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Vibration Measurements of Clinched Joints

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Abstract

As a result of the trend towards lightweight construction in sustainable manufacturing, there has been a significant increase in the use of clinched joints in engineering structures and components. Mechanical structures assembled by clinching are expected to possess a high damping capacity. The aim of this paper is to provide an experimental measurement technique for the investigation of the forced vibration behavior of clinched joints. The dynamic test software and the data acquisition hardware were used in the experimental measurement of the dynamic response of the clinched joints. The frequency response functions of the clinched joints of different clinching point number were measured and compared.

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Keywords: Clinching; single-lap joint; vibration; experimental measurement; frequency response functions

1. Introduction

There is an increasing need to design lightweight structures such as vehicle body shells. Some relative new joining techniques have drawn more attention in recent years because they can join lightweight materials that are dissimilar, coated and hard to weld with conventional spot welding [1-4]. Clinching has been developed rapidly into a new branch of mechanical joining techniques [5, 6]. In Zheng et al.'s paper [7], the extensible die clinching process has been simulated using finite element (FE) method. The material flowing patterns have been compared between the fixed grooved die clinching and the extensible die clinching. Yang et al. [8] studied clinching process of cooper alloys based on numerical simulation combined with experiments. The process monitoring systems are able to distinguish between accidental and systematic process errors and can, therefore, keep unnecessary plant stops to a minimum and ensure high levels of plant availability. The influence of process parameters in extensible die clinching has been systematically investigated by Lambiase and colleague [9-11]. Clinched joints were produced under different forming loads to evaluate the evolution of the joints' profile experimentally. By means of 3D ANSYS FEA, the influence of the Young's modulus and Poisson's ratio of the structural adhesives on the natural frequencies, natural frequency ratios, and mode shapes of the single-lap clinch-bonded hybrid joints was deduced by the present author and coworkers [12].

Despite these impressive developments, unfortunately, research in the area of dynamic properties of the clinched joints is relatively unexplored. The need, therefore, exists to study dynamic behavior of clinched joints. In present study, an experimental technique was provided for the prediction of the forced vibration behavior of clinched joints. The LMS (Leuven Measurement System) CADA-X dynamic test software and the LMS-DIFA Scadas II 48 channel data acquisition hardware were used in experimental measurement of the dynamic response of the joints. The frequency response functions (FRFs) of the clinched joints of different clinching point number were measured and compared.

2. Configuration, material properties of clinched joints

The clinched joints comprise upper sheet and lower sheet. The two 5052 aluminium alloy sheets were 0.11m long, 0.04m wide and 0.002m thick and were joined at the lap

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section with one and two clinching points as shown in Fig. 1. In order to make it easy to describe the different clinched joints, the following nomenclature is used:

S-clinched joint: clinched joint with one clinching point

D-clinched joint: clinched joint with two clinching points

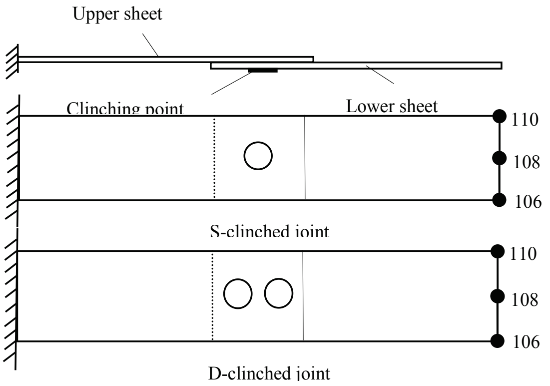

Fig. 1. Single lap cantilevered clinched joints

3. Free vibration measurements of clinched joints

3.1. Experimental set-up and data acquisition hardware

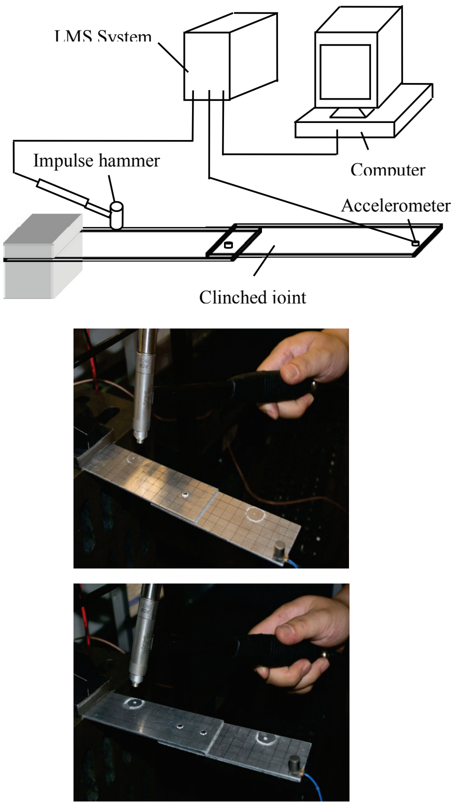

Fig. 2. Experimental set-up for free vibration measurements of the clinched joints

The experimental set-up used for free vibration measurements of clinched is shown in Fig. 2. The LMS CADA-X software was used in conjunction with the LMS-DIFA Scadas II 48 channel data acquisition hardware for the following dynamic tests. The software has a high speed 12-bit or 16-bit analogue to digital converter (ADC), 48 channels with programmable dual filter (PDF), and four channels of signal generation via a quadruple digital to analogue converter (QDAC) [13]. One end of the clinched joints was clamped in a heavy support. To fully excite the beams, an excitation is accomplished by impulse hammer with a built in force transducer, at a location which was 20% of the length of the joint from the clamped end and very close to a free edge.

An accelerometer was fixed to selected points on the joint and was used to measure the frequency response of the joint at these points. The output of the force transducer and accelerometer were connected to LMS system which amplify and transduce the force and acceleration signals into voltages. These voltage signals were sampled and digitised by the data acquisition system which transferred the measured data to the computer for processing using the LMS CADA-X modal analysis software.

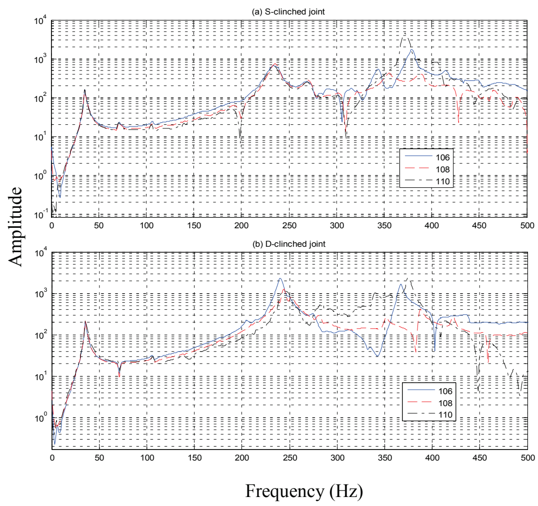

Fig. 3. FRFs of free vibration measurements of S-clinched and D-clinched joints

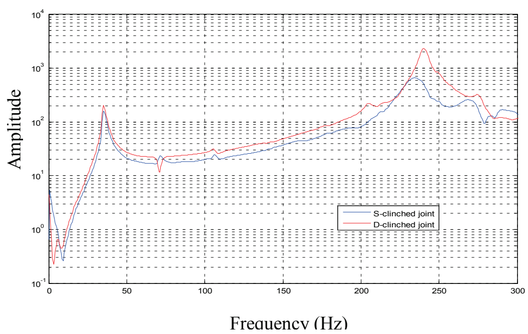

Fig. 4. Comparison between FRFs of free vibration of S-clinched and D-clinched joints

3.2. Comparison of FRFs for free vibration of S-clinched and D-clinched joints

The FRFs of the S-clinched and D-clinched joints were measured using the LMS CADA-X experimental modal analysis software and the LMS-DIFA Scadas II data acquisition hardware. The frequency range of the measurements was 0 Hz-2000 Hz. The number spectral lines were set up as 1024, which corresponded to a resolution of 1.953 Hz, in order to obtain an accurate indication of the variation of the FRFs. As the first several vibration modes are more important, only frequency range 0 Hz-500 Hz will be discussed in this section.

In the case of vibration of the single-lap cantilevered clinched joints, some typical points on the free edge were chosen for response points because they can better represent the dynamical characteristic of the joints. The location of nodes at the free edge of S-clinched and D-clinched joints is shown in Fig. 1. Nodes 106, 110 and 108 in Fig. 1 are the nodes at the two corners and centre of the free edge of the single-lap cantilevered clinched joints.

The overlay of the FRFs measured experimentally at the two corners and centre of the free edge of the S-clinched and D-clinched joints are shown in Fig. 3. It can be seen from Fig. 3 that the typical points at the two corners (nodes 106 and 110) can better represent the dynamical characteristic of the jointss than the typical point at the centre (nodes 108) at which the mode 3 (around 370 Hz) can not be clearly recognized.

Comparison between FRFs of S-clinched and D-clinched joints at node 106 is shown in Fig. 4. In this figure, the red line denotes the FRFs of D-clinched joint and the blue line represents the FRFs of S-clinched joint. It is clear from Fig. 4 that even the FRFs of the two clinched joints are very similar, the natural frequencies of D-clinched joint are slightly higher than those of S-clinched joint. This discrepancy can be attributed to the fact that increasing the clinching point number would increase the stiffness of the clinched joint and results in higher natural frequencies.

4. Forced vibration measurements of clinched joints

4.1 Experimental set-up for forced vibration measurements of clinched joints

Similar to the test set-up for free vibration measurements, the LMS CADA-X software was used in conjunction with the LMS-DIFA Scadas II 48 channel data acquisition hardware for forced vibration measurements of single-lap cantilevered clinched joints. To fully excite the joints, an electromagnetic exciter (shaker) was connected to excitation point of the clinched joints, via a force transducer bonded with the joint, at a location which was 20% of the length of the joint from the clamped end and very close to a free edge. The shaker was excited by a band limited random signal which was produced digitally in a LMS system by the LMS CADA-X experimental modal analysis software. The digital signal was converted into an analogue signal by the data acquisition system, amplified by a power amplifier and applied to the shaker. An accelerometer was fixed to selected points (response points) on the joint and was used to measure the frequency response of the joint at these points. The test rig for forced vibration measurements of single-lap cantilevered clinched joints is shown in Fig. 5.

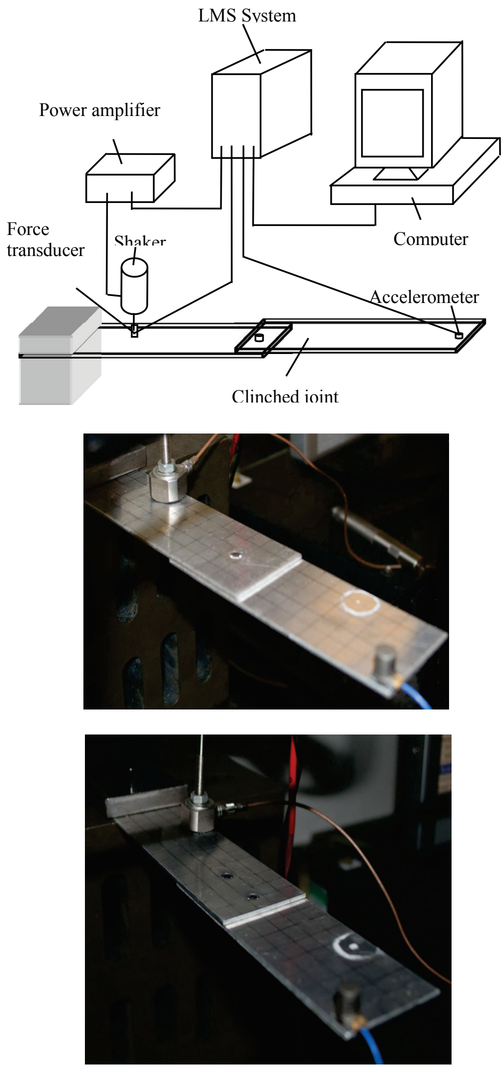

Fig. 5. Experimental set-up for forced vibration measurements of

4.2 Comparison of FRFs for forced vibration of S-clinched and D-clinched joints

The forced vibration behaviour of the S-clinched and D-clinched jopints were measured using the LMS CADA-X experimental modal analysis software and the LMS-DIFA Scadas II data acquisition hardware. The frequency range of the measurements was 0 Hz-2000 Hz, the same as the case of the free vibration measurements. The number spectral lines were also set up as 1024, which corresponded to a resolution of 1.953 Hz, for obtaining an accurate indication of the variation of the FRFs. Frequency range 0 Hz-500 Hz will be discussed in this section.

The overlay of the FRFs measured experimentally at the two corners and centre of the free edge of S-clinched and D-clinched jopints are shown in Fig. 6. It can be seen again that the typical point at the two corners (nodes 106 and 110) can better represent the dynamical characteristic of the joints than the typical point at the centre (nodes 108) at which the mode 3 (around 390 Hz) can not be clearly recognized.

Comparison between FRFs of S-clinched and D-clinched joints at node 106 is shown in Fig. 7. It can be seen from Fig. 7 that even the FRFs of the two clinched joints are very similar but the change trends of the natural frequencies and the amplitudes of the clinched joints are not clear. Such discrepances can be addressed to the additional masses of the force transducer.

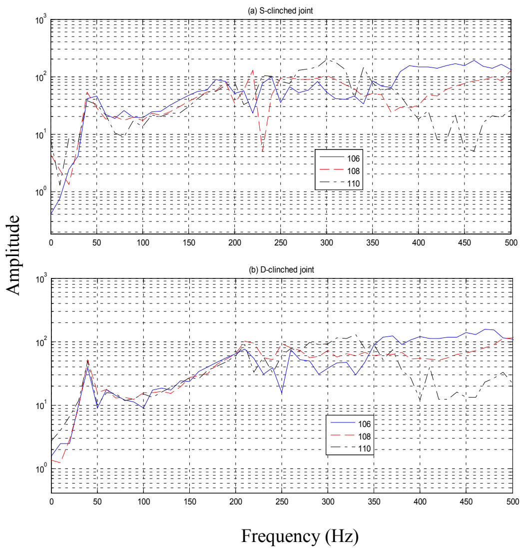

Fig. 6. FRFs of forced vibration measurements of S-clinched and D-clinched joints

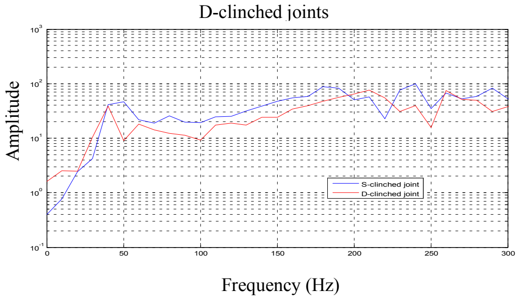

Fig. 7. Comparison between FRFs of forced vibration of S-clinched and D-clinched joints

5. Summary

It can be seen from above measurements and analyses that both free and forced vibration measurement techniques are efficient for the experimental measurements of the dynamic response of the single-lap cantilevered clinched joints. In the case of the free vibration measurements, dynamic response of the clinched joints can be measured easily as the experimental set-up is simple. This simple experimental set-up also results less effect from extra force transducer mass. As the excitation was accomplished by impulse hammer, however, the excitation quality is largely depends on the experience of experimenter. On the other hand in the case of the forced vibration measurements, steady excitation quality can be obtained easily because a shaler was used to excite the joints. As the shaker was connected to excitation point of the clinched joints via a force transducer bonded with the joints, the force transducer mass contributed to the overall system mass. The dynamic model of the single-lap cantilevered clinched joints should be changed to a certain degree and thus the dynamic response of the joints should be affected by the force transducer. As the vibration measurement techniques proposed are efficient for the experimental measurements of the dynamic response of the single-lap cantilevered clinched joints, they can be used for further research on vibration based non-destructive damage detection in the joints.

Acknowledgements

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