Automotive products process flow

ArcelorMittal Duisburg

- Pig Iron
- Scrap
- Ladle furnace
  - Vacuum Degassing
  - RH Degassing
  - Continuous casting billets 700 Kt
  - Continuous casting blooms 1200 Kt
- Billets 155²
- Blooms 385X265
- Bar & Billet mill 800 Kt
- Wire Rod Mill 450 Kt
  - Wire Rod 5.5-25
- Wire Processing (annealing, pickling, phosphating) by local subcontractor
- Heat Treatment (soft annealing, stress relieving, normalising) 12 Kt

ArcelorMittal Warsaw

- Scrap
- Electric Arc Furnace 530 Kt
- Ladle furnace
- Vacuum Degassing
- Continuous casting billets 530 Kt
- Billets for rolling 140² 160² 220²
- Bar Mill 370 Kt
- Finishing EC & US test 140 Kt
- Wire Rod Mill 360 Kt
  - Wire Rod 15-52 14.3-42.5
- Wire Rod 15-100 14.3-70.3
- Bars 20-80
- Peeling 1.2 Kt
- Heat Treatment (soft annealing, stress relieving, normalising, spheroidising; Q+T) 65 Kt

ArcelorMittal Gandrange

- Oxygen Converter 1500 Kt
- Desulphurisation
- Oxygen Converter 1500 Kt
- Continuous casting billets 530 Kt
- Billets for rolling 140² 160² 220²
- Bar Mill 370 Kt
- Finishing EC & US test 140 Kt
- Wire Rod Mill 360 Kt
  - Wire Rod 15-52 14.3-42.5
- Wire Rod 15-100 14.3-70.3
- Bars 20-80
- Peeling 1.2 Kt
- Heat Treatment (soft annealing, stress relieving, normalising, spheroidising; Q+T) 65 Kt
Today the wire rod mill offers products on a high-end quality spectrum, and the billet mill produces advanced bainitic steels for hot forging.

The new rod mill is set to become European benchmark for high value added wire-rod in mechanical properties, tolerances, surface quality.

Facilities

- Steel plant:
  - Two oxygen converters (TBM process)
  - Ladle furnace
  - Steel ladle vacuum treatment: circulation degasser (RH) and tank degasser (VD), as per metallurgical need
  - Steel conditioning (Argon & Nitrogen stirring)
  - 2 casters bloom & billet
- Billet rolling mill:
  - Reversing breakdown and finishing stand
- Finishing line for bars & billets:
  - Conditioning with ultrasonic and surface testing (TOM)
  - Annealing devices (up to 9 m length): soft annealing, normalising
  - Dimension control
  - Surface grinding (including robot)
- Wire rod rolling mill:
  - High speed single-strand 28 stands including pre-block
  - Thermo-mechanical rolling incl. loop
  - 104 m long stelmor line
- Wire rod processing (annealing, pickling, phosphating) upon request

Strengths

- Production of crude steel with lowest C content (< 100 ppm) and a defined alloy concentration.
- Refining of metal charges in 150 t converters due to a specific model calculation incl. management of lance status, oxygen flow rate and alloys.
- Ladle metallurgical centre for precise alloying, reduction of solute gases, desulphurisation and adjustment of melting temperature.
- Bloom and billet casters with re-oxidation prevention and mould stirring.
- Most modern layout and equipment on a new single-strand wire rod mill like thermo-mechanical rolling and special cooling devices for a fine-grained structure.
- Special customer requirements upon request.

Product range

- Wire rods
  - in 5,5 to 25 mm (steps of 0,5 mm)
  - Maximum coil weight: 3 tonnes
  - Tolerances: according to DIN EN 10108: 2005
  - Coil dimensions (mm):
    - inner diameter 800
    - outer diameter 1,250
    - coil length 2,300
- Round Bars / Square Billets for forging
  - in 100 to 170 mm (Round) / 63 to 200 mm (Square)
  - Maximum bundle weight: 10 tonnes
  - Strapping: 6 steel bands
  - Labelling: content upon request

Final applications

- Cold heading qualities:
  - steel for cold extrusion; fasteners
- Heat treatable steel grades:
  - components of common rail systems
- Carbon grade: offshore; pre-stressed steel
- Alloved spring steel: Valve springs; clutch springs
  - tension/ compression and axle springs
- Free-cutting steel
  - special shape turned parts
  - shafts and hydraulic systems
- Bainitic steel
  - front axle beam, steering lever & knuckle parts

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ArcelorMittal Gandrange

Products for Automotive and Mechanical Engineering markets with a large range of bars and wire rods.

**Final applications**
- Carbon and micro-alloyed steel grades
  - Hot forging / stamping
  - Cold forming
- Cold heading qualities
  - Steel for cold extrusion; fasteners
- Free-cutting steel grades
  - Special shape turned parts
  - Shafts and hydraulic systems
- Heat treatable steel grades
  - Components of Common Rail systems
- Carbon and alloyed spring steel
  - Tension/ compression and axle springs, torsion bars

**Facilities**
- Bar & Wire rod rolling mill:
  - Furnace with tight temperature control
  - Sizing block
  - On-line dimensional control
  - Garrett coiling for wire rod
- Finishing line for bars:
  - Multi-roll straightener
  - Sawing and chamfering devices (45° or 60° from 0,2 up to 4mm)
  - Surface control (Circoflux)
  - Ultrasonic control device
- Bar processing upon request:
  - Heat treatment: soft annealing, normalising, spheroidising and stress relieving treatments
- Wire rod processing (annealing, pickling, phosphating) upon request

**Strengths**
- Possibility to source steel from both BOF and EAF routes
- A wide range of grades and dimensions on Bars and Wire Rods
- State of the art Sizing Block and Bar Conditioning
- Mini-mill flexibility in order to meet customer needs

**Product range**
- Wire rod
  - Rounds: 15 to 52 mm (steps of 0,1 mm)
  - Hexagons: 14,3 to 42,5 mm
  - Coil weight standard: 2,5 tonnes
  - Other coil weights available upon request
- Coil dimensions (mm):
  - Inner diameter 900
  - Outer diameter 1400
  - Coil length 1500 max
- Bars:
  - Rounds: 15 to 100 mm (steps of 0,1 mm)
  - Hexagons: 14,3 to 70,4 mm
  - Maximum bundle weight: 8 tonnes
  - Length: 5 to 12 meters
  - Strapping: 4 to 8 steel bands
  - Labelling: 2 per bundle
  - Tolerances acc. EN10060 A to P, tighter tolerances upon request

**Final applications**
- Carbon and micro-alloyed steel grades
  - Hot forging / stamping
  - Cold forming
- Cold heading qualities
  - Steel for cold extrusion; fasteners
- Free-cutting steel grades
  - Special shape turned parts
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  - Labelling: 2 per bundle
  - Tolerances acc. EN10060 A to P, tighter tolerances upon request
Facilities

- Steel plant:
  - Electric arc furnace with eccentric bottom tapping
  - Ladle furnace
  - Vacuum degassing
  - 4 strand billet caster
- Bar rolling mill:
  - 18 stands in continuous system roll line
- Finishing line:
  - Straightening machines
  - Milling and chamfering devices
  - Surface control (Circograph, Circoflux)
  - Ultrasonic control device
  - Antimixing control - spectrotest devices, packaging, marking
- Bar processing:
  - Heat treatment: soft annealing, normalising, isothermal, spheroidising and stress relieving treatments, quenching and tempering
  - Peeling

Strengths

- Production of wide range of steel grades
- Flexibility of mini-mill
- Steel with controlled/regulated sulphur content
- Micro alloys steel with Nb, V, B
- Steel with "restricted hardenability" (Jominy, 2/3 of band)
- Full downstream capability: heat treatment and peeling on bars

Final applications

- Case hardening steels
  - Parts such as camshafts, gearbox shafts, engine parts
- Heat treatable steel grades
  - Components of steering system, braking system, axle hubs, front axles
- Cold heading qualities
  - Steel for cold extrusion, fasteners, screws, ball pins
- Carbon and micro-alloyed steel grades
  - Hot forging / stamping – flanges, conrods
  - Cold forming
- Carbon and alloyed spring steel
  - Tension/compression and axle springs
- Bearing steel
  - Bearing rings

Product range

- Bars:
  - Rounds 20 to 80 mm
  - Length 3.5–12 m, tolerance acc. to EN 10060 (P)
  - Tolerance acc. to EN 10060 (P) < heat treatment, tighter tolerances upon request
  - Maximum bundle weight: 10 tonnes
  - Strapping: minimum 3 steel bands or more possible upon request
  - Labelling: content upon request
  - Heat treatment up to 12 m except for quenching and tempering up to 6 m.
  - Peeling upon request by local subcontractor
- Also produces rebars 10–40 mm, merchant bars, angles, flat bars and ingots for forging & rolling.
### Improved Machinability Steels

Improved Machinability Steel grades have small amounts of additional alloying elements to improve machinability. Alloying elements are added during secondary steelmaking specifically to modify the steel inclusion population. Some elements form controlled inclusions to promote chip formation and break-up during subsequent machining, while others melt locally at the tool / work piece interface acting as a lubricant and reducing tool wear. Possible additions include Sulphur, Lead, Tellurium, Bismuth and Selenium.

**Specifications**

<table>
<thead>
<tr>
<th>Grade designation</th>
<th>Duisburg</th>
<th>Gandrange</th>
<th>Warsaw</th>
<th>Comments</th>
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</table>

### Quenched and Tempered Steels

Quenched and Tempered Steel grades have greater hardenability than structural carbon steels. The grades contain specific amounts of alloying elements to favour transformation of austenite into martensite during the quenching process. After forging, the work piece is quenched in water, polymer or oil to increase the hardness even in thick sections (through-hardening). The tempering process allows to obtain the best compromise between strength, ductility and toughness.

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<td>(Q+T)</td>
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</tbody>
</table>

Common Rail: rocker arms, pistons, crankshaft; UTS > 1100 MPa

Rocker Arms, Crankshaft: UTS > 1200 MPa

Crankshaft
Bainitic Steels for Forging

Bainitic Steels are designed for applications requiring a good compromise between Tensile Strength and Ductility, and offer the added benefit of eliminating the final Quench and Tempering process usually performed to achieve high properties. Controlled cooling after forging steers the Austenite transformation into the Bainitic region. The fine tuning of alloying elements will enable to reach the desired level of strength, taking into account the customer process and the size of the part.

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<td>SOLAM ® B1100</td>
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<td>&quot;Truck Front Axle Beam, Steering Knuckle, Steering Arm UTS &gt; 1100 MPa&quot;</td>
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<td>&quot;Crankshaft (Induction Hardened) - UTS &gt; 1150 MPa&quot;</td>
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<td>SOLAM ® B1200</td>
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<td>&quot;Common rail, Axle Beam, Steering Lever (hot forged parts 30-100 mm) - UTS &gt; 1200 MPa&quot;</td>
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<td>20MnCr++</td>
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<td>●</td>
<td>&quot;Injectors, Injection Nozzles - UTS &gt; 1200 MPa&quot;</td>
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</tbody>
</table>

Cold Heading Steels

Cold heading steels are designed to fulfill the most demanding customer specifications. So, the formability, ductility and strength required for producing by cold deformation the most complex parts is offered by a wide range of low carbon, alloyed, micro-alloyed and boron grades produced according to international standards. Closely controlled rod manufacturing practices ensure their good internal soundness and their defect-free surface. For specific grades, a close control of the chemical composition and post-rolling cooling allow the achievement of requested mechanical properties of the parts even by cold heading without final heat treatment.

To produce cold headed fasteners, threaded rods, wheel bolts, rivets, studs, nuts, U-bolts & welded studs and other complex formed parts for automotive, engineering and construction industries.

Specifications

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</tbody>
</table>

- Industry in all dimensions
- In development (part trial or produced)
- In-house development

Additions of Se possible to globulise the sulphurs;
Additions of Pb, Bi and Te possible to improve machinability.
## Spring Steels

Spring Steels are Medium or High Carbon Steels with very high Yield Strength. This property allows the part formed with these grades to return to their original shape after significant bending or twisting. The principal alloying elements to achieve the high yield strength are Silicon and Manganese. For the very demanding applications, the grades are processed with high cleanliness level: hence, a very good fatigue behaviour.

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Case Hardening Steels

Case Hardening Steels are used for parts requiring high surface wear resistance but retaining a soft core that absorbs stresses without cracking. After forging, the outer layer is carburised (diffusion of carbon) and/or carbon-nitrided and then locally hardened by quenching. The grades are Low-Carbon steels with addition of suitable alloying elements. These additions typically include Chrome and Manganese, but also Nickel and Molybdenum can be involved to increase the through-hardening for larger cross-sections. A special characteristic of this kind of grade is the Jominy curve, which needs to be well controlled.

### Specifications

<table>
<thead>
<tr>
<th>Grade des.</th>
<th>Duisburg</th>
<th>Gandrange</th>
<th>Warsaw</th>
<th>Comments</th>
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</tbody>
</table>

Axles / Shafts
Pinions
Gears
Micro-Alloyed Steels

Micro-Alloyed Steel grades allow to produce parts with higher strength obtained as forged. Typical additions include Niobium, Vanadium and Titanium. These additions increase yield strength by precipitation hardening, and also offer finer grain structures. These 2 effects increase the strength of the forged parts compared to conventional Carbon steels.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Duisburg</th>
<th>Gandrange</th>
<th>Warsaw</th>
<th>Comments</th>
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</thead>
<tbody>
<tr>
<td>10MnV6</td>
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<td>UTS &gt; 550 MPa</td>
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<td>22MnV6</td>
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<td>UTS &gt; 650 MPa</td>
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<td>UTS &gt; 750 MPa</td>
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<td>38MnSiV5-6</td>
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<td>●</td>
<td>Crankshaft, Pistons - UTS &gt; 850 MPa</td>
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<td>44MnSiV6</td>
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<td>Rocker Arms - UTS &gt; 900 MPa</td>
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<tr>
<td>C70S6</td>
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<td>●</td>
<td>●</td>
<td>Splittable Connecting Rod - UTS &gt; 900 MPa</td>
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</table>

Bearing Steels

Bearing Steels are High-Carbon grades with very high mechanical properties achieved by quench and tempering combined with a very high wear resistance. Depending on the type of applications, different levels of cleanliness will be required to avoid inclusions that initiate fatigue during rolling contact.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Duisburg</th>
<th>Gandrange</th>
<th>Warsaw</th>
<th>Comments</th>
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<td>C10 to C25</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>Mechanical Application / Tooling</td>
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<tr>
<td>C30 to C60</td>
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<td>●</td>
<td>●</td>
<td>Bearing Ring</td>
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<tr>
<td>C68 to C92</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C55 - Integrated Running Gear</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C70 - Integrated Running Gear</td>
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</tbody>
</table>

Carbon Steels

Carbon Steel grades are the combination of 3 families: Low, Medium and High Carbon. Low Carbon steels: Carbon range between 0.1 to 0.25%. One of the most common type of steels used for general purposes and are inherently easier to cold-form and handle (draw, bend, etc.) due to their soft and ductile nature.

Medium Carbon steels: approximately 0.30 to 0.59% Carbon content. Can be heat treated to have a good balance of ductility and strength. These steels are typically used in large parts, forgings, machined and automotive.

High Carbon steels: above 0.60% of Carbon content. High Tensile and Yield strengths. Used for applications in which high strength, hardness and wear resistance are necessary, such as wear parts, gear wheels, chains, brackets.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Duisburg</th>
<th>Gandrange</th>
<th>Warsaw</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>C10 to C25</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>Camshaft, Common Rail, Injectors, Joint Casing</td>
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<tr>
<td>C30 to C60</td>
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<td>●</td>
<td></td>
</tr>
<tr>
<td>C68 to C92</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
</tbody>
</table>

Additions of Se possible to globulise the sulphurs; Additions of Pb, Bi and Te possible to improve machinability.
Main missions

- Contribute with ArcelorMittal Long Carbon to strategic development of Automotive, Energy & Construction markets for Bars & Wires products
- Support plants in process improvement & new process developments
- Innovate to supply new steel solutions generating high value creation

Main activities

- Develop new solutions & new products: Conception of new steel grades (SOLAM®, FreeForm®, Maflex®...)
- Design of thermal treatments to achieve desired microstructure
- Surface treatment and coatings development (galvanising, galfanising, paints, lacquers, powder...)
- Qualify manufacturing & service properties of products
- Expertise process/product, to provide technical support to the plants & customers
- Contribute to conception & optimisation of processes by using Finite Element and other specific models: liquid metallurgy, casting, hot rolling, hot and cold forming, heat treatment, ...
- Support for instrumentation of industrial processes (Thermal camera, pyrometers, force sensors...)

R&D Facilities

- Numerical modelling from liquid metallurgy, casting to hot rolling & cold forming
- Product characterisation at micro & macro scale (Field Emission Gun SEM, macro-probe, torsion & fatigue machines, dilato-plastometry, corrosion chambers...)
- Process pilots for machinability, drawing and heat treatment
- Support from the ArcelorMittal R&D network (Automotive Research centres of Montataire & Maizières-les-Metz)
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A new dynamic in Long Steel Solutions

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