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# DEPENDENCY OF TEMPERATURE ON WOODEN MATERIALS' MECHANICAL PROPERTY AND EFFECT OF IMPACT ENERGY ABSORPTION OF SHOCK ABSORBERS

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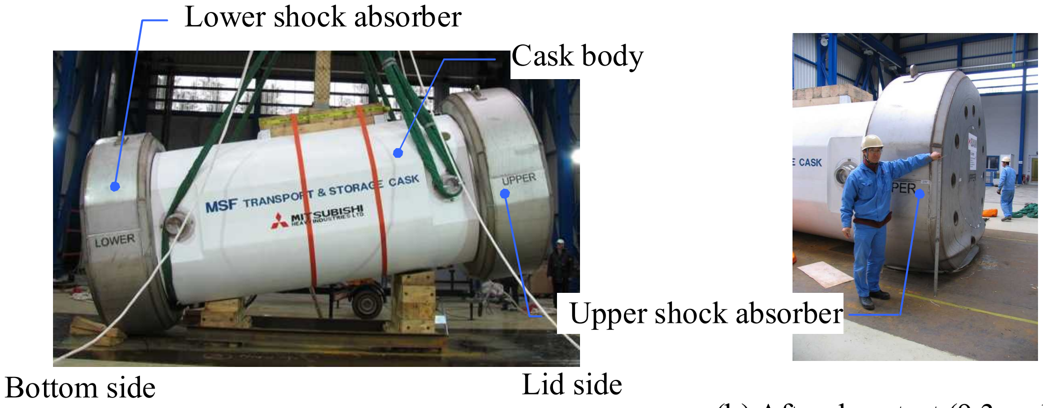
## 1. ABSTRACT

A series of drop tests with a full scale drop test model and a 1/2.5 scale drop test model for "MSF cask (Mitsubishi Spent Fuel Cask)" were conducted. Shock absorber compression tests were conducted at room temperature and at high temperature as well to confirm a temperature dependency of compression properties.
This paper indicates shock absorber compression test results concerning compression properties and their temperature dependency for shock absorber.

## 2. INTRODUCTION

MSF (Mitsubishi Spent Fuel) cask for transport and storage of higher burn-up and shorter cooling time fuels have been developed. A series of drop tests in line with IAEA transport regulations [1] were conducted with a full scale model and a 1/2.5 scale model by the German Federal Institute for Materials Research and Testing (BAM) to prove structural integrity of MSF cask. Figure 1 shows the full-scale drop test model used for slap-down drop test. To simulate an impact response in drop test, it is important to identify compression properties of shock absorber. It is also important to confirm a temperature dependency of compression properties because an actual cask would be subjected to elevated temperature. This paper describes wood element test results and shock absorber compression tests to obtain compression properties for wooden materials and for shock absorber respectively. Outline is as follows:
(1) Shock absorber for MSF cask
(2) Wood element tests
(3) Shock absorber compression tests




(a) Before drop test (b) After drop test (9.3m slap down)

**Figure 1. Full Scale Drop Test Model for MSF Cask**

## 3. SHOCK ABSORBERS FOR MSF CASK

### 3.1 Feature

Shock absorbers for drop test model consisted of three kinds of woods, inner and outer steel plates. Wood blocks were held and constrained by the inner steel plates and covered by outer steel plates. Oak wood with drilled holes, which had higher compression strength than the other wood materials, were arranged on the side of cask body. Red cedar and balsa wood were arranged on the upper side and at the corner. The shock absorbers had been manufactured under clearance control.

### 3.2 Energy absorption properties

Slap down tests with the full-scale model and 1/2.5 scale model were conducted and the acceleration time histories were obtained respectively. Figure 2 shows load – displacement characteristics during slap-down drop impact. A displacement of shock absorber was determined by double integral of acceleration value and a load from shock absorber to cask body by acceleration value times mass of cask. The characteristics for 1/2.5 scale shock absorber were converted to that of full scale model according to a similarity law.

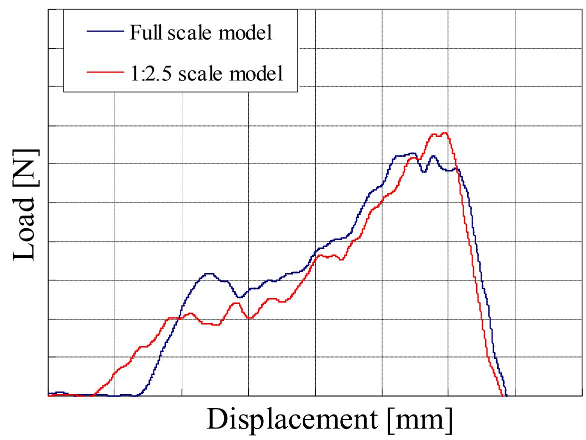



**Figure 2. Load–Displacement Characteristics obtained from Drop Tests**

## 4. WOOD ELEMENT TESTS

Wood element tests were conducted to obtain compression properties of each wood material as basic data. Constraint conditions and temperature conditions of wood specimen were considered as parameters.

### 4.1 Test conditions

Test matrix is shown in Table 1. Three kinds of test specimens shown in Figure 3 were applied.

High constraint : a test specimen was inserted into a steel constraint ring.

Medium constraint : a test specimen was inserted into a ring made of the same wood as the test specimen. They were also inserted into a steel pipe.

Low constraint : no constraint around a test specimen was provided.

### 4.2 Test system

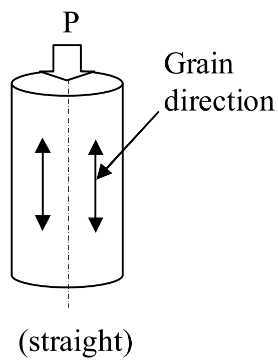
The wood element tests were conducted with a 9800kN press machine. A test specimen was placed in the center of the machine to compress it. At this time, load-time histories and displacement-time histories during compression were measured with a load cell and displacement gauges, respectively.

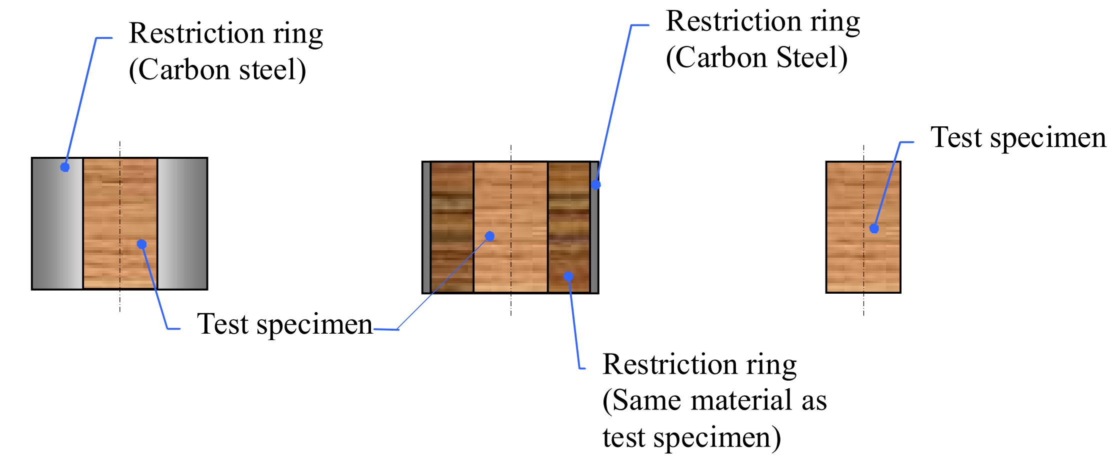
### 4.3 Test results

Figure 4 shows stress – strain curves for each wood material obtained from the wood element tests. In case with low constraint, the generated stress was relatively lower than the other conditions. In case with high constraint, the generated stress was increased in the range of high strain.

**Table 1. Test Matrix for Wood Element Tests**

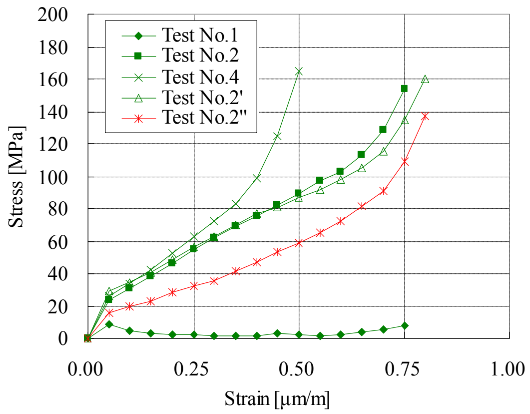
| Test No. | Material | Grain direction | Constraint | Temp.( ºC) |
|---|---|---|---|---|
| 1 | Oak | Straight | Low | RT |
| 2 | | | Medium | RT |
| 4 | | | High | RT |
| 2’ | Oak | Straight | Medium | RT |
| 2” | | | | 90 |
| 12 | Red Cedar | Straight | Low | RT |
| 13 | | | Medium | RT |
| 15 | | | High | RT |
| 13” | Red Cedar | Straight | Medium | 90 |
| 22 | Balsa | Straight | Medium | RT |
| 23 | | | | 90 |



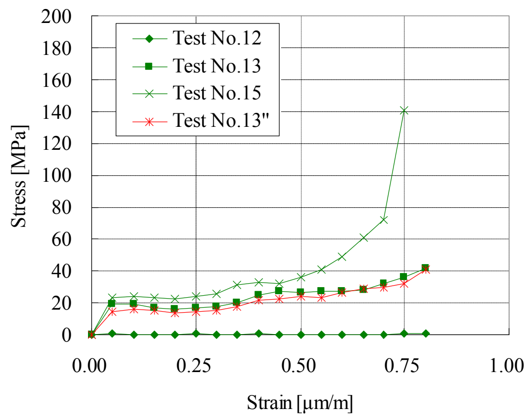



(a) High constraint (b) Medium constraint (c) Low constraint

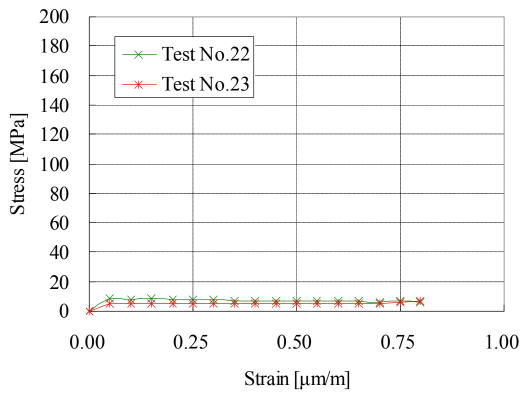
**Figure 3. Test Specimens**




(1) Oak (with drilled hole)




(2) Red Cedar (with drilled hole)




(3) Balsa

**Figure 4. Stress-strain Curves for each Wood Material**

## 5. SHOCK ABSORBER COMPRESSION TESTS

Shock absorber compression tests were conducted at the BAM test facility considering slap down condition. Because wood strength is known to have temperature dependency and to decrease the strength at elevated temperature [2], the tests were conducted at room temperature and at high temperature (average temperature of 100 ºC) to evaluate a temperature dependency of compression properties for shock absorber.

### 5.1 Test conditions

- Specimen: Semicircle type model of 1/2.5 scale shock absorber (drop test model)
- Temperature: room temperature, high temperature (average temperature of 100 ºC )*)

*) Heaters were embedded in a fixing mount to rise a temperature of specimen from inside, which simulated an actual shock absorber heated from cask body side. Wood temperatures were measured by thermo couples during heating and compression.

### 5.2 Test system

These tests were conducted with a 25MN press machine shown in Figure 5. A test specimen was placed in the center of the machine to compress it. At this time, load-time history and displacement-time history during compression was measured with a load cell and displacement gauges, respectively.

### 5.3 Test results

Figure 6 shows comparison of load-displacement characteristics obtained from the tests between at room temperature and at high temperature (average temperature of 100ºC). These results indicate as follows:

- Load-displacement characteristics at 100ºC (average) corresponded to 53±5% of that at room temperature regardless of strain value.

Figure 7 shows comparison of load-displacement characteristics between test results and analysis results. The analysis result was calculated with an in-house code “CASH” [3] using the stress-strain profile for each wood material obtained from the wood element tests under medium constraint. These results indicate as follows:

- Load was increased in a range of large deformation. Especially when deformation amount was more than 100mm, load was increased rapidly and difference between test results and analysis results became larger. This is because strain of wood itself was increased due to deformation and constrain conditions around the wood were higher.

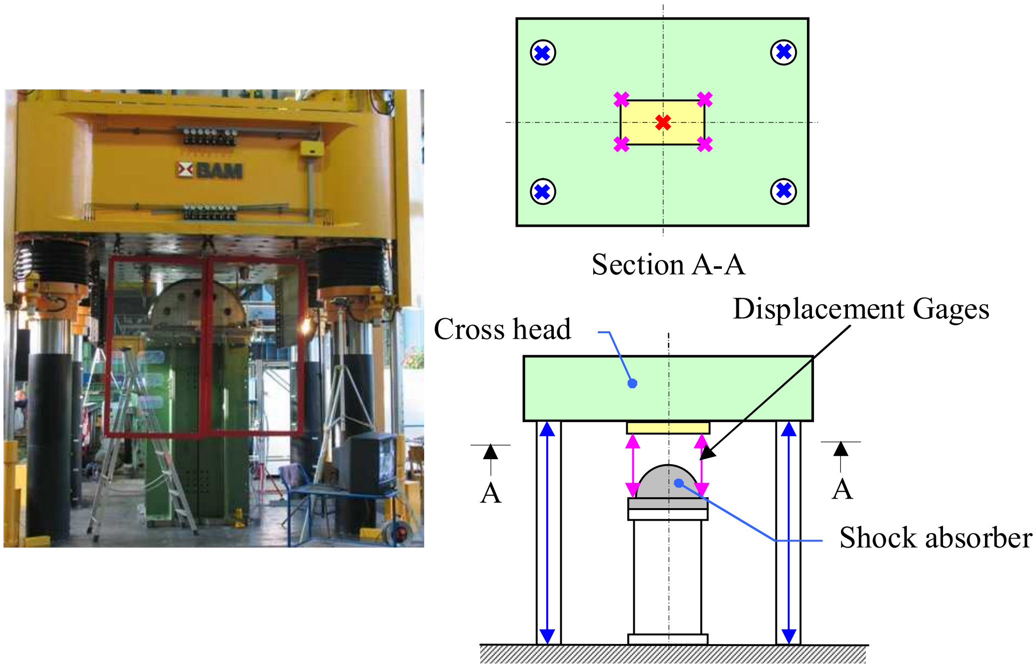



Figure 5. Compression Test System

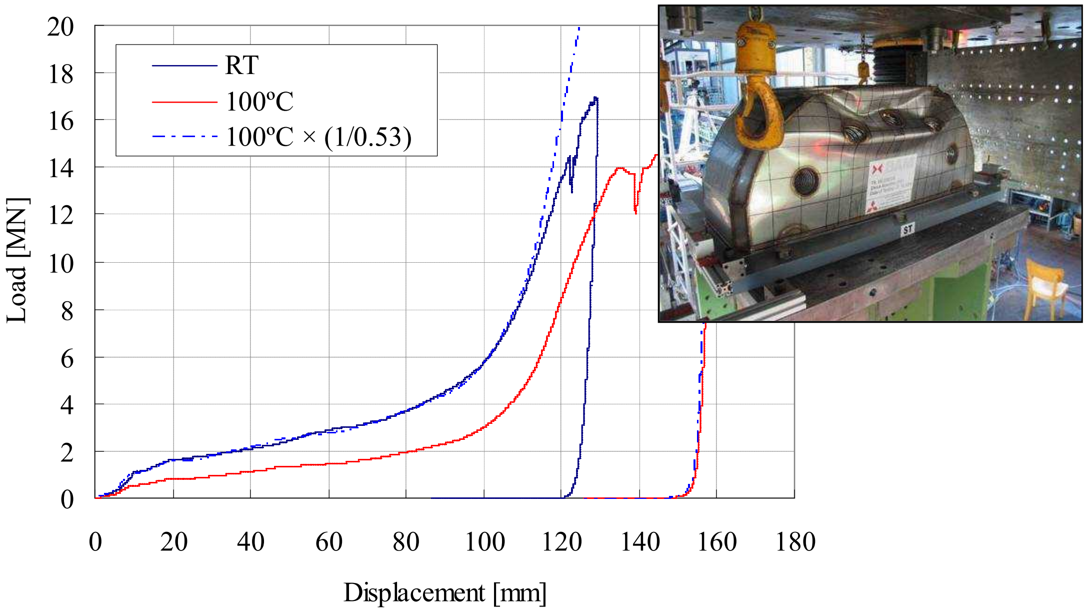



Figure 6. Comparison of Load–Displacement Characteristics between RT and 100ºC

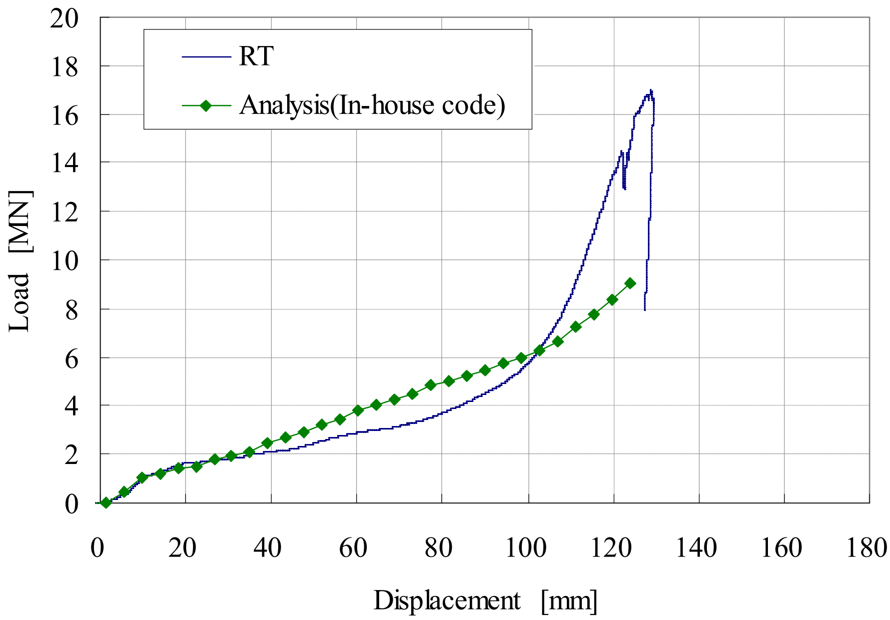



Figure 7. Comparison of Load–Displacement Characteristics between Test and Analysis

## 6. CONCLUSIONS

Wood element tests on three kinds of wood, which are applied to shock absorbers for MSF cask, were respectively conducted to obtain compression properties as basic data. These results confirmed that difference of properties was caused by constraint conditions. Compression properties as component of shock absorber were obtained from shock absorber compression tests at room temperature and at elevated temperature. As a result, wood strength decreased at a constant rate regardless of strain value. Compression properties obtained from the shock absorber compression tests are used for establishment of a shock absorber analysis model for MSF cask.

## 7. ACKNOWLEDGMENTS

MHI thanks BAM for giving MHI the opportunity to present pictures taken on the BAM test facilities in Germany. Statements in this presentation concerning test results reflect MHI's point of view only; MHI's statements do not represent the official BAM point of view, and are subject to further investigations within the German licensing procedure.

## 8. REFERENCES

[1] : Regulations for the Safe Transport of Radioactive Material, 2005 Edition Safety Requirements, Safety Standards Series No. TS-R-1 (Date of Issue: Thursday, 15 September, 2005)
[2] : F. Kollmann, " Technologie des Holzes u. der Werkstoffe" 2Aufl. Bd.1 (1951)
[3] : T.Ikushima(JAERI) and S.Hode(MHI), Simplified Analysis Computer Programs and Their Adequacy for Radioactive Materials Shipping Casks, PATRAM 1989.