Characteristics of damping in components of a spot-welded frame

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Abstract

This paper describes a damping ratio for each component of a spot-welded frame composed of cold-rolled steel sheets. A spot-welded frame is used as part of an automotive body and a cabin of construction machinery. Their damping ratios need to be understood in design. The spot-welded frame is divided into spot-welded flange parts and other portions. Damping ratios of these components have been measured by impact tests. It was found that damping ratios of non-spot-welded sheet metals have little dispersion and are independent of frequency and shape. It was found that damping ratios of spot-welded flange members are related to the spot-pitch and thickness. Additionally it was found that a damping ratio of a spot-welded frame is smaller than that of a spot-welded flange member under the same parameters and is larger than that of a non-spot-welded sheet metal. It was found that the difference in their damping ratios depends on the shape of the non-spot-welded sheet metal portion in a spot-welded frame. The degree of the difference was clarified by our suggested method to evaluate the damping ratio of a spot-welded frame.

Keywords: damping ratio, spot-welding, sheet metal, cold-rolled steel sheet, impact test.

1 Introduction

Good riding quality is needed for a car and a construction machinery because the operator rides on for many hours. Therefore, it is important to understand the vibration behaviour in design. An automotive body and a cabin of a construction
machinery are constructed by some spot-welded frames in the view of both a function and an economy. It is needed to understand a damping ratio of each spot-welded frame. These frames are spot-welded some sheet metals pressed to a complex section. It is difficult to understand damping ratios of their spot-welded frames because their structures are complex.

In this study, the difference of damping ratios in some components of a spot-welded frame was investigated, which was made of cold-rolled sheet steel (JIS SPCC) used in a cabin of a construction machinery.

2 Components of spot-welded frame

A spot-welded frame is divided into two components, spot-welded flange parts and another portion (hereinafter referred to as box portion) as shown in Fig.1. The spot-welded flange part is composed of two flat sheet metals. Characteristics of damping in this flange part are considered to be due to friction behaviour between these sheet metals [1][2]. The box portion depends on characteristics of material damping. The damping ratio of a spot-welded frame is considered to be the result of the combination of the friction damping and the material one.

![Figure 1: A schematic drawing of a spot-welded frame.](image)

In this study, at first, the material damping ratio was investigated using some non-spot-welded sheet metals by impact tests [3]. Next, the damping ratio of a spot-welded flange part was investigated using some flange members spot-welded two sheet metals [4]. Then the damping ratio of a spot-welded frame was investigated by impact tests and by our damping ratio evaluation analysis [3].

Characteristics of the damping in the above components have been analysed using their damping ratios and relations between their damping ratios have been determined.
3 Experiment

Fig.2 is a schematic drawing of the impact test to measure the damping ratio. The test was performed with a test sample hung by a string. A force was measured as input data by an impulse hammer [DYTRAN, S800A, Sensitivity:2.23 [mV/N]], accelerations were measured as output data by acceleration pick-ups [TEAC, 613, Sensitivity:2.82 [mpC/G]] and the input data and the output one were processed in a FFT analyser [ONO SOKKI, CF-3400J], and then frequency transfer functions were estimated. In order to calculate some modal damping ratios of a test, a curve fitting was performed with the frequency transfer functions of all the measurement points on a test sample by using modal analysis software [SMS, STAR System].

![Figure 2: A schematic drawing of impact test.](image)

4 Damping ratio of a non-spot-welded sheet metal

The damping in a non-spot-welded sheet metal is dominant to material damping. In general, a damping ratio depends on rigidity. Therefore, each sheet metal, which has its own shape of cross section and own thickness, must have its own damping ratio. In this chapter, the material damping ratio was investigated with some non-spot-welded sheet metals. Impact tests as in shown in Fig.2 were performed with flat sheet metals and pressed sheet metals shown in Fig.3. Frequency response functions through thickness direction were investigated at 27 measurement points in the frequency range 1-500Hz. Test results are shown in Fig.4.
The variation of the material damping ratio with frequency and plate shape was insignificant from Fig.4. In another front, the damping ratio of a flange member spot-welded two sheet metals is 0.1% at its minimum as shown in chapter 5. Therefore, the material damping ratio is considered to be a result of a constant value in the case of comparing the damping ratios of spot-welded members.

For the above reason, the damping ratio of a non-spot-welded sheet metal i.e. the material damping ratio was estimated as 0.07% by averaging measurements.
5  Damping ratio of a flange member spot-welded two flat-sheet metals

Damping ratios of the flange members as shown in Fig.5 were measured by impact tests. Test samples were 8 kinds of flange members combined a spot-pitch (p=40mm, 60mm, 80mm and 100mm) and thickness (t=1.2mm and 1.6mm). Measurements were in 18 points.

![Figure 5: Test samples.](image)

5.1 Dependence on frequency

In this clause, the relation between the damping ratio and frequency was examined. Relations between the modal damping ratios and the spot-pitch of flange members with thickness i.e. t=1.2mm and 1.6mm are shown in Fig.6. It was found that each flange member has its own eigen-modes e.g. the damping ratio depends on frequency. However, the damping ratio on the 1st mode is predominant. It is because the tendency of the 1st modal damping ratio is similar to that of the average damping ratio on the same spot-pitch. For instance, though the 3rd modal damping ratio in the case of spot-pitch p=60mm is considerable, the average damping ratio mitigates the characteristic. This conforms to the experience that the influence of the 1st mode is the most significant on a cabin of a construction machinery.

For the above reason, the consideration of parameters in a flange member is more important than the expression for the dependence on frequency, in order to understand the characteristic of damping in a flange member. The equivalent viscous damping ratio is defined as the average of some modal damping ratios in a flange member.
5.2 Influence of spot-pitch

Relations between the equivalent viscous damping ratio and the spot-pitch of flange members are shown in Fig.7. It is found that the damping ratio increases with increasing spot-pitch. This tendency is considered to be a result of the increasing friction damping since the clearance of two sheet metals increases when the spot-pitch increases.

5.3 Influence of thickness

Relations between the equivalent viscous damping ratio and the thickness of flange members are shown in Fig.8. It is found that the damping ratio decreases with increasing thickness. This tendency is considered to be a result of the
decreasing friction damping since it is difficult to contact two sheet metals when the thickness increases i.e. the bending rigidity increases.

Figure 7: Relations between the equivalent viscous damping ratio and the spot-pitch of flange members.

Figure 8: Relations between the equivalent viscous damping ratio and the thickness of flange members.

6 Comparison of each components and spot-welded frame

Damping ratios of the spot-welded frames shown in Fig.9 were calculated by our suggested method to evaluate the damping ratio in order to compare the damping ratio of a spot-welded frame to that of a flange member or the material damping ratio. Comparisons of a damping ratio of a spot-welded frame with one of a spot-welded flange member and a material one are shown in Fig.10.

It is found that the damping ratio of a flange member is biggest because of the friction damping and the material damping ratio is smallest with the same parameters. It is found that the damping ratio of a spot-welded frame is smaller...
than that of a spot-welded flange member. This is considered to be a result of the decreasing friction damping in the flange parts of a spot-welded frame by the influence of the box portion of the frame.

Figure 9: Spot-welded frames.

Fig.10 shows that the difference in the damping ratio of a spot-welded frame with that of a spot-welded flange member is large under spot-pitch $p=80\text{mm}$ and is small at spot-pitch $p=100\text{mm}$. One is due to the decreasing friction damping in a flange part of the spot-welded frame by the increasing rigidity of the frame. The other is due to the increasing influence of the friction damping in the flange part of a spot-welded frame by the decreasing rigidity of the frame. Therefore, the box portion of a spot-welded frame is predominant over the damping ratio of the frame.

Figure 10: Comparisons of a damping ratio of a spot-welded frame with that of a spot-welded flange member and a material one.

Fig.10 shows that the difference in the damping ratio of a spot-welded frame with that of a spot-welded flange member is large under spot-pitch $p=80\text{mm}$ and is small at spot-pitch $p=100\text{mm}$. One is due to the decreasing friction damping in a flange part of the spot-welded frame by the increasing rigidity of the frame. The other is due to the increasing influence of the friction damping in the flange part of a spot-welded frame by the decreasing rigidity of the frame. Therefore, the box portion of a spot-welded frame is predominant over the damping ratio of the frame.
Damping ratios of some spot-welded frames with each section as shown in Fig.11 were calculated by our suggested method to evaluate the damping ratio in order to investigate the influence of the box portion of a spot-welded frame for the damping ratio of a spot-welded frame. Relations between damping ratios and spot-pitch with respect to each thickness are shown in Fig.12.

Results of the frame shown in Fig.9 show that the influence of the thickness on damping ratio is small when the box portion of a spot-welded frame has the rectangle section with the maximum side length less than the spot-pitch. The frame shown in Fig.11 (b) is in this pattern. Therefore, the damping ratio is slightly less than that of the frame shown in Fig.9 because of the smaller influence of the thickness and spot-pitch.
From results of the frame shown in Fig.9, the influence of the thickness on damping ratio is large and that of the spot-pitch on damping ratio is large, when the box portion has the rectangle section with the maximum side length not less than the spot-pitch. The frame shown in Fig.11 (a) is in this pattern. Therefore, the damping ratio is smaller than that of the frame shown in Fig.9 because of the larger influence of the thickness and spot-pitch.

7 Conclusion

The following conclusions were derived in regard to the spot-welded frame made of cold-rolled sheet steel (JIS SPCC) used in a cabin of a construction machinery.

1) Damping ratios of non-spot-welded sheet metals were independent of frequency and shape, so the damping ratio i.e. the material damping ratio was estimated as 0.07%.
2) The damping ratio of a flange member increases with increasing spot-pitch and decreases with increasing thickness.
3) The damping ratio of a spot-welded frame is smaller than that of a flange member under the same parameters and is larger than that of a non-spot-welded sheet metal.
4) The portion except the flange parts is predominant over the damping ratio of a spot-welded frame.
5) The influence of the thickness on damping ratio is small, when the portion except the flange parts has the rectangle section with the maximum side length less than the spot-pitch.
6) The influence of the thickness and that of the spot-pitch on damping ratio are large, when the portion except the flange parts has the rectangle section with the maximum side length not less than the spot-pitch.

References