

Dynamic Cyclic Bending, Kinetic to Strain Energy, Deceleration Systems.

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Abstract

During the period of 2001 to 2003 an investigation has been completed at the University of Pretoria, which explored the application of a cyclic plastic bending deceleration system in a dynamic environment. The system consisted of a user-defined number of inline guide rollers, with a metal element threaded in an over and under arrangement. This metal element, when drawn through the rollers, was subjected to bending and reverse bending as the material moved from roller to roller. This action allowed for kinetic energy to be absorbed by means of the kinetic to strain energy transformation mechanism. In the past, this concept and the performance prediction thereof had been proved reliable under quasi-static conditions however, the performance prediction under dynamic conditions remained uncharted.

The study performed at the University of Pretoria produced a dynamic performance prediction model. The various predictions were compared to scale experimental simulations, as well as dynamic finite element analyses. The comparison between the predictions, (mathematical prediction, experimental model results and the finite element analyses) proved to be extremely accurate and consistent. A full-scale evaluation would be the next remaining step to evaluate the system's suitability for future application in industry.

Opsomming

Gedurende die periode van 2001 tot 2003 was 'n studie afgehandel by die Universiteit van Pretoria, ten einde die toepassing van sikliese plastiese buigings vertraging sisteme, onder dinamiese toestande. Die sisteme behels n gebruiker-gespesifiseerde hoeveelheid staal rollers wat inlyn langs mekaar gerangskik is. 'n Staal strook word tussen die rollers deur gevleg. Wanneer die strook aan die een punt tussen die rollers deur gesleep word, buig die strook herhaaldelik om die spoor tussen die rollers deur te volg. Hierdie buigings proses absorbeer energie deur middle van omskakeling van kinetiese na vervormings energie. In die verlede is n model ontwikkel om breekkrag lewering onder kwasi-sitiese toestande betroubaar te voorspel. 'n Dinamiese lewerings model is nog nie ontwikkel nie.

Tydens die Universiteit van Pretoria se ondersoek is n dinamiese model ontwikkel en wiskundig geprogrammeer, wat dan die breekkrag lewering van die sisteem onder dinamiese toestande voorspel. Hierdie wiskundige voorspellings is dan vergelyk meet 'n afgeskaalde eksperimentele model wat gebou is by die Universiteit van Pretoria, asook 'n dinamiese eindige element analise van die model. Die vergelyking van al drie resultate, (wiskundige model, eksperimentele opstelling en die eindige element analise) was baie goed en herhaalbaar. Die volgende logiese ontwikkelings stadium in voorbereiding vir industriële teopassing van hierdie sisteme, sal dus volskalse toetse wees.

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List of symbols

a	Acceleration. (m/s^2)
D	Coefficient in stress strain relation. (Mild steel characteristic)
F	Force applied by deceleration system (N)
FEM	Finite Element Method
FEML	Finite Element Model
FEA	Finite Element Analysis
Gs	Gravitational acceleration. ($9.8m/s^2$)
M	Mass of cage. (kg)
Msec	Millisecond. (0.001sec)
n	Number of rollers in roller assembly.
p	Exponent in stress strain relation.
R	Roller radius (m)
t	Strip thickness (m)
w	Roller width (m)
σ_{yd}	Dynamic yield stress approximation. (Mpa)
σ_{yo}	Static yield stress of material. (Mpa)
ϵ'	Strain rate at the point of plastic deformation. (/s)
ϵ_x	Strain at distance y from neutral plane.
y	Distance from neutral plane. (m)
ρ	Curvature radius of neutral plane. (m)

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1 Introduction

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energy absorbing systems capable of harnessing and dissipating such large forces.

A possible hazard with such a device would be its failure under shock loading, which extensively involves the transport of vast amounts of potential energy and materials. Any resulting fragments could have the same kinetic energy as the decelerator over or under-ward. It is therefore essential that the decelerator and its components are exposed to the maximum amount of shock loading and subjected to failure tests under a load sustained over a period of up to 1000 hours. The decelerator system is of almost 1000 kg weight.

Against this background, the author has been invited by the National Commission for the Promotion of Science and Technology (COSTA) and the University of Pretoria to conduct a study on the design and development of a decelerator system for the purpose of protecting the crew of a space vehicle in the event of a launch abort. The study was conducted in two phases. In the first phase, the author conducted a literature survey and identified the key issues. In the second phase, the author conducted a series of experiments to identify the existing decelerator systems and their performance. The decelerator systems were evaluated and efforts were made to improve the design and develop their own decelerator system.

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A prominent problem with the highly effective systems used for crew restraint is its sensitivity to deceleration rate, and therefore, the velocity of the decelerated mass at impact [1,2]. This factor drastically varies the performance of a specific configuration under a constant condition, and that of a dynamic real life situation [3].

The first complication regarding the application of the system is the need to accurately and consistently predict the performance for any configuration and that, for any conceivable situation. This is important due to the stringent deceleration specifications which humans can be subjected to for limited periods of time [4]. The challenge is to incorporate the parameters of a dynamic deceleration system into a calculation which, when fed the operating conditions, would deliver an accurate performance prediction.