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Optimisation of a beam in bending subjected to severe inertia impact loading

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ABSTRACT

This paper summarises an optimal analytical study of a bar when it is subjected to shock inertia loading such that the severe bending causes permanent yielding. The findings are related to a practical case study application and help explain the necessary actions that have to be taken to minimise the impact damage. The analysis relates the sudden strain energy which the bar gains following an impact (when either the stationary bar is collected by a body moving with substantial momentum or alternatively when the moving bar is suddenly brought to a halt) and establishes the bending strength as a function of mass, stiffness and other kinematic conditions. The optimal analysis results in a surprising paradox which is borne out in the actual detail design solution to a critical component which had caused major maintenance problems in the braking system of a railed vehicle. The study reveals some interesting findings relating to the best bar configuration in terms of geometrical design, support locations and material choice.

1. Introduction

In this work we study a bar which is subjected to a severe impact causing bending and hence determine the subsequent shock stresses that occur due to the inertia beam force created. The objective of the analysis is to determine the optimal arrangement as although maximising bending strength and stiffness is necessary, the adding of material increases mass and thus the magnitude of the inertia force acting. Parameters which have been considered are the bar material properties, its geometry and the spacing position of the stops or, alternatively, the grabbing supports.

Two cases are considered, firstly when the bar is initially lying in a stationary state and then collected by a pair of striking grips which are moving at a speed V and with considerable momentum thus producing action forces F and causing the bar to move suddenly to that speed as shown in Fig. 1a. Also, the reverse situation, shown in Fig. 1b, which is where the beam moves with speed V and is then suddenly stopped by a pair of equally spaced rigid stops producing reaction forces F. Such situations occur in practise, in the braking system of the bobsleigh start track of the University of Bath (UK) [1], which is what stimulated the need for the study.

2. Strain energy

It is assumed that the bar of mass m is collected from stationary by a heavy vehicle of mass M ($M \gg m$), which moves at speed V_1 and forces the bar to move at speed V by forces F (see Fig. 1a).

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