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# TIME – FREQUENCY DYNAMIC CHARACTERISTICS 2D IN THE QUALITY ASSESSMENT OF WELDED JOINTS

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***Abstract***

*The authors of the article have been looking for a new parameters and dynamic characteristics, which can be applied to non-destructive testing of welded joints. All characteristics have been based on recorded data generated during the vibration tests of welded joints with and without failures. The article deals with the methods of assessing welding joints using 2D: time – frequency dynamic characteristics. A calculation procedure used for analysing simultaneous changes of the response modules, registered by acceleration sensors was presented. Vibrations amplitudes were transformed to a function of time and frequency (simultaneously) and presented over 2D time – frequency characteristics. The analyses of the characteristics were performed for a plate without any welded joint, for a plate with non-defected welded joint and for a plate with a welded joint defected by an edge bonding. Having analysed registered 2D time – frequency dynamic characteristics it can be noticed that presenting the responses analysed simultaneously over the time and frequency allows evaluating if examined system maintains non-linearity and, at the same time, it allows to indirectly assess the quality of the welded joint. The proposed measure parameters of the quality of a welded joint can be defined as a dispersion of colours on the obtained characteristics. The faults (and the vibration nonlinearity) of the welded joints is bigger if the dispersion is greater.*

***Keywords:*** *welding, welded joints, non-destructive testing, NDT, SHM, vibrations, time – frequency characteristics*

## 1. Introduction

NDT (Non-Destructive Testing) is a wide group of analysis techniques to evaluate the properties of a material without causing its damage or decreasing its appropriable properties. The before mentioned type of examination is referred to as non-destructive testing. It allows to identify and localize possible flaws of a material, which are called material defects, namely material cracks, contaminants, or internal structure irregularities [5, 6].

The authors of the article are searching for new parameters and characteristics, which may be used in non-destructive research of welded joints. In the first stage of analysis of research results, the authors, basing on the recorded spectrum of responses have calculated the attenuation spectra with FFT method. On the basis of the calculated attenuation spectra, the authors have chosen the most appropriate type of modal hammerhead as well as the optimal spot of impact on the welded plate [1].

The next stage of the research was to assess the rate of dispersion of the spot and the power of impact of the modal hammer. To assess both the effects of impact and dispersion of the spot, trials have been conducted, during which several attempts were made on the given point with the same head, but with different power of impact each. The responses consequently were obtained (while measuring the coordinates of hits was registered). Admissible dispersion was then suggested, to which spectral analysis of dynamical characteristics was applied with statistical methods. On the basis of statistical figures, it has been confirmed that application of the impact with 'a free hand' may bring the repetition of spectres (power and dispersion) on an acceptable level. The authors described the results of the analysis in their article [2]. In the article [3] the authors have described assumptions of welded joints assessment method after analysing the distribution of amplitude spectres mean value calculated with the use of window function method (merit of median is a kind of statistical measure which analysis for a given welded joint enables to assess its quality). The window function method allows performing a simulation of the signal analysis in the field of time and frequency. The research has shown that the analysis of distribution of amplitude spectra's merit of median calculated by the use of the window function method indicates the differences of amplitude spectra in terms of welds. At the same time, it identifies both their quality and flaws, which are interconnected with them. The essential data about the quality of a welded joint is provided by the distribution of amplitude spectres mean value calculated by the use of the window function method. The analysis of testing results based on calculation of damping decrement, which changes in time and with the response change, has been presented by the authors in the article [4]. The results have shown that the analysis of a time change of damping decrement in relation to welded plates enables the assessment of quality and type of weld faults [8].

## 2. The analysis of time-frequency dynamic characteristics 2D

The complementation of the amplitude-frequency analysis (FFT) presented in the previous articles is its combination with the analysis of the change in vibration amplitudes in the time domain.

The calculation procedure 1 – 3 has been implemented to present the simultaneous changes of response modules (1) which were recorded by accelerometer in the time and frequency domain.

$$|X| = g(t, f), \tag{1}$$

where:

$|X|$ – vibration module calculated for the accelerometer-registered responses,

t – time vector,

f – frequency vector,

g (t,f) – dependency presenting the change of vibration modules in the time and frequency domain.

By the application of Cartesian product formula for vectors t(i) and f(i), which represent discrete time and frequency variable of an analysed response, matrixes (2) were calculated. They form a point net on the TF plane (T – time, F – frequency).

$$(T(i,j), F(i,j)) = (t(i), f(j)), \tag{2}$$

where:

i, j – number of points of time and frequency vector,

$T, F$ – matrixes of time T(i,j) and frequency F(i,j) calculated with the use of Cartesian product formula for vectors t(i) i f(j).

Next, the points of matrix FFT (i,j), which represent the spectra of amplitude vibrations registered by accelerometer, have been marked on this defined net.

Therefore, time-frequency dynamic characteristics 2D are the planes drawn in space defined by the set of points (3).

$$\{T(i,j), F(i,j), FFT(i,j)\}. \tag{3}$$

The colour function has been used to draw the abovementioned planes by the use of Matlab program. In so doing, on the Fig. 1-3 the change of response amplitude in the time and frequency domain was introduced, where the change of response amplitude in the time domain has been marked with a colour on an assumptive colour scale.

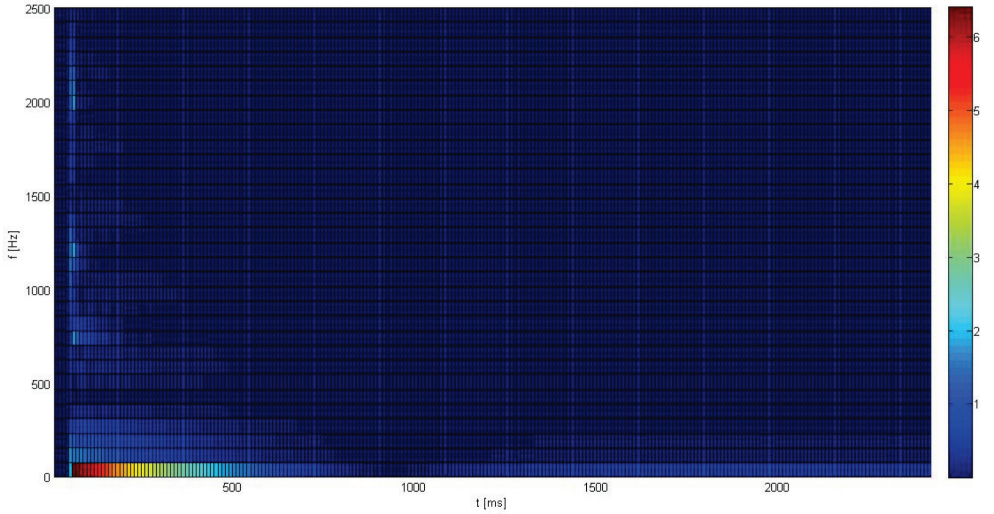


*Fig. 1 Time-frequency dynamic characteristics 2D for a plate with no welded joints (0) for the impact made by an modal hammer with a metal head*

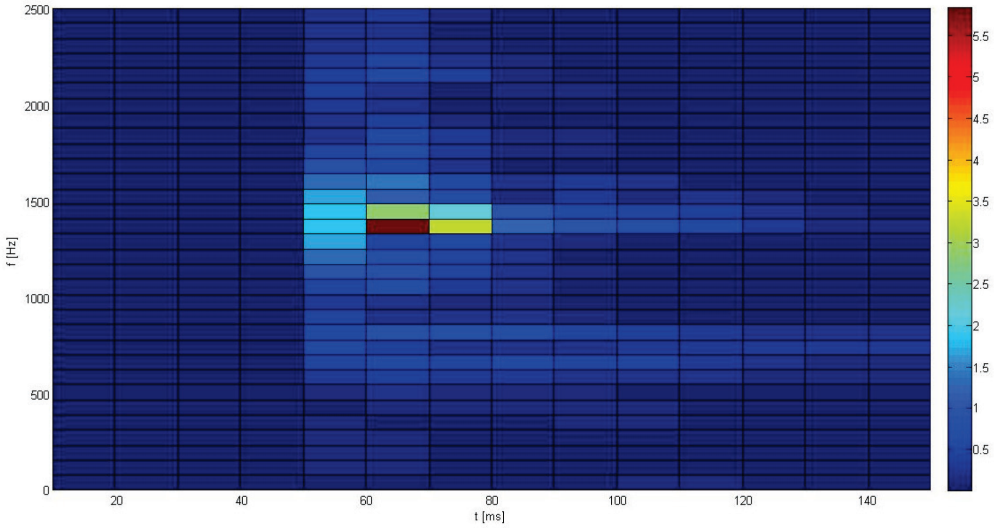


*Fig. 2 Time-frequency dynamic characteristics 2D for a welded plate with non-defected welded joint (2202) for the impact made by an impact modal with a metal head*

Having analysed the characteristics presented in Fig. 1-3 it is clearly visible that presentation of response on both the time and frequency domains allows to assess whether the tested configuration remains linear and, at the same time, indirectly enables to estimate the quality of a welded joint. In this instance, the measure of the quality of a welded joint may be the dispersion of colours on the characteristics presented above.

The time-frequency dynamic characteristics presented in the Fig. 1-3 enable to assess the quality of a welded joint. The analysis of given characteristics proves that the plate with no welded joint (Fig. 1) has the lowest dispersion range, whereas in other cases (Fig. 2 and 3) the dispersion range is much higher.

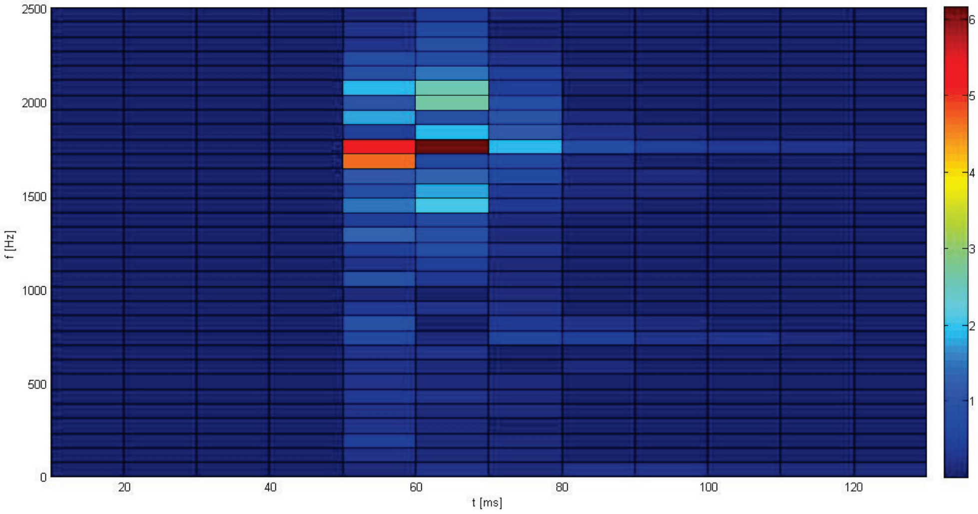


*Fig. 3 Time-frequency dynamic characteristics 2D for a welded plate with a fault (lack of side fusion [2127]) for the impact made by impact hammer with a metal tip*

## 3. Conclusion

Diagnostic data acquired as a result of the analysis of time-frequency dynamic characteristics 2D allows to assess the condition and quality of joints. Due to the availability of image processing functions in numerous computational programs, it is possible to apply the proposed time-frequency dynamic characteristics 2D in order to detect any joint decrements. This can be performed by the use of automatic construction monitoring systems like SHM.

The application of both the analysis of the distribution of amplitude spectres mean value calculated with the use of window function method as well as the use of time-frequency dynamic characteristics allowed to scan the accelerometers responses both in the time and frequency domain. In the characteristics presented above, the most reliable measure to assess the quality of a welded joint may be the colour dispersion, which is a clear signal of additional dissipation and an indicator of a welded joint flaw.

The proposed quality assessment method requires further tests as well as the introduction of a third dimension such as a module variable of calculated spectral amplitude. Then, apart from applying the data referring to time-frequency dynamic characteristic, there would be a possibility to use also the information about the intensity of changes in amplitude spectra.

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