Experimental Analysis Methods in the Study of a Shock Absorber Behaviour Under Dynamic Loads

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ABSTRACT

This paper deals with the analysis of the data obtained,during dynamic tests, by means of a high speed camera. These tests concerned the qualification of a carbon steel shell type shock absorber used for the protection of a spent fuel transport cask in the reference accident conditions foreseen by the relevant IAEA regulations./1/ The films, recorded during several drop test series on scale models,were analyzed in order to obtain informations about the overall dynamic behaviour of the cask and the plastic deformation mechanism of the shock absorber during the impact.

1. INTRODUCTION

For the study and design of the particular metallic shock absorber undergoing to large plastic deformation during the energy absorption phenomenon, it is very important to individuate exactly the deformation mechanism to which the absorbed kinetic energy values and transmitted load levels are strictly related.

At the "Dipartimento di Costruzioni Meccaniche e Nucleari" of the University of Pisa, a theoretical and experimental program /2/ for the qualification of a carbon steel shell type shock absorber was carried out in the frame of a research and development program supported by the ENEA. The shock absorber under study is used for the mechanical protection of a 64 tons LWR spent fuel transport packaging, designed and constructed by AGN (Fig. 1). In the case of this packaging, the most restrictive design conditions are defined by the reference accident conditions and expecially, at least from a structural point of view, by the 9 mt. free drop tests on an unyelding surface, foreseen in the IAEA transport regulations.

During the mentioned experimental program three series of 9 mt. drop tests on scale models(with weights ranging about 80 - 8000 kg) was performed.

The models were dropped in different positions(vertical, lateral and bended according to two different angles) on the target so that different parts of the shock absorber were directly involved in the impacts.

In the performed tests the meridional and circonferential strains in several points of the shock absorber surface as well as the cask model acceleration were registered by means of strain gauges and piezoelectric accelerometers respectively. Moreover the overall deformation and displacements

(*) Work performed within the frame-work of the ENEA safety research programmes (contract AC-5 ENEA - University of Pisa).

of the structures were recorded with an high speed camera (capable of recording up to 32000 ph/sec) and analyzed by means of a suitable film analyzer.

The results of this type of analysis are dealt with mainly in the present paper.

2. ANALYSIS OF DATA OBTAINED BY A HIGH SPEED CAMERA

During the impact tests the camera film rate was fixed between 1500 ÷ 3000 ph/sec, depending on the lighting available, the model dimensions and the fundamental frequencies of the phenomena.

The films were elaborated by means a film analyzer that allowed to determine the time-displacement relations of characteristic points of the cask models during the shock absorber deformation.

In the Figg. 2 - 3 the time-displacement curves of a charactetistic point (corresponding to an accelerometer position) of two different scale models for vertical drop tests are shown. In the Figg. 4 - 5 instead, for the same cask models, the corrisponding curves obtained in lateral drop tests are shown. In the tests of the above mentioned type, the model centroid trajectory, during the first impact, is easily defined being directly normal to the target. In the subsequent recoil phase the model angular oscillations are very small (few tenths of a degree) as it is possible to observe in the registered films.

In the case of the tests carried on, the time displacement relation, obtained by means of the film analysis, results to be in fine agreement with the data derived from the double integration of the acceleration recordings related to the vertical directions, as it is posssible to see from the comparison of the corresponding diagrams in the mentioned Figures 2 - 5. The slopes as well as the curvatures of the two types of curves are the same in practice, therefore the velocity and acceleration associated to the displacement-time relations result quite similar. The smoothness of the displacement diagram derived from the acceleration recordings depends on the effect of the numerical integration that tends to smooth the highest frequencies.

In the drop tests performed with the model axis bended toward the target surface, the mass centroid trajectory is not defined so easily. In these cases, the absolute orientation of the acceleration components , registered during the impact,are not known. Therefore the cask centroid displacement-time relation cannot be obtained by direct integration of the acceleration data and other informations are needed in order to associate a particular acceleration level to the relevant shock absorber mechanism of deformation. The high speed film analysis may be very usefull from this point of view. In Fig. 6 the horizontal and vertical displacement of a cask point (point A) as well as the axis rotation versus time,for a drop test performed on a model with the axis inclined by about 25 ° on the vertical,are shown. As it is possible to see, the cask kinetic energy is absorbed by several subsequent impacts on different points of shock absorber which allow to justify several otherwise hardly comprehensible singularities of the registered data.

In Fig. 7, the model acceleration components parallel (a_p) and normal (a_n) to the cask axis as well as the model position corresponding to several acceleration values, obtained by means of the film analysis ,are shown.

In the same Figure the corresponding values of the horizontal (a_o) and vertical (a_v) accelerations are reported as obtained combining the two components as follows:

$$a_o = a_p \sin \alpha + a_n \cos \alpha$$
$$a_v = a_p \cos \alpha - a_n \sin \alpha \qquad 1)$$

It is worth to point out the importance of the possibility of correlating the acceleration level and the shock absorber behaviour during the deformation in order to limit under a given value the overall dynamic load transmitted to the cask.

In the Fig. 8, for the vertical drop test,several pictures of the shock absorber deformation are shown.

3. CONCLUSIONS

The analysis of the data obtained in dynamic tests on shok absorbers by means of an high speed camera , seem to be in any case capable to supply a valuable and indipendent confirmation of the reliability of several types of tests data concerning the shock absorber behaviour as the levels of the acceleration transmitted to the protected structure.

Moreover this technique appears to be a necessary tool to analyze impacts where the trajectory of the body to be protected with the shock absorber is not known directly "a priori" as well as to individuate the deformation mechanism of complex structures under dynamic loads.

4. REFERENCES

/ 1 / IAEA - "Regulations for the safe transport of radioactive materials" S.S. n. 6 , 1973 Revised Edition - Vienna 1979

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/ 3 / AQUARO D. - G. FORASASSI "Analysis of the behaviour under impact loads of a shell type shock absorber for LWR spent fuel transport packaging" 7th International Symposium on packaging and transportation of radioactive materials". New Orleans, Louisiana USA 15-20 May 1983

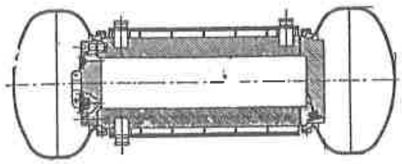
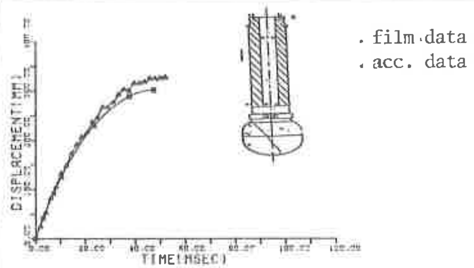


Fig. 1: Spent nuclear fuel cask model with the shell type shock absorber.



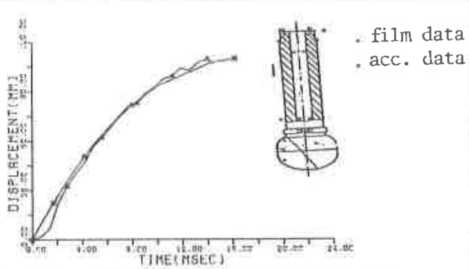
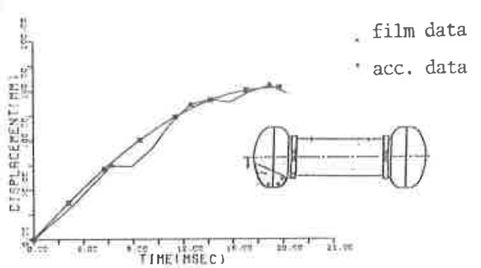


Fig. 2: Comparison between the time-displacement relations derived by the film analysis and acceleration integration for a vertical drop test with the large model.

Fig. 3: Comparison between the time-diplacement relations derived by the film analysis and acceleration integration for a vertical drop test with the small model.



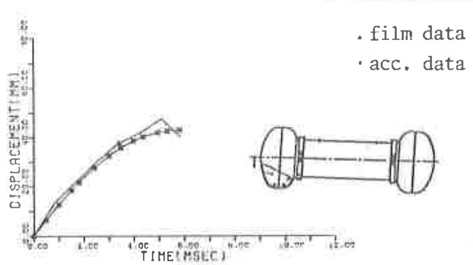


Fig. 4: Comparison between the time-displacement relations derived by the film analysis and acceleration integration for a lateral drop test with the large model.

Fig. 5: Comparison between the time-displacement relations derived by the film analysis and acceleration integration for a lateral drop test with the small model.

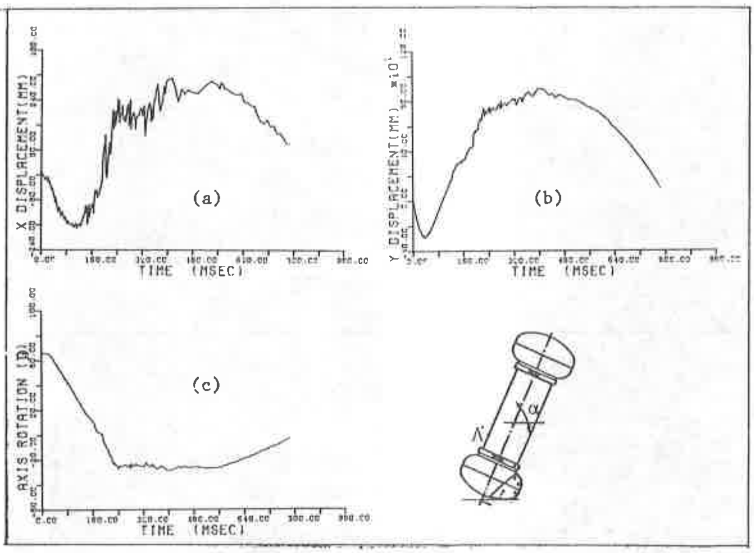


Fig. 6: Film analysis data obtained in axis inclined drop tests: point A horizontal (a) and vertical (b) displacement and axis rotation (c).

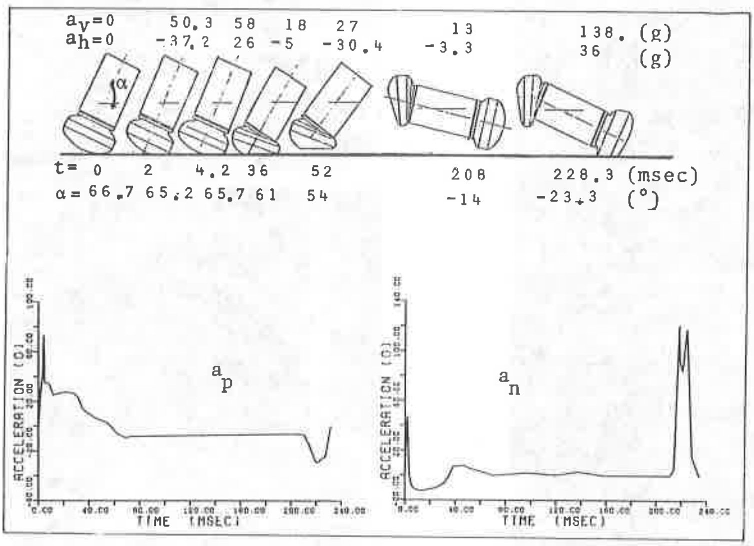


Fig. 7: Comparison between acceleration data and model configurations in an axis inclined drop tests.

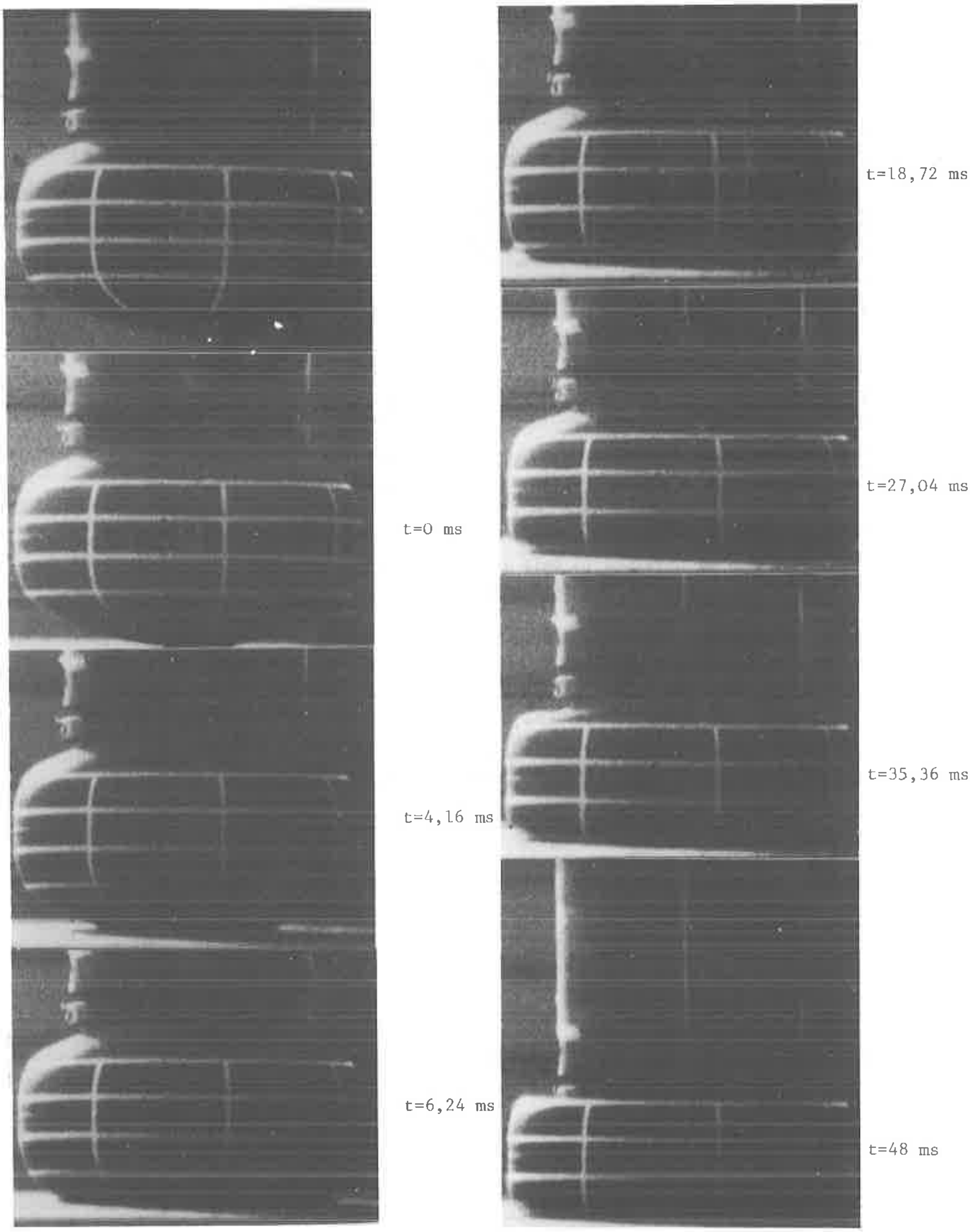


Fig. 8: Shock absorber deformation in a vertical drop test with the large model.