

## **Mechanical properties determined by uniaxial compression test at room temperature of DPX-5**

Gunnar Ove Nevstad

Forsvarets forskningsinstitutt/Norwegian Defence Research Establishment (FFI)

3 June 2008

FFI-rapport 2008/01156

87301

P: ISBN 978-82-464-1459-1

E: ISBN 978-82-464-1460-7

## **Keywords**

DPX-5

Mekanisk testing

Kompresjon

## **Approved by**

Jan Ivar Botnan

Director

## Sammendrag

Legemer av DPX-5 Lot DDP07J0001E Ch 01/07 har vært presset ved romtemperatur under vakuum med en holdetid på 60 sekunder og en kraft på 2000 kp/cm<sup>2</sup> etterfulgt av kompresjonstest for måling av mekaniske egenskaper ved romtemperatur. Gjennomsnittlig oppnådde resultater var med hensyn på maks stress 2.46 MPa, forlengelse ved maks stress 4.26 % og E-modulus 101.0 MPa. Dette er resultater som forventet for denne type komposisjon.

## English summary

Pellets of DPX-5 Lot DDP07J0001E Ch 01/07 pressed at room temperature under vacuum with a dwell time for 60 s and a force of 2000 kp/cm<sup>2</sup> have been tested in uniaxial compressive test at room temperature. Obtained average results for max stress are 2.56 MPa, strain at max stress 4.26% and E-modulus 101 MPa are all as expected.

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## 1 Introduction

M72 LAW (Light Antiarmour Weapon) has been redesigned with a new warhead for urban warfare. M72 ASM-RC (Anti-Structure Munition Reduced Caliber) has as the name indicates a new warhead for combat in light buildings. This requires a main charge explosive different from that used in shaped charge warheads. Candidates as main charge explosive are aluminized PBXs which can be press filled into the warhead. Recently DPX-6 has been qualified according to STANAG 4170 (1) and accompanying AOP-7 (2) and fulfils the requirements to be a candidate as main charge explosive for M72 ASM-RC. One other candidate is DPX-5 having more HMX and less aluminium than DPX-6. DPX-5 is at the moment not type qualified. Uniaxial compressive testing are not separate tests of the qualification programme, but since an ageing programme (3) were these properties normally are obtained during the qualification will not be performed we did the tests separately.

Here we will report on uniaxial compressive properties of DPX-5 pellets pressed under vacuum at room temperature. The uniaxial compressive test has been performed according to STANAG 4443 (4).

## 2 Experimentally

### 2.1 Pressing

The tested pellets contained DPX-5 from Lot No DDP07J0001E Ch. 01/07. Control report for the used explosive is given in Appendix A. All pellets were pressed by Chemring Nobel AS. The pressing was carried out with a force of 2000 kp/cm<sup>2</sup> at room temperature under vacuum with a dwell time of 60s.

### 2.2 Uniaxial Compressive Test

The compression testing was performed on a MTS, High Rate Test System on cylindrical charges with diameter 20.88±0.02 mm and height 22.7±0.1 mm. The compression rate was 50 mm/min. Precondition time was 2 hours or more. The used test conditions were as described in STANAG 4443 (4). All pellets were tested by use of a load cell of 5 kN. Appendix B gives test report sheets for every tested pellets and contains all necessary information about each pellet and the condition under which they were tested. In addition the test report sheet shows the stress-strain curve.

### 3 Results

#### 3.1 Density of tested pellets

We did receive 6 pellets of DPX-5 Ch. 01/07 to be tested in compression tests. Before testing the pellets were measured with regard to diameter and height in addition to the weight. Tabl1 3.1 summaries the obtained results, in addition the table gives calculated density.

Pellet No	Height (mm)	Diameter (mm)	X-Sect. Area (mm <sup>2</sup> )	Volume (mm <sup>3</sup> )	Weight (g)	Density (g/cm <sup>3</sup> )
1	22.64	20.88	342.41	7752.24	15.1776	1.958
2	22.73	20.88	342.41	7783.06	15.1968	1.953
3	22.67	20.88	342.41	7762.51	15.1915	1.957
4	22.74	20.88	342.41	7786.48	15.1792	1.949
5	22.71	20.88	342.41	7776.21	15.1951	1.954
6	22.74	20.88	342.41	7786.48	15.2182	1.954
Average						1.954±0.003

Table 3.1 Properties of pressed pellets to be tested mechanically

#### 3.2 Compression properties

Figure 3.1 gives all stress strain curves obtained for the tested pellets. The form of the curves has small variation. Three of the pellets have a slightly higher maximum stress than the last three.

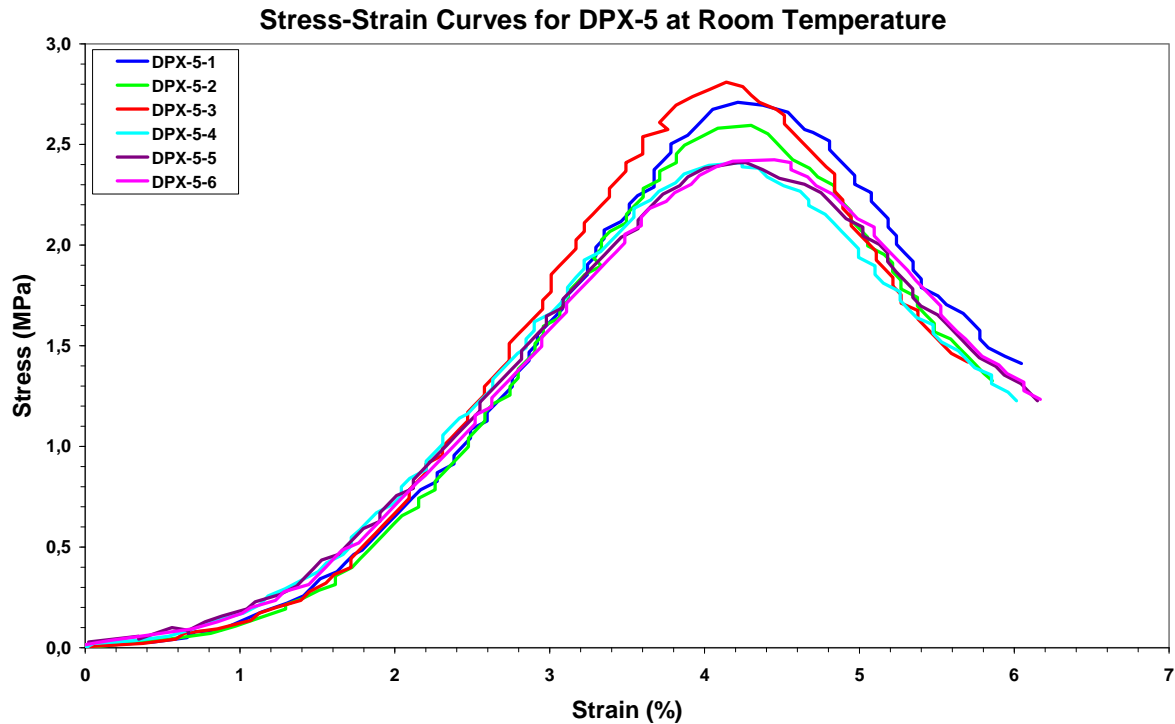


Figure 3.1 Stress strain curves for DPX-5 at room temperature.



For the strain at maximum stress the differences between the six curves are small. Table 3.2 summarizes the obtained results for each tested pellet in addition to the average results for all tested pellets.

<b>Pellet No</b>	<b>Max Stress (MPa)</b>	<b>Strain at Max Stress (%)</b>	<b>E-Modulus (MPa)</b>
<b>DPX-5-1</b>	2.709	4.21	109.48
<b>DPX-5-2</b>	2.595	4.30	106.79
<b>DPX-5-3</b>	2.809	4.14	113.81
<b>DPX-5-4</b>	2.409	4.24	93.00
<b>DPX-5-5</b>	2.410	4.22	91.46
<b>DPX-5-6</b>	2.424	4.45	91.21
<b>Average</b>	<b>2.56+0.17</b>	<b>4.26+0.11</b>	<b>101.0+10.2</b>

*Table 3.2 Table 3.2 gives the compressive properties for DPX-5 at room temperature.*

The obtained results for DPX-5 are different with regard to max stress compared with the results we obtained for DPX-6 produced under the same conditions. DPX-6 is a similar composition as DPX-5 except the HMX/Al ratio. For DPX-6 we obtain 10.2 MPa for max stress compared to only 2.6 MPa for DPX-5. The average compression at max stress is slightly higher for DPX-5 than for DPX-6, 4.3 % compared to 4.0 %. With regard to E-modulus the values for DPX-6 are 4 times as high as for DPX-5 due to the much higher max stress.

## Appendix A Control Report for DPX-5 Ch 01/07

CHEMRING NOBEL AS  
High Energy Materials

Kontrollrapport  
etter EN 10204 – 2.2

Kjøper / Mottaker Nammo Raufoss AS Postboks 162 2831 Raufoss	Bestillingsnummer 59919-1/SOL/3				Rapportnummer RD-16/07	
	Bestillingsdato 12.09.07				Kontroll dato 04.10.07	
Produsent Chemring Nobel AS High Energy Materials N-3475 Sætre NORGE	Produksjonsdato Sept 2007				Offentlig oppdragsnummer	
	Lot nummer DDP07J0001E				Mengde 100 kg	
Sprengstofftype DPX-5				Leveringsbetingelser/Teknisk underlag Spesifikasjon 016/00-K-005		
<b>Analyseresultater</b>						
	Sammensetning				Fuktighet	Volumvekt
	HMX	Aluminium	HyTemp	DOA		
KRAV	64,4±2,0 %	30,0±2,0 %	1,4±0,5 %	4,2±1,0 %	≤ 0,10 %	Min 0,80 g/cm <sup>3</sup>
RESULTAT Ch 01/07	66,3	30,0	0,9	2,8*	0,02	1,04
	Granulatfordeling, % gjennom USSS Nr.					
	6 (3350 μ)	8 (2360 μ)	12 (1700 μ)	18 (1000 μ)	25 (710 μ)	40 (425 μ)
KRAV	Informativ	Informativ	Informativ	Informativ	Informativ	Informativ
RESULTAT Ch 01/07	100	100	97	51	14	1
<p>*: Avvik godkjent av J.C.Olsen pr tlf 5/10-07 Fremmede partikler: Ingen</p> <p><i>Øyvind H. Johansen</i> Øyvind H. Johansen FoU Sjef</p> <p><i>Alf Berg</i> Alf Berg Senior Produkt Ingeniør</p>						

Figure A.1 Copy of the Control report for tested DPX-5.

## Appendix B Uniaxial Compression Data Test Sheets

### TEST REPORT SHEET

Uniaxial Compressive Test

Page 1 of 6 Pages

#### TEST SITE INFORMATION

Laboratory: FFI  
 Date: 14 January 2008  
 Test Procedure:  
 NATO Test Procedure Number: 102.01  
 Date Tested: 04 December 2007  
 POC: Gunnar Ove Nevstad

#### TEST CONDITIONS

Temperature (°C): 20  
 Relative Humidity (%): NA  
 X-Head Speed (mm/min): 50  
 Machine Type: MTS Servo Hydraulic Tester  
 Grip Type:  
 Machine Stiffness (kN/mm):

#### SPECIMEN INFORMATION

Dimensions: Length (Gage Length): 22.64 mm  
 Width:  
 Thickness (Diameter): 20.88 mm  
 X-Sectional Area (mm<sup>2</sup>): 342.41

Form: *Cylindrical*

Preparation Method: *As received L/D=1.0843*

Manufacturing Method: *Pressed at room temperature with Vacuum, Dwell time 60 s, Force 2000 kp/cm<sup>2</sup>.*

Source: *Chemring Nobel AS*

Lot or ID Number: *Ch 01/07 Pellet No1*

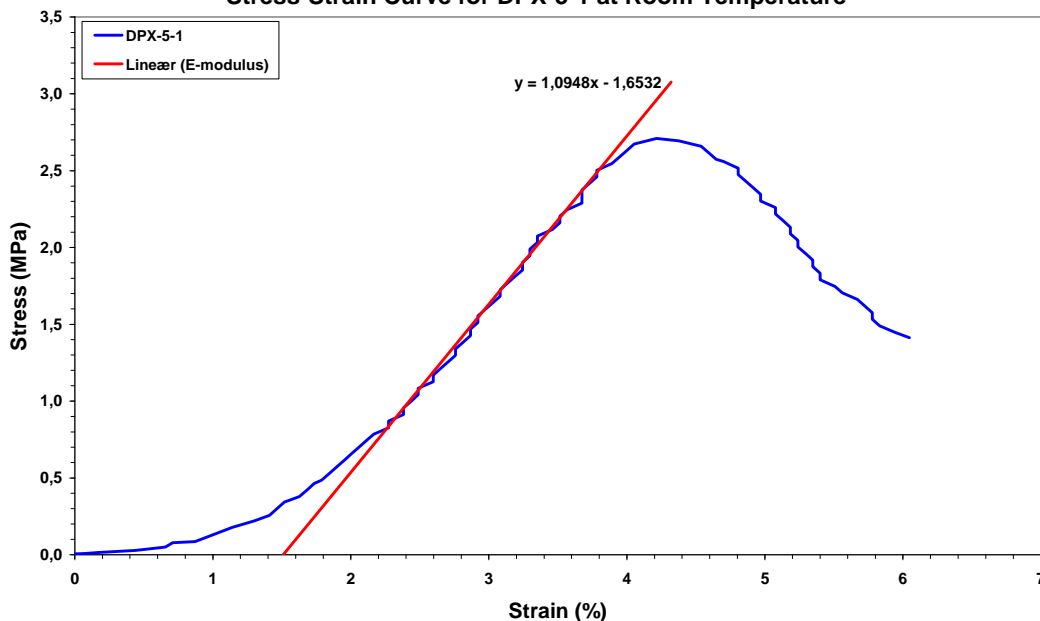
Preconditioning:

Condition Period: *2 hours*

Composition: **DPX-5**

Component	Percent
<u>HMX</u>	<u>66.3</u>
<u>Aluminium</u>	<u>30.0</u>
<u>DOA</u>	<u>2.8</u>
<u>HYTEMP</u>	<u>0.9</u>

Stress-Strain Curve for DPX-5-1 at Room Temperature



Max STRESS: 2.709 MPa

STRAIN at Max Stress: 4.21 %

E-Modulus: 109.48 MPa

**TEST REPORT SHEET**  
Uniaxial Compressive Test

Page 2 of 6 Pages

**TEST SITE INFORMATION**

Laboratory: FFI  
Date: 15 January 2008  
Test Procedure:  
NATO Test Procedure Number: 102.01  
Date Tested: 04 December 2006  
POC: Gunnar Ove Nevstad

**TEST CONDITIONS**

Temperature (°C): 20  
Relative Humidity (%): NA  
X-Head Speed (mm/min): 50  
Machine Type: MTS Servo Hydraulic Tester  
Grip Type:  
Machine Stiffness (kN/mm):

**SPECIMEN INFORMATION**

Dimensions: Length (Gage Length): 22.73 mm  
Width:  
Thickness (Diameter): 20.88 mm  
X-Sectional Area (mm<sup>2</sup>): 342.41

Form: *Cylindrical*

Preparation Method: *As received L/D=1.0886*

Manufacturing Method: *Pressed at room temperature with vacuum, Dwell time 60 s, Force 2000 kp/cm<sup>2</sup>.*

Source: *Chemring Nobel AS*

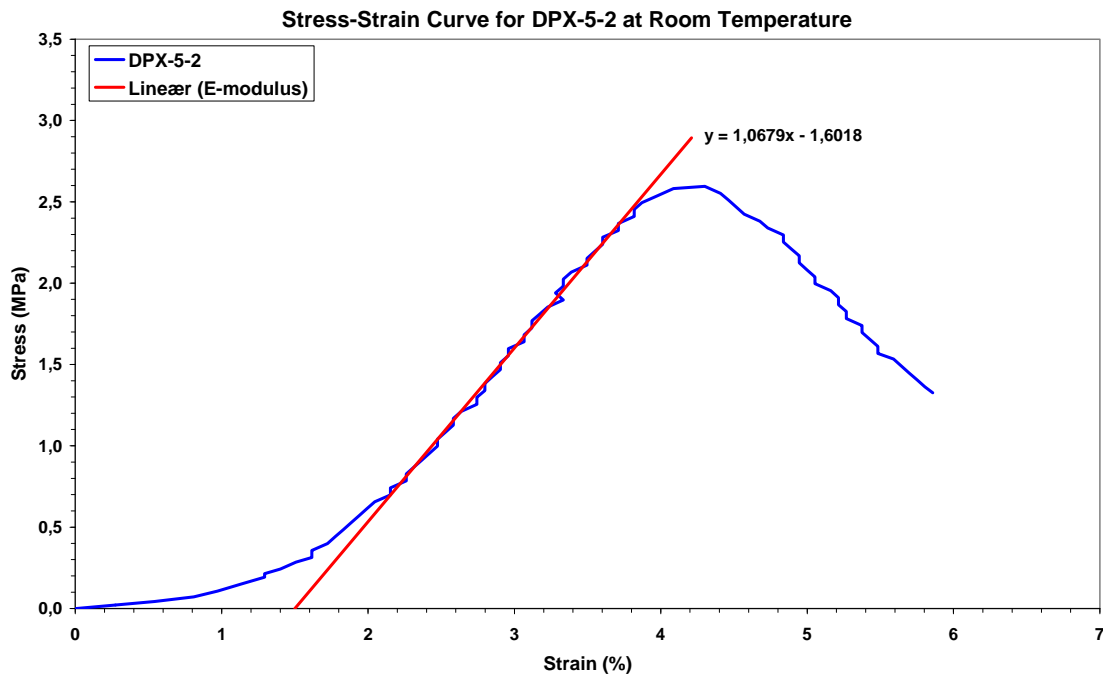
Lot or ID Number: *Ch 01/07 Pellet No 2*

Preconditioning:

Condition Period: *2 hours*

Composition: **DPX-5**

Component	Percent
<u>HMX</u>	<u>66.3</u>
<u>Aluminium</u>	<u>30.0</u>
<u>DOA</u>	<u>2.8</u>
<u>HYTEMP</u>	<u>0.9</u>
<u> </u>	<u> </u>



Max STRESS: 2.595 MPa

STRAIN at Max Stress: 4.301 %

E-Modulus: 106.79 MPa

**TEST REPORT SHEET**  
Uniaxial Compressive Test

Page 3 of 6 Pages

**TEST SITE INFORMATION**

Laboratory: FFI  
Date: 15 January 2008  
Test Procedure:  
NATO Test Procedure Number: 102.01  
Date Tested: 04 December 2006  
POC: Gunnar Ove Nevstad

**TEST CONDITIONS**

Temperature (°C): 20  
Relative Humidity (%): NA  
X-Head Speed (mm/min): 50  
Machine Type: MTS Servo Hydraulic Tester  
Grip Type:  
Machine Stiffness (kN/mm):

**SPECIMEN INFORMATION**

Dimensions: Length (Gage Length): 22.67 mm  
Width:  
Thickness (Diameter): 20.88 mm  
X-Sectional Area (mm<sup>2</sup>): 342.41

Form: *Cylindrical*

Preparation Method: *As received L/D=1.0857*

Manufacturing Method: *Pressed at room temperature with vacuum, Dwell time 60 s, Force 2000 kp/cm<sup>2</sup>.*

Source: *Chemring Nobel AS*

Lot or ID Number: *Ch 01/07 Pellet No 3*

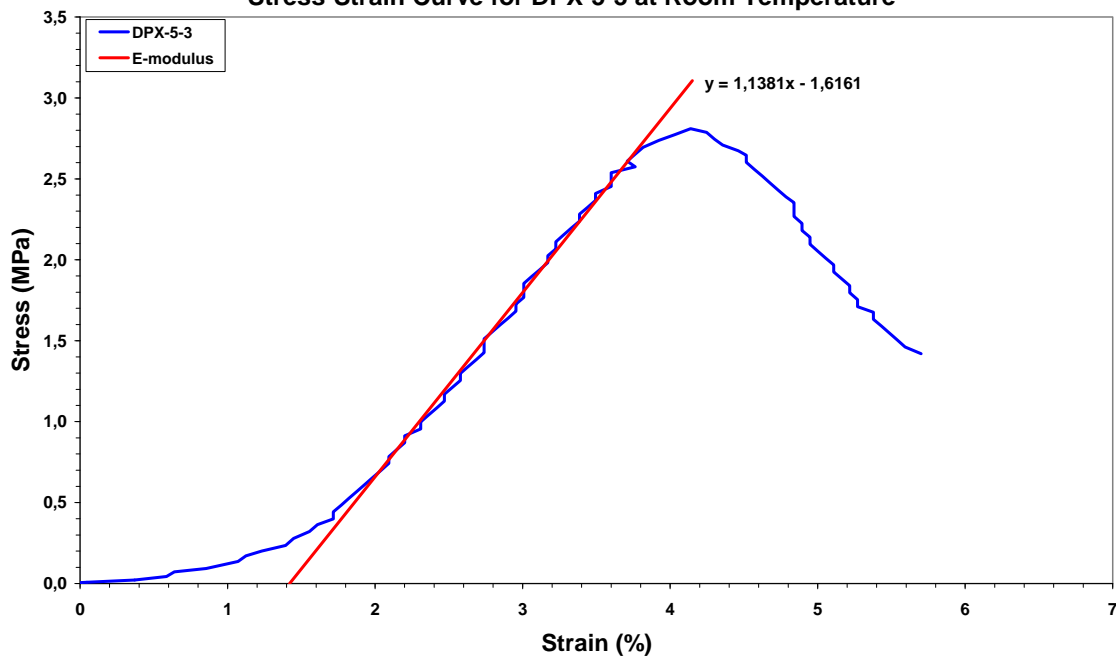
Preconditioning:

Condition Period: *2 hours*

Composition: **DPX-5**

Component	Percent
<u>HMX</u>	<u>66.3</u>
<u>Aluminium</u>	<u>30.0</u>
<u>DOA</u>	<u>2.8</u>
<u>HYTEMP</u>	<u>0.9</u>
<u> </u>	<u> </u>

**Stress-Strain Curve for DPX-5-3 at Room Temperature**



Max STRESS: 2.809 MPa

STRAIN at Max Stress: 4.139 %

E-Modulus: 113.81 MPa

**TEST REPORT SHEET**  
Uniaxial Compressive Test

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**TEST SITE INFORMATION**

Laboratory: FFI  
Date: 15 January 2008  
Test Procedure:  
NATO Test Procedure Number: 102.01  
Date Tested: 04 December 2006  
POC: Gunnar Ove Nevstad

**TEST CONDITIONS**

Temperature (°C): 20  
Relative Humidity (%): NA  
X-Head Speed (mm/min): 50  
Machine Type: MTS Servo Hydraulic Tester  
Grip Type:  
Machine Stiffness (kN/mm):

**SPECIMEN INFORMATION**

Dimensions: Length (Gage Length): 22.74 mm  
Width:  
Thickness (Diameter): 20.88 mm  
X-Sectional Area (mm<sup>2</sup>): 342.41

Form: *Cylindrical*

Preparation Method: *As received L/D=1.0891*

Manufacturing Method: *Pressed at room temperature with vacuum, Dwell time 60 s, Force 2000 kp/cm<sup>2</sup>.*

Source: *Chemring Nobel AS*

Lot or ID Number: *Ch 01/07 Pellet No 4*

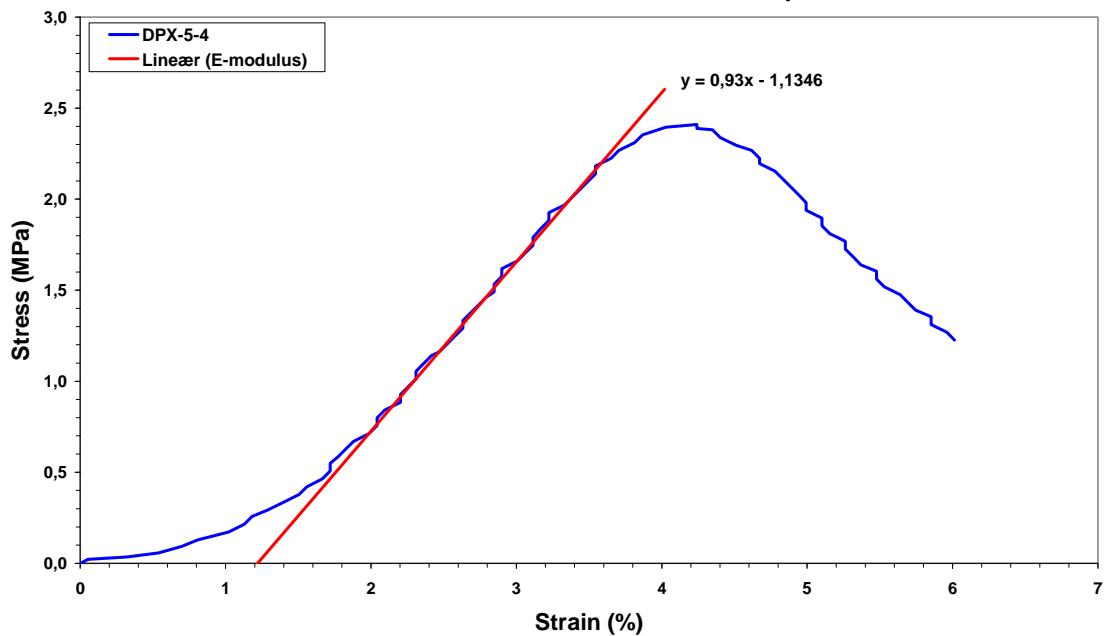
Preconditioning:

Condition Period: *2 hours*

Composition: **DPX-5**

Component	Percent
<u>HMX</u>	<u>66.3</u>
<u>Aluminium</u>	<u>30.0</u>
<u>DOA</u>	<u>2.8</u>
<u>HYTEMP</u>	<u>0.9</u>

**Stress-Strain Curve for DPX-5-4 at Room Temperature**



Max STRESS: 12.409 MPa

STRAIN at Max Stress: 4.24 %

E-Modulus: 93.0 MPa

**TEST REPORT SHEET**  
Uniaxial Compressive Test

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**TEST SITE INFORMATION**

Laboratory: FFI  
Date: 15 January 2008  
Test Procedure:  
NATO Test Procedure Number: 102.01  
Date Tested: 04 December 2006  
POC: Gunnar Ove Nevstad

**TEST CONDITIONS**

Temperature (°C): 20  
Relative Humidity (%): NA  
X-Head Speed (mm/min): 50  
Machine Type: MTS Servo Hydraulic Tester  
Grip Type:  
Machine Stiffness (kN/mm):

**SPECIMEN INFORMATION**

Dimensions: Length (Gage Length): 22.71 mm  
Width:  
Thickness (Diameter): 20.88 mm  
X-Sectional Area (mm<sup>2</sup>): 342.41

Form: *Cylindrical*

Preparation Method: *As received L/D=1.0876*

Manufacturing Method: *Pressed at room temperature with vacuum, Dwell time 60 s, Force 2000 kp/cm<sup>2</sup>.*

Source: *Chemring Nobel AS*

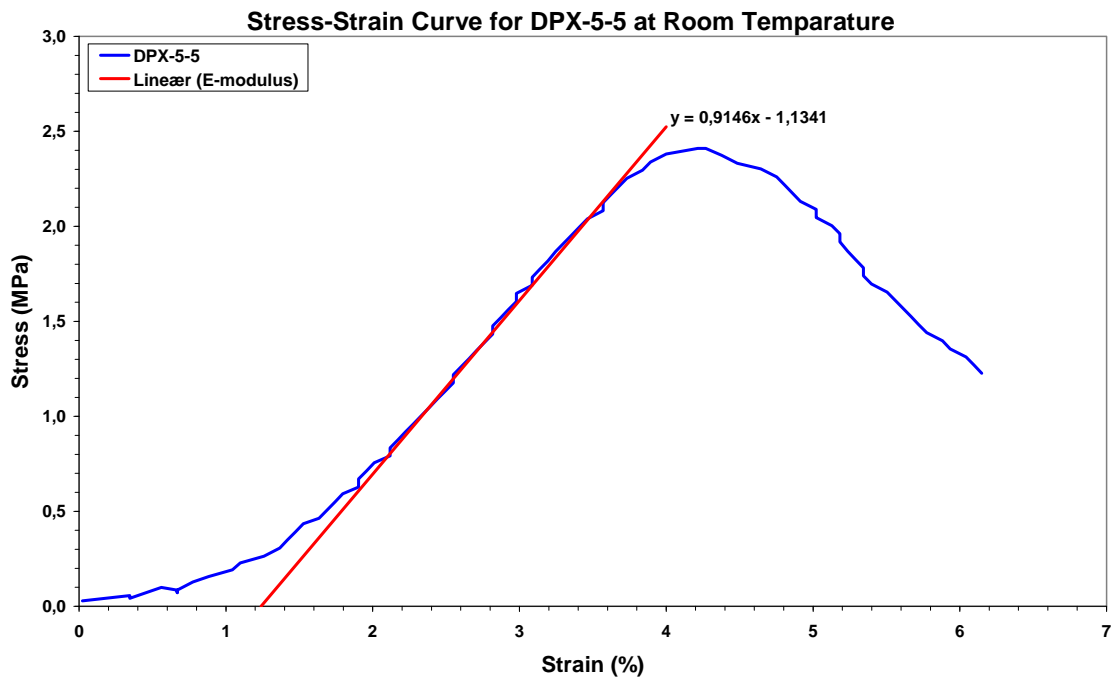
Lot or ID Number: *Ch 01/07 Pellet No 5*

Preconditioning:

Condition Period: *2 hours*

Composition: **DPX-5**

Component	Percent
<u>HMX</u>	<u>66.3</u>
<u>Aluminium</u>	<u>30.0</u>
<u>DOA</u>	<u>2.8</u>
<u>HYTEMP</u>	<u>0.9</u>



Max STRESS: 2.410 MPa

STRAIN at Max Stress: 4.215 %

E-Modulus: 91.46 MPa

**TEST REPORT SHEET**  
Uniaxial Compressive Test

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**TEST SITE INFORMATION**

Laboratory: FFI  
Date: 15 January 2008  
Test Procedure:  
NATO Test Procedure Number: 102.01  
Date Tested: 04 December 2006  
POC: Gunnar Ove Nevstad

**TEST CONDITIONS**

Temperature (°C): 20  
Relative Humidity (%): NA  
X-Head Speed (mm/min): 50  
Machine Type: MTS Servo Hydraulic Tester  
Grip Type:  
Machine Stiffness (kN/mm):

**SPECIMEN INFORMATION**

Dimensions: Length (Gage Length): 22.74 mm  
Width:  
Thickness (Diameter): 20.88 mm  
X-Sectional Area (mm<sup>2</sup>): 342.41

Form: *Cylindrical*

Preparation Method: *As received L/D=1.0891*

Manufacturing Method: *Pressed at room temperature with vacuum, Dwell time 60 s, Force 2000 kp/cm<sup>2</sup>.*

Source: *Chemring Nobel AS*

Lot or ID Number: *Ch 01/07 Pellet No 6*

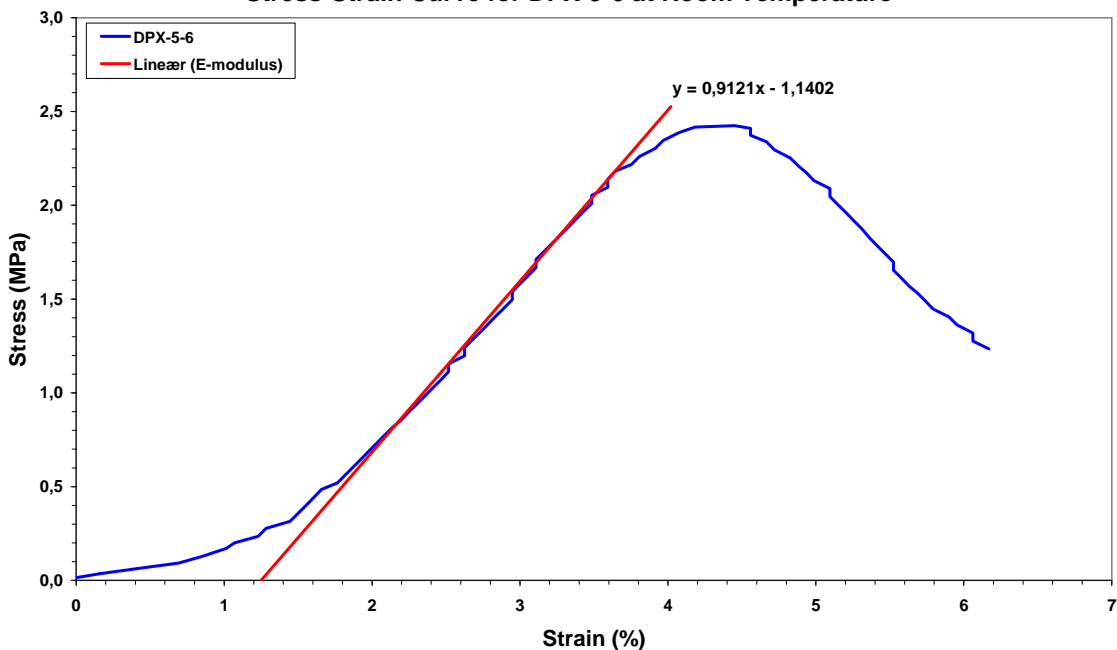
Preconditioning:

Condition Period: *2 hours*

Composition: **DPX-5**

Component	Percent
<u>HMX</u>	<u>66.3</u>
<u>Aluminium</u>	<u>30.0</u>
<u>DOA</u>	<u>2.8</u>
<u>HYTEMP</u>	<u>0.9</u>

**Stress-Strain Curve for DPX-5-6 at Room Temperature**



Max STRESS: 2.424 MPa

STRAIN at Max Stress: 4.45 %

E-Modulus: 91.21 MPa



## References

- (1) NATO (AC/326 Subgroup 1) (2001): STANAG 4170 Edition 2, "Principles and Methodology for Qualification of Explosive Materials for Military Use".
- (2) NATO /AC/326 Subgroup 1) (2004): AOP-7, Edition 2 Rev. 1, "Manual of Data Requirements and Tests for the Qualification of Explosive Materials for Military Use".
- (3) NEVSTAD Gunnar Ove (2006): Mechanical properties of DPX-6 before and after accelerated Ageing at 71°C, FFI/RAPPORT-2006/13686, Unclassified.
- (4) NATO /MAS (1998): STANAG 4443 PPS (Edition 1), "Explosives Uniaxial Compressive Test ". MAS/285-PPS/4443, 14 July.