GREAT DESIGNS IN STEEL

A COMPREHENSIVE CHARACTERIZATION OF NEXMET® 1000 FORMABILITY

Wei Wu, Ph.D
Research & Innovation, AK Steel Corporation
What is NEXMET® 1000?
NEXMET 1000 is next generation (3rd generation) advance high strength steel (AHSS) of AK Steel Corporation. It can be categorized as carbon steel or TRIP-assisted Quenched and Partitioned (Q&P) steel.

Where is NEXMET® 1000 produced?
NEXMET 1000 is manufactured locally in Dearborn, MI.
MECHANICAL PROPERTIES

<table>
<thead>
<tr>
<th></th>
<th>YS (MPa)</th>
<th>UTS (MPa)</th>
<th>UE(%)</th>
<th>TE(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP590</td>
<td>370</td>
<td>620</td>
<td>16</td>
<td>26</td>
</tr>
<tr>
<td>DP780</td>
<td>470</td>
<td>830</td>
<td>12</td>
<td>17</td>
</tr>
<tr>
<td>DP980</td>
<td>690</td>
<td>1030</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>GI NEXMET 1000</td>
<td>700</td>
<td>1010</td>
<td>15</td>
<td>21</td>
</tr>
<tr>
<td>Uncoated NEXMET 1000</td>
<td>650</td>
<td>1050</td>
<td>15</td>
<td>20</td>
</tr>
</tbody>
</table>

GI NEXMET 1000, 1.2 mm
“Typical” HER = 22 pct%
MICROSTRUCTURE

Electron Backscatter Diffraction

- Austenite (FCC)
- Ferrite (BCC) & Martensite (BCT)

Neutron Diffraction Pattern

GI NEXMET 1000, 1.2 mm Retained Austenite Volume Fraction (RAVF): 12%
CHARACTERIZATION OF FORMING LIMIT CURVE USING DIGITAL IMAGE CORRELATION (DIC)

- Determination of FLC: ISO12004-2;
- 102 mm (4””) diameter steel ball;
- Lubricant: Teflon & grease.

A in mm: 20, 50, 80, 100, 120, 130, 140, 160
FORMING LIMIT CURVES: NEXMET 1000 VS. OTHER GRADES
FORMING LIMIT CURVES OF NEXMET 1000: VARIOUS THICKNESS
FORMING LIMIT CURVES OF NEXMET 1000: DIFFERENT SAMPLE ORIENTATIONS

NEXMET 1000 1.6 mm
- GI TD
- Uncoated TD
- Uncoated LD
- Uncoated DD

Minor True Strain

Major True Strain

-0.30 -0.25 -0.20 -0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20 0.25 0.30
T-SHAPE FORMING

(a) T-Shape Die
(b) Upper Die, Center Pocket, Lower Punch, Vertical Wall, Lower Binder
(c) 3 Camera DIC system
T-SHAPE FORMING: NEXMET 1000 VS. DP980

<table>
<thead>
<tr>
<th></th>
<th>Draw forming maximum depth (mm)</th>
<th>Stretch forming maximum depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA DP980, 1.2 mm</td>
<td>11.7</td>
<td>10.1</td>
</tr>
<tr>
<td>GI NEXMET 1000, 1.2 mm</td>
<td>16.1</td>
<td>11.5</td>
</tr>
</tbody>
</table>
DEFORMATION MODES AND STRAIN PATHS DURING T-SHAPE FORMING

GI NEXMET 1000, 1.2 mm

Draw Forming
Fractured at 16.1 mm

Stretch Forming
Fractured at 11.5 mm
SPRINGBACK AND SPRINGBACK CONTROL

What is the effect of post-stretching on the formability???
EFFECT OF DRAW / STRETCH FORMING ON T-SHAPE FORMING

- Case 1: Draw Forming (10% Blank Thickness)
- Case 2: Stretch Forming (115 Ton Binder Tonnage)
- Case 3: Draw Forming 6 mm + Stretch Forming
- Case 4: Draw Forming 10 mm + Stretch Forming
- Case 5: Draw Forming 12 mm + Stretch Forming
- Case 6: Draw Forming 13 mm + Stretch Forming
STRAIN DISTRIBUTION ON T-SHAPE PANEL

Case 1: Draw Forming 16 mm
DEFORMATION MODES AND STRAIN PATHS

Case 1: Draw Forming

Case 2: Stretch Forming

Case 3: 6+7

Case 4: 10+3

Case 5: 12+2

Case 6: 13+2
DEFORMATION MODES AND STRAIN PATHS DEPENDENCY OF MARTENSITE PHASE TRANSFORMATION

Loc. 2

Loc. 5

Loc. 6

Loc. 10

Loc. 4

Major True Strain (mm/mm)
Minor True Strain (mm/mm)
CONCLUSIONS

The forming limit of NEXMET 1000 is comparable to DP780, and much higher than DP980.

NEXMET 1000 exhibits excellent formability in T-shape forming.

The T-shape forming depth of NEXMET 1000 is further improved in post-stretching.

The deformation mode and strain path dependence of martensite phase transformation for NEXMET 1000 agrees with previous studies.
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Panagiotis (John) Makrygiannis
Feng Zhu
Haoling Jia

Product Development:
Grant Thomas
Jeremy Hansman
Amrinder Gill
FOR MORE INFORMATION

Wei Wu
AK Steel Corporation
313-317-1298
wei.wu@aksteel.com

Yu-Wei Wang
AK Steel Corporation
313-623-4942
yu-wei.wang@aksteel.com
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