and developed photo-layer can absorb and scatter an incident radiation. If the image is observed at the normal to the photo-layer plane direction an image is direct black and white. In the scattered light the image inversion takes place. The blue light filter is placed on the way of the direct radiation, and the red light filter - on the way of the scattered (diffuse) radiation. Then the images are superimposed and obtain a pseudo-color image. The original image is shown on figure 1, the pseudo-color image is presented in figure 2.

Pixel color in RGB system. The two coordinates are the coordinates of the pixel on the plane, and three other components are the intensities of the red, green and blue colors. The obtained groups are called clusters. The method is efficient but has one considerable disadvantage. It requires knowing a-priori, at least approximately, the number of clusters. The image segmentation allows lowering the amount of information and discussion.

The half-tone X-ray image of the seam weld, shown in figure 1, was observed in the direction normal to the screen. Then it was observed at two opposite angles plus-minus 30 degrees through the two optical filters of the complementary colors, namely, the red and the blue. The optical filters were taken
from the set of color optical glasses and had markings "C3C-22" and "KC-11". Both images were registered by the digital photo-camera and then were superimposed on each other. The photo-camera was CanonPowerShotSX620HS with the following main characteristics: the matrix with 21.1 megapixels, the screen of 3 inches, capability of macro-regime. The resulting image is represented in pseudo-colors figure 2. The computer monitor used in experiments was ACER ExtensaEX2519-C33F. We used that relatively inexpensive model because the more expensive monitors did not have ability of appearing complementary image when the observation angle was in the range from minus 30 to plus 30 degrees with respect to the vertical plane. Now the time to recall that the average sensitivity of a human eye to black and white images is around 10%, but sensitivity to the color changes is about ten times higher. Thus, in order to achieve the same effect using the black and white images it is necessary to take several images with different exposures. The result of such multiple exposure images is in figure 3.

Figure 3. Half-tone X-ray images of the weld joint taken with different exposure times.

Note that in industrial X-ray control only black and white photo-layers are used so far. Thus, the proposed method utilizing analysis of half-tone X-ray images allows saving expensive photo-material. The authors describe in more details the experimental procedure. The original half-tone image in the standard procedure is observed and analyzed in the direction close to the normal. Then the same image is analyzed at the angles plus-minus 30 degrees. The images appear complementary to each other. Under inversion here we mean the interchange of black and white colors. The next step is the registration of each image by the digital photo-camera through the optical glass filters "C3C-22" and "KC-11". Other optical filters also have been used in experiments but the mentioned combination showed the optimal results. The next operation is the superimposition of the images and scaling in the vertical direction to the size of the original image. Another variant of the experimental setup is the positioning of the digital photo-camera perpendicularly to the monitor and taking the direct images and observing the monitor.
screen through two complementary mirrors. In this case the ray’s paths are taken in such manner that two inverted black and white images come to the camera simultaneously. Then various complementary optical filters can be inserted in two branches. The best result has been obtained again with the optical glass filters "CЗC-22" and "KC-11". Results of the image inversion by the proposed optic-electronic method are represented in figure 3. The authors used the digital photo-camera CanonPowerShotSX620HS with following main characteristics: the matrix with 21.1 megapixels, the screen of 3 inches, capability of macro-regime. The angles were taken in the range 15-30 degrees with the step of 1 degree. The computer monitor used in experiments was ACERExtensaEX2519-C33F. That relatively inexpensive model was used because most of more expensive models did not reveal the effect of the image inversion when the observation angle is within the range from minus 30 to 30 degrees in the vertical plane.

Figure 3 shows for comparison black and white half-tone images of the seam weld with various exposures. Since the sensitivity of an average human eye to changes of intensity is around 10% for each image it can distinguish not more than 10 levels of brightness. In order to have more half-tones it is necessary to take images with different exposures and then compare the whole series of the images, all 7 images. If the pseudo-color coding for images are used then it is enough to have only one original black and white image. Note that in industrial X-ray control only black and white photo-layers are used so far. Thus, the proposed method using the analysis of half-tone X-ray images allows saving the expensive photo-material.

3. Conclusion
The possibilities of the method proposed by the authors for seam welds quality control are demonstrated, the method being based on optical mixing of two colors belonging to the edges of spectral range. The future investigations might be related with circuit and device improvement to make the setup more mobile and capable of being used in the field conditions where welding is carried out. The possibilities of the real-time optic-electronic pseudo-color coding of images are briefly considered. The proposed method in no way diminishes the importance of other methods but can add and extend their capabilities. The color segmentation of black and white images is more preferred in real-time when the image is analyzed on the LCD monitor screen. In this case the pseudo-color image the image is represented by RGB model and the main part of the image corresponds to the green range of spectrum for which a human eye has maximum sensitivity.

References
[1] Suvilova K A, Polezhaeva A I, Noskov M F, Tatarnikov V I, Rubanovich M G and Razinkin V P 2017 Int. Conf. of Young Specialists on Micro/Nanotechnologies and Electron Devices EDM 368-70
[2] Noskov M F 2018 14th Int. Sci.-Technical Conf. APEIE 140-2
[3] Nemirovskiy V B and Stoyanov A K 2017 Computer Optics 41 59-66
[4] Nemirovskiy V B, Stoyanov A K and Goremykina D S 2016 Computer Optics 40 740-5
[5] Nemirovskiy V B and Stoyanov A R 2012 Bulletin of the Tomsk Polytechnic University 205-10
[6] Kolobrodov V G and Pivtorak D A 2013 Measurement methods of the diagnostics 58-62
[7] Kozlov V L and Vasilchuk A S 2015 Measurement methods of the diagnostics control 220-9
[8] Ivanikov V P and Kabukoba A V 2014 Medical physics 51-66
[9] Gundin A A, Gundina M A and Cheshkin A N 2016 Science and technology 15 225-32
[10] Lisitsyna L I, Blokhin A A, Starovoytova T M, Navrotsky N L, Chirkova G S and Fateev A M 2017 Dependence of Brightness of a Glow of Points of Compliance on Heart Rate EDM-2017 (Novosibirsk: NSTU) 613-5