Experimental Testing of Impact Limiters for RAM Packages under Drop Test Conditions

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In context with new cask designs and their approval procedure the experimental testing of impact limiters under drop test conditions becomes more and more important in order to assess their damage mechanics behavior and safety margins for validation reasons. In recent years various designs of impact limiters have been tested by the Federal Institute for Materials Research and Testing (BAM) within specific component testing and particularly with regard to type B package approval procedures.The main objective of drop tests with RAM packages is to demonstrate that the containment and radiation shielding maintains its integrity during and after the mechanical tests as per normal and accident conditions of transport. Furthermore, the tests have to investigate the effectiveness of fixing of the shock absorbers at the cask.

Experimental Realization

BAM operates three drop test facilities to evaluate package response to mechanical tests demonstrating safety under mechanical accident conditions.

200 tons drop test facility

Indoor drop test facility

Drop test machine

characteristics	200 tons drop test facility	Indoor drop test facility	Drop test machine
max. mass of test object	200 000 kg	5 000 kg	1 000 kg
max. hook height	30 m	12.5 m	12 m
impact area	10 m x 4.5 m	4 m x 2 m	2 m x 2 m
target mass	2 630 000 kg	298 000 kg	18 000 kg
target area	14 m x 14 m	6 m x 6 m	2 m x 2 m

Material and Geometry

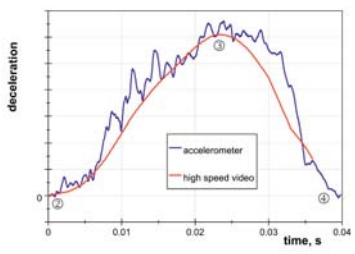
Typical constructions of impact limiters consist of compartments of built thin steel sheets filled with different types of wood and various compositions of directions of wood fibers. In most cases, layered spruce wood is inserted between the thin steel sheets. But other relevant filler materials are used, for example aluminum honeycombs or polyurethane foams. Wood or other damping materials absorb the major part of the kinetic energy, while the steel sheets provide the integrity of the impact limiter during the impact process and the fixation to the cask body. Moreover, the steel sheets restrain the lateral dilation of the wood inside the limiter.

Different impact limiters designs (unequal and equal octaeder, round, round with circumferential interruptions)

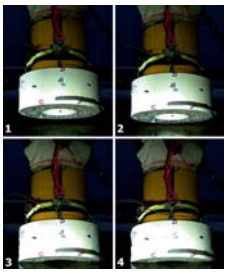
Impact limiter built of thin steel plates filled with wood of different kind and fiber direction

High-Speed Motion Analysis

High-speed video technique with motion analysis of an impacting specimen represents an practical verification for the analysis of the impact event and the kinematic behavior of the cask with impact limiters in addition to acceleration measurements. The chronological synchronization of high speed videos with corresponding acceleration time histories using adequate signal analysis software gives the opportunity for better mechanical interpretation and understanding analyzing acceleration signals, but also strain signals. Significant signal parts of the acceleration time curve during impact can be possibly related to visual mechanical events occurring at the impacting container or the target.



Comparison of deceleration time histories determined by high-speed video and accelerometer.



Impacting test specimen. Single shot from high-speed video (4000 fps) in chronological order.

Strain and Deceleration Measurement

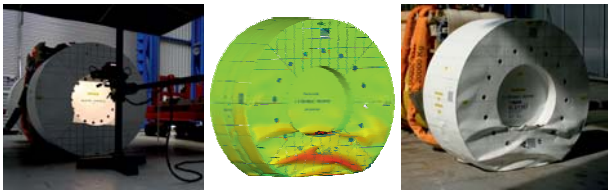
In drop tests the adequate instrumentation of a specimen with sensors is an important tool to evaluate its mechanical behavior during impact and to gain quantitative impact characterizing data. Generally, the instrumentation incorporates the measurement of strains and decelerations at the package. Test results as deceleration-time and strain-time functions constitute a main basis for the validation of assumptions in the safety analysis, for the evaluation of calculations based on finite-element methods as well as are important for extrapolation of scale model testing on full-sized package within approval design assessment. Also, these test results could be an advantageous basis for the assessment of design alterations.

Data acquisition (left), central soldering terminal (middle), accelerometer and strain gauge on an impact limiter (right)

3-d Surface Shape Measurement and Deformation Analysis

The optical fringe projection method in combination with close-range photogrammetry is especially suited to investigate impact limiters implementing 3-d roundabout surface digitization. The impact limiter deformation is calculated from the difference between the surface shapes originating from the after and before drop states. The digital impact limiter models can be used for a huge number of flexible documentation and analysis tasks without new or repeated measurements.

- Digital documentation of complete 3-d limiter shape in graphical data formats
- Shape deviation from CAD model
- Shape deformation with respect to the reference state before drop test
- Surface or point based verification of Finite-Element simulation
- Data evaluation of point like or feature coordinates
- Data evaluation using the approximation of various geometric primitives



3-d measurements with fringe projection method and close-range photogrammetry

Conclusion

Radioactive materials transport packages are usually equipped with impact limiters in order to reduce impact loading onto the package and its components for containment, shielding and criticality safety. Impact limiters can have various designs, and different materials are used for that purpose. To assess impact limiters functions, and to obtain quantitative data for the verification of calculations, a set of appropriate measurement techniques has to be applied during drop tests. BAM recommends strain and acceleration measurements, high-speed video for kinematic analysis and comparison with acceleration measurements and photogrammetry for evaluation of lid movement and projected fringe methods for quantitative impact limiter deformation analysis. The combined application of these methods provides a good knowledge on impact limiter behavior.

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