Solution technologies of die material coating and tooling high-strength steels stamping dies

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Hitachi Metals, Ltd.
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Toughness
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Current Problem of Standard D2/1.2379

<Process from Raw material to Mass production>

Raw Material → Machining → Heat Treatment → Finishing → Die Setting

Trial use

Increasing workload...

Mass-Production

Die life...

quality variations *lot-to-lot variation

Increasing dimensional change, deforming...

Adjust Rework

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Relationship between ‘insoluble carbide’ and ‘heat treatment dimensional change’

Carbide Expansion
Matrix (ferrite)
Rolling/Fiber direction
Thickness direction

Heat treatment
# Relationship between carbide distribution and wear resistance

Impact and adhesive wear resistances are related to the carbide distribution.

<table>
<thead>
<tr>
<th>Wear mode</th>
<th>Carbide distribution</th>
<th>Preferable microstructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>High pressure area</td>
<td>Large / Sparse</td>
<td>D2/1.2379</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sliding area</td>
<td>Small / Dense</td>
<td>Powder metal</td>
</tr>
</tbody>
</table>

**High pressure area**
- Large / Sparse: Small Contact area, Pressure, Shallow wear depth
- Small / Dense: Large Contact area, Pressure, Deep wear depth

**Sliding area**
- Large / Sparse: Deep wear depth
- Small / Dense: Shallow wear depth
**Microstructure**

**D2/1.2379**
- Coarse & directional carbide
  - Large & anisotropic HT deformation
  - Medium galling & wear resistance
  - Characteristics will be affected by grain direction

**SLD-i**
- Small, dense & homogeneous carbide
  - Small & isotropic HT deformation
  - Good galling & wear resistance
  - Achieve higher hardness than D2/1.2379

**SLD-MAGIC**
- Large carbide + very small and dense carbide
  - Small HT deformation
  - Good galling & wear resistance
  - Very good machinability & toughness
Alloy Design

- Ductility (Toughness)
  - Good

- Wear resistance

- S7
- A2
- M2
- D2/1.2379
- Powder metal (4 Vanadium)
- SLD-MAGIC
- 8%Cr steel
- SLD-i

Wear resistance → Good
Ductility (Toughness) → Good
# Wear resistance (Pin-on-disc test)

## Conditions

<table>
<thead>
<tr>
<th>Item</th>
<th>Condition</th>
</tr>
</thead>
</table>
| Test piece    | Grade  
D2, SLD-i, SLD-Magic and 8Cr                  |
|               | Hardness 60HRC                                 |
| Disc          | Alumina                                        |
| Surface pressure | 7.8 MPa                                       |
| Friction Speed | 0.42 m/sec                                     |
| Friction length | 377 m                                         |

## Results

![Graph showing wear resistance](image)

- **D2/1.2379**: Poor
- **SLD-i**: Good
- **SLD-MAGIC**: Good
- **8%Cr Steel**: Very Good

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**ASTM G99-05**

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Galling Resistance

<Conditions>

<table>
<thead>
<tr>
<th>Item</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of Stroke</td>
<td>60mm</td>
</tr>
<tr>
<td>Pressing Velocity</td>
<td>60spm</td>
</tr>
<tr>
<td>Lubricant</td>
<td>Rust prevention oil *delivery condition</td>
</tr>
<tr>
<td>Work</td>
<td>980MPa HSS</td>
</tr>
<tr>
<td>Work Thickness</td>
<td>1.4mm (No Zn plating) Clearance:5%</td>
</tr>
<tr>
<td>Die surface condition</td>
<td>Polished by #8000 paper (2-4μm)</td>
</tr>
</tbody>
</table>

<Results>

<table>
<thead>
<tr>
<th>Holding Pressure (kg \cdot f)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLD-i</td>
</tr>
<tr>
<td>SLD-MAGIC</td>
</tr>
<tr>
<td>8%Cr Steel</td>
</tr>
</tbody>
</table>

Schematic diagram of test condition

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**Charpy Value**

Notch: 10R  
Direction: L-T  
Thickness: > 60 mm  

(Q) 1030°C  
(T) 500-520°C  
Hardness: 61-62HRC

- **D2/1.2379**  
- **SLD-i**  
- **SLD-MAGIC**  
- **8%Cr Steel**
Scratch adhesion test

Rockwell Diamond indenter (R=0.2mm)

Coating: AlCrSiN 3μm or TRD 8~10μm

Load ON

Complete delamination

Load (N)

Distance (mm)

Complete delamination (N)

- PVD (AlCrSiN)

- TRD

D2/1.2379 SLD-i 8%Cr
**Toughness**

Specimen size: 4x3x36mm

0.5mm/min

Stress roller

Support roller

Longitudinal direction Tempered at:
- 500~540°C
- 200°C

Bar chart showing:
- D2/1.2379
- SLD-i
- SMD-MAGIC
- 8%Cr Steel
Machinability

- End milling

Annealed:
Vc=30m/min,
Depth of cut: 0.5mm
By f8 coated HSS endmill

- Drilling

Annealed:
Vc=100m/min, 7958rpm
Feed: 0.12mm/rev
Hole depth: 12mm
By f4 coated carbide drill
(non-step, external lubricant)

No chipping or breaking after machining
### Summary

<table>
<thead>
<tr>
<th>Item</th>
<th>D2/1.2379</th>
<th>SLD-i</th>
<th>SLD-MAGIC</th>
<th>8Cr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness</td>
<td>O</td>
<td>+</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Dimensional change</td>
<td>O</td>
<td>++</td>
<td>++</td>
<td>~ ~ ~</td>
</tr>
<tr>
<td>Galling resistance</td>
<td>O</td>
<td>+</td>
<td>++</td>
<td>O</td>
</tr>
<tr>
<td>Wear resistance</td>
<td>O</td>
<td>++</td>
<td>+</td>
<td>~ ~ ~</td>
</tr>
<tr>
<td>Deflecting strength</td>
<td>O ~−</td>
<td>O</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Machinability</td>
<td>O ~−</td>
<td>O</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Weldability</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

Rating: (Poor) —− < − < O < + < ++ (Excellent)
Mill Run Test of SLD-i and D2/1.2379
- Share Tool for 1500 MPa Martensite Steel

Material information

<table>
<thead>
<tr>
<th>Application</th>
<th>Cross Member Floor Panel Part</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>1.5 mm</td>
</tr>
<tr>
<td>Hardness</td>
<td>52 HRC</td>
</tr>
<tr>
<td>Strength</td>
<td>1500 MPa</td>
</tr>
<tr>
<td>Failure mode of dies</td>
<td>Wear/Galling</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Application</th>
<th>Grade</th>
<th>Hardness</th>
<th>Coating</th>
<th>Die life before re-sharpening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share Tool</td>
<td>SLD-i</td>
<td>60~62 HRC</td>
<td>Bare surface</td>
<td>35,000 cuts</td>
</tr>
<tr>
<td></td>
<td>D2/1.2379</td>
<td>60~62 HRC</td>
<td>Bare surface</td>
<td>5,000 cuts</td>
</tr>
</tbody>
</table>

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Mill Run Test of SLD-i and D2/1.2379

Punch dies for burring of hub bearing

<table>
<thead>
<tr>
<th>Spec</th>
<th>73.86±0.01 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLD-i</td>
<td></td>
</tr>
<tr>
<td>Sample 1</td>
<td>73.863 mm</td>
</tr>
<tr>
<td>Sample 2</td>
<td>73.856 mm</td>
</tr>
<tr>
<td>Sample 3</td>
<td>73.859 mm</td>
</tr>
<tr>
<td>Sample 4</td>
<td>73.867 mm</td>
</tr>
<tr>
<td>Sample 5</td>
<td>73.859 mm</td>
</tr>
<tr>
<td><strong>Pass rate</strong></td>
<td><strong>100% (5/5)</strong></td>
</tr>
</tbody>
</table>

Pass rate of D2/1.2374 10%

<table>
<thead>
<tr>
<th>Application</th>
<th>Grade</th>
<th>Coating</th>
<th>Die life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punch dies for burring</td>
<td><strong>SLD-i</strong></td>
<td>TD coated</td>
<td>More than 500,000 hits WITHOUT repairing</td>
</tr>
<tr>
<td></td>
<td><strong>D2/1.2379</strong></td>
<td>TD coated</td>
<td>10,000 – 100,000 hits with repairing</td>
</tr>
</tbody>
</table>
Thank You