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International Journal of Impact Engineering 31 (2005) 483–496
INTERNATIONAL JOURNAL OF IMPACT ENGINEERING
www.elsevier.com/locate/ijimpeng

Improvement of energy absorption of impacted column due to transverse impact

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Received 13 May 2003; received in revised form 19 October 2003; accepted 20 December 2003

Abstract

The effect of a transverse impact on the buckling behavior of a column under axial impact loading was experimentally investigated. A column under an axial impact was subjected to a transverse impact to instantaneously reduce the structural stiffness. It was found that the absorption of the axial impact energy increased due to the post-buckling deformation being enlarged by transverse impact, though the axial impact load decreased. The experiment showed that the time elapsed from the beginning of the axial impact to the transverse impact significantly influenced the energy absorption. A transverse impact applied simultaneously with an axial impact produced the highest energy absorption. To compare the efficiency of the present method, tests without a transverse impact on specimens that had dents were also conducted. It was confirmed that the present method could increase the energy absorption without loosing any structural stiffness or static strength.
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Keywords: Energy absorption; Axial impact; Transverse impact; Beam buckling

1. Introduction

Safety is a vital issue in the design of modern vehicles. Generally, when a vehicle collides, its structures collapse within the crushable zone to absorb the impact energy for safety of the passenger [1–3]. The most common method to easily collapse a vehicle is to reduce its structural stiffness by adding imperfections to the structure, such as dents and bents to the side members [4,5]. On the other hand, high stiffness in a structure is required as a primary design specification to give a better driving performance, and to reduce vibration and noise. In the practical design,

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doi:10.1016/j.ijimpeng.2003.12.009

Nomenclature

A	sectional area of axial impactor
A_0	minimum sectional area of specimen
c	velocity of longitudinal stress wave
E	young's modulus of axial impactor
E_{ab}	absorbed axial impact energy
$H(t)$	Heaviside step function
l	length of axial impact bar
P	axial impact load
P_{TF}	tensile failure load
Q	transverse impact load
t	time
t_T	transverse impact time
u	axial displacement at the top of specimen
v_A	axial impact velocity
v_T	transverse impact velocity
σ_y	yield stress
ε	strain of axial impact bar
ρ	density of axial impactor

however, the stiffness must be compromised to satisfy both requirements simultaneously. Since vehicle speed and driving comfort is expected to continually increase in the future, higher stiffness of the structure will be a very important requirement. Therefore, it is important to maintain high stiffness while improving the energy absorption using alternative ways.

In a previous study, the authors have investigated the effect of a transverse impact on the buckling behavior of a column under static axial compression to control energy absorption [6]. In this paper, the effect of a transverse impact on the buckling behavior of a column under axial impact loading was investigated experimentally. Particularly, the authors clarified that the axial energy absorption of a column was improved by applying a transverse impact. The method was proven to be more efficient than adding imperfections to a column.

Generating column buckling by applying an axial impact and generating beam bending by applying a transverse impact have been reported in several studies [7–9]. Some other studies describe the transverse impact problems of a structure that is simultaneously subjected to static axial force [10–13]. However, the effect of a transverse impact on the buckling behavior of a column under an axial impact has not been investigated yet, especially regarding energy absorption.

The experimental model considered in this study was a column that was axially impacted by a bar at the top end. During the axial impact, another bar transversely impacted the column to improve the axial energy absorption. To determine the efficiency of this method, axial impact tests on a dented column without a transverse impact were also conducted. Finally, this method was evaluated from the viewpoints of energy absorption and static structural properties.

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