Special Steels for Precise Die and Mold

**FM ALLOY® DURO™**

For Cold Work

**High Toughness Grades**
- DURO-F1
- DURO-F3
- DURO-F7

**High Wear Resistance Grade**
- DURO-SP
DURO-Created by NACHI’s original technology
Steels with superior balance of toughness and wear resistance for precise die and mold

- DURO series, special steels for precise die and mold, are high quality and high grade materials which are made by NACHI’s original technology of steel manufacturing and refining.
- They have less non-metallic inclusion and segregation that can cause fractures. Also shows superior performance because of great control of carbide quantity and size.

Properties of DURO for Cold Work

- DURO for Cold Work has two type grades, High Toughness Grades are DURO-F1, F3, F7, High Wear Resistance Grade is DURO-SP.
- Each grade has a different balance of toughness and wear resistance, so whatever the application, there is a DURO grade available.

Typical Nachi Steel Grades

<table>
<thead>
<tr>
<th>Classification</th>
<th>Grade</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Speed Steels (HSS)</td>
<td>SKH9D</td>
<td>Die and Punch</td>
</tr>
<tr>
<td></td>
<td>HSU2C</td>
<td>Plus Punch</td>
</tr>
<tr>
<td></td>
<td>HM42</td>
<td></td>
</tr>
<tr>
<td>Powder Metallurgical HSS</td>
<td>FAX Series</td>
<td>Punch</td>
</tr>
<tr>
<td>Alloy Tool Steels</td>
<td>ICS22</td>
<td>Die for Eye Glasses</td>
</tr>
<tr>
<td></td>
<td>MDS9</td>
<td>Mold for Rubber</td>
</tr>
<tr>
<td></td>
<td>MCR1</td>
<td>Die and Punch</td>
</tr>
<tr>
<td>Steel for Precise Die and Mold</td>
<td>DURO-F1, 3,</td>
<td>Cold Work Die and Punch</td>
</tr>
<tr>
<td>(DURO Series)</td>
<td>7, SP</td>
<td></td>
</tr>
<tr>
<td>FM ALLOY</td>
<td>DURO-F1, N1</td>
<td>Hot Work Die and Punch</td>
</tr>
<tr>
<td>Plastic Mold Steel with Corrosion</td>
<td>PROVA-400</td>
<td>Plastic Mold</td>
</tr>
<tr>
<td>Resistance and Mirror Finish</td>
<td>NPR1</td>
<td>Injection Molding Machine Parts</td>
</tr>
<tr>
<td>Corrosion and Wear Resistance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alloy Steel</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Benefits of DURO

• DURO is made by a highly purified procedure, to have high toughness and fatigue strength because of very little non-metallic inclusions.
• Quantity and size of carbides in DURO microstructure are controlled to have a superior balance of toughness and wear resistance.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Grade</th>
<th>Hardness</th>
<th>Strong Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Toughness Matrix HSS</td>
<td>DURO-F1</td>
<td>HRC 54-60</td>
<td>High toughness die and mold steel Has the highest toughness in all die and mold materials that get HRC60.</td>
</tr>
<tr>
<td></td>
<td>DURO-F3</td>
<td>HRC 57-62</td>
<td>Well balance steel Is a medium grade between F1 and F7, has good toughness and wear resistance.</td>
</tr>
<tr>
<td></td>
<td>DURO-F7</td>
<td>HRC 59-65</td>
<td>High wear resistance steel Has high hardness of HRC65, and still shows high toughness.</td>
</tr>
<tr>
<td>High Wear Resistance HSS</td>
<td>DURO-SP</td>
<td>HRC 60-67</td>
<td>Super high wear resistance steel Has higher wear resistance than PM HSS, and still shows good toughness.</td>
</tr>
</tbody>
</table>

“*DURO-F1 is also good for hot work, please reference NACHI catalog “DURO for Hot Work”.

Microstructure

DURO Series have the best balance for quantity and size of carbides in each grade and a uniform microstructure with minor segregation.
Features of DURO-F Series, High Toughness Steels

Mechanical Properties

High bending fracture strength

DURO-F Series show high bending fracture strength in hardness range HRC 56-65.

Superior Charpy impact resistance

DURO-F Series show superior charpy impact resistance in hardness range HRC 56-65.

Grindability of DURO-F Series

Better grindability than other material

Grindability of DURO-F Series is better than M2 and D2.

Ground Ratio = (weight loss of a sample)/(weight loss of a wheel)

Surface Grinder Machine
Wheel: WA60K
Feed: 60m/min
Depth: 0.05 mm
RPM: 2000 min⁻¹

Grindability of DURO-F Series is better than M2 and D2.
## Heat Treatment of DURO-F Series

### Heat treatment condition

<table>
<thead>
<tr>
<th>Grade</th>
<th>Requirement</th>
<th>Aus. [°C (°F)]</th>
<th>Temp. [°C (°F)]</th>
<th>Hardness (HRC)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DURO-F1</strong></td>
<td>For toughness</td>
<td>1100 (2012)</td>
<td>580 x 2 (1076)</td>
<td>56.0</td>
</tr>
<tr>
<td></td>
<td>Standard</td>
<td>1120 (2048)</td>
<td>560 x 2 (1040)</td>
<td>58.0</td>
</tr>
<tr>
<td></td>
<td>For wear</td>
<td>1160 (2120)</td>
<td>560 x 2 (1040)</td>
<td>59.5</td>
</tr>
<tr>
<td><strong>DURO-F3</strong></td>
<td>For toughness</td>
<td>1100 (2012)</td>
<td>580 x 2 (1076)</td>
<td>59.0</td>
</tr>
<tr>
<td></td>
<td>Standard</td>
<td>1140 (2084)</td>
<td>580 x 2 (1076)</td>
<td>60.0</td>
</tr>
<tr>
<td></td>
<td>For wear</td>
<td>1160 (2120)</td>
<td>560 x 2 (1040)</td>
<td>61.5</td>
</tr>
<tr>
<td><strong>DURO-F7</strong></td>
<td>For toughness</td>
<td>1120 (2048)</td>
<td>600 x 2 (1112)</td>
<td>60.0</td>
</tr>
<tr>
<td></td>
<td>Standard</td>
<td>1120 (2048)</td>
<td>580 x 2 (1076)</td>
<td>62.5</td>
</tr>
<tr>
<td></td>
<td>For wear</td>
<td>1180 (2156)</td>
<td>560 x 2 (1040)</td>
<td>65.0</td>
</tr>
</tbody>
</table>

*Thickness of sample: 50 mm, vacuum furnace + pressure gas quenching (about 4 bar)

*Hardness may vary depending on material size and method, condition or facilities of heat treatment.

### Hardness chart

DURO-F1 can be used in range HRC 54-60.
To get HRC 60 it is suggested to use a salt bath furnace.

DURO-F3 can be used in range HRC 57-62.
If hardness under HRC 57 is necessary, DURO-F1 is recommended.

DURO-F7 can be used in range HRC59-65.
Features of DURO-SP, High Wear Resistance Steel

Mechanical Properties

Superior wear resistance

DURO-SP shows superior wear resistance compared not only to matrix HSS but conventional HSS and even PM HSS.

Minimal loss of strength with rough surface

◆ Bending fracture strength

DURO-SP shows less surface roughness and strength decreases because of better wear resistance than PM HSS.

*Generally strength of materials decreases by notch effect as surface roughness of the materials become worse.

◆ Charpy impact resistance

DURO-SP shows less charpy impact resistance decrease than PM HSS.

*Generally strength of materials decreases by notch effect as surface roughness of the materials become worse.

Applications

<table>
<thead>
<tr>
<th>Grade</th>
<th>Application</th>
<th>Life comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>DURO-F1</td>
<td>Blanking punch</td>
<td>5 times longer than other matrix HSS</td>
</tr>
<tr>
<td>DURO-F3</td>
<td>Forming roll</td>
<td>2 times longer than other cold work die steel</td>
</tr>
<tr>
<td>DURO-F7</td>
<td>Forming rack</td>
<td>1.5 times longer than other matrix HSS</td>
</tr>
<tr>
<td>DURO-F7</td>
<td>Fine-blanking punch</td>
<td>4 times longer than other matrix HSS</td>
</tr>
<tr>
<td>DURO-SP</td>
<td>Flow forming mandrel</td>
<td>5 times longer than other matrix HSS</td>
</tr>
<tr>
<td></td>
<td>Injection die</td>
<td>8 times longer than other matrix HSS</td>
</tr>
</tbody>
</table>
Heat treatment of DURO-SP

Heat treatment condition

<table>
<thead>
<tr>
<th>Grade</th>
<th>Requirement</th>
<th>Temp. [˚C (˚F)]</th>
<th>Hardness (HRC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DURO-SP</td>
<td>For toughness</td>
<td>1120 (2048)</td>
<td>600 × 3 (1112)</td>
</tr>
<tr>
<td></td>
<td>Standard</td>
<td>1160 (2120)</td>
<td>580 × 3 (1076)</td>
</tr>
<tr>
<td></td>
<td>For hardness and</td>
<td>1200 (2192)</td>
<td>560 × 3 (1040)</td>
</tr>
<tr>
<td></td>
<td>wear resistance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Thickness of sample: 50 mm, vacuum furnace + pressure gas quenching (about 4 bar)

*Hardness may vary depending on material size and method, condition or facilities of heat treatment.

Hardness of DURO-SP

- The best heat treatment of DURO-SP differs depending on applications.
- For fine blanking around HRC 64 is a standard hardness.
- For flow forming mandrel HRC 60-62 is common and for some cold work forming punches over HRC 67 could be a good choice.

Hardness chart

DURO-SP can be used in range HRC 60-67. HRC 62-64 is normally recommended.

Sample choices of steel grade for applications

<table>
<thead>
<tr>
<th>Current Grade</th>
<th>Life Factor</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM HSS</td>
<td>Wear, Micro chipping</td>
<td>○</td>
</tr>
<tr>
<td></td>
<td>Chipping, Fracture</td>
<td>○</td>
</tr>
<tr>
<td>M2</td>
<td>Wear, Micro chipping</td>
<td>○</td>
</tr>
<tr>
<td></td>
<td>Chipping, Fracture</td>
<td>○</td>
</tr>
<tr>
<td>Matrix HSS</td>
<td>Wear, Micro chipping</td>
<td>○</td>
</tr>
<tr>
<td></td>
<td>Chipping, Fracture</td>
<td>○</td>
</tr>
<tr>
<td>D2</td>
<td>Wear, Micro chipping</td>
<td>○</td>
</tr>
<tr>
<td></td>
<td>Chipping, Fracture</td>
<td>○</td>
</tr>
<tr>
<td>H13</td>
<td>Wear, Micro chipping</td>
<td>○</td>
</tr>
</tbody>
</table>

○: Best  ○: Good
OVERSEAS MANUFACTURING COMPANIES

AMERICA

- **NACHI TECHNOLOGY INC.**, 713 Pushville Road, Greenwood, Indiana, 46413, U.S.A.
  Tel: +1-317-535-5000 Fax: +1-317-535-8484
  URL: http://nachtitech.com/

- **NACHI MACHINING TECHNOLOGY CO., LTD.**, 17500 Twenty-three Mile Road, Macomb, Michigan, 48044, U.S.A.
  Tel: +1-586-233-0099 Fax: +1-586-233-4571
  URL: http://www.nachimtc.com/

- **NACHI PRECISION NORTH CAROLINA INC.**, 1836 Lindbergh Street Suite 400, Charlotte, North Carolina, 28208, U.S.A.
  Tel: +1-704-391-1511 Fax: +1-704-391-1648

- **NACHI BRASIL LTDA**, Avenida Jaba II, No.3350, Jardim Sao Pedro, Mogi das Cruzes, S.P., BRAZIL, 08380-000 Fax: +55-11-4793-8800 Fax: +55-11-4793-8870
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- **MIAMI BRANCH**, LATIN AMERICA DIV., 2351 W.N.W. 70th Ave., Doral, Florida 33172, U.S.A.
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- **NACHI ROBOTIC SYSTEMS INC.**, 22285 Roethel Drive, New, Michigan, 48371, U.S.A.
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  URL: http://www.nachirobotics.com/

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