Molybdenum and Stainless Steel - about Mines and Markets

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Prospects for the development of the Russian stainless steel market

Chelyabinsk, 22nd March, 2007
Molybdenum

- Properties and uses
- Sources
- Market observations
Molybdenum

- Properties and uses
First Use of Molybdenum

Total 2006: approx. 425 million lb – 190,000 t

Source: IMOA Estimates
Molybdenum Metal & Alloys

Properties

High melting point – 2610°C

• High hot strength
• High wear resistance
• Good corrosion resistance

High temperature vacuum furnace
Molybdenum Metal & Alloys

Uses

- Glass melting electrodes
- High temperature furnaces
- Halogen lamps – sealing and supporting wire
- Electronic industry – high power semiconductor parts
- Mo spray wire and sputtering targets for coating applications
- Metal and plastic forming

TZM piercing plug for rolling stainless steel tubes

Courtesy of Plansee
Molybdenum in Alloy Steels

Molybdenum is almost always used in combination with other metals including:

- Chromium
- Nickel
- Vanadium
- Tungsten
- Niobium

Moly grade steels are usually required for high end applications.
Effects of Molybdenum

In tool steels (average Mo 0.8%) and in high speed steels (average Mo content 5%):

- moly enhances hardenability
- contributes to secondary hardening
- is an important constituent of the primary $M_6C$-carbide (hardness > 2000 HV), which confers wear resistance
Effects of Molybdenum

in constructional steels &
high strength low alloy steels-HSLA
(Mo content 0.1-1.2%)
moly enhances

- hardenability
- strength and toughness
- weldability
- elevated temperature strength
- resistance to sulfide stress cracking

Oil rigg with drill pipe
Orbis photo
Uses of moly grade constructional steels/HSLA

Applications cover the whole energy chain from raw material production through end use:

- Quenched & tempered (Q&t) CrMo seamless oil country tubular goods.

- HSLA pipelines for Oil and Gas

- High temperature CrMo and CrMoV grades for petrochemical processing and energy generation.

- Q & t CrMo engineering steels in automotive, shipbuilding, aerospace
Uses of moly grade constructional steels

Energy generation

Oil & Gas transportation
Uses of moly grade constructional steels

Gears made of CrMo carburising steel…

for everything that moves
Effects of Molybdenum

in stainless steels

(average Mo content approx. 2.2%)

• moly improves corrosion resistance
Use of moly grade stainless steels

• About 10 % of world stainless steel production is molybdenum grade with average 2.2% Mo

• Moly grade stainless steels are invaluable in industrial processing such as
  • chemical, petrochemical,
  • pulp and paper
  • oil and gas,
  • power generation
Use of moly grade stainless steels

Stainless steel has become the material of choice for many architectural uses around the world.
Use of stainless steel - grade selection is critical.

Nobody likes stainless steel which is rusting.

Moly-grade stainless steels are resistant to de-icing salt or coastal air attack.
Use of moly grade stainless steel

AISI 316 stainless steel with 2.2 % Mo has replaced aluminum at Brussels Atomium.
Molybdenum

• Sources
Global Production - Geographically

- Southamerica: 38%
- Northamerica: 19%
- China: 36%
- CIS & Mongolia: 7%

Total 2006: 425 million lb – 192,000 t

Source: IMOA; Adams Metals
Global Production – Mine Types

- By-product West: 60%
- Primary West: 16%
- China & CIS: 24%

Total 2006: 425 million lb – 190,000 t

Source: IMOA; Adams Metals
Molybdenum from Primary Mining

Calculation example:

- Ore grade 0.2% Mo yielding 1.8 kg/t Mo in concentrate
  - Producing 1 t of Mo ctd requires 550 t of ore

- Annual production of 10,000 t Mo contd. in MoS$_2$ concentrate requires mining and milling
  5.5 million t of ore (approx. 20,000 t per day)

The initial investment for a primary mine usually requires several hundred million US Dollars.
Molybdenum from Primary Mining

Henderson operational schematic

Courtesy of Climax Molybdenum
Molybdenum By-product from Copper Mining
Molybdenum By-product from Copper Mining

- Copper mines producing molybdenum as byproduct usually have ore grades falling between 0.5% and 1.5% Cu (5 to 15 kg/t) and between 0.01% and 0.05% Mo (0.1 to 0.5 kg/t).

- Major operations mine more than 50 million tons of ore per year, producing in excess of 200,000 t of copper and between 5,000 and 15,000 t Mo contained in MoS$_2$ concentrate as by-product.

- The revenues from molybdenum are usually less than 10% of total sales.

- Consequently the moly output of these mines follows the copper market rather than the demand for molybdenum.
Molybdenum supply structure

- CIS-Mongolia
- China
- Western By-Product
- Western Primary

By-product and Chinese production increases significantly

Climax mine started: 1918

Source: Climax Molybdenum, presented at Ryans’s Notes Conference 2005
Molybdenum

• Market Observations
Global Molybdenum Use

Source: IMOA; Adams Metals
Molybdenum Price Driven by Energy-and by China Demand

Source: Metals Week Dealer Oxide Price
Molybdenum Price and Price of Crude Oil 1970 through 2005

$/lb Mo

$/Barrel Crude Oil

Source: Metals Week Dealer Oxide Price; Oilenergy.com
By-product and China-Production Increased Significantly Since 1990

Source: IMOA
Moly Price Was Below $4.00/lb in 10 of the Last 15 Years

Source: Metals Week Dealer Oxide Price
Molybdenum Price and Western Primary Production

Source: IMOA; Metals Week Dealer Oxide Price
Molybdenum Market: Demand and Price

Source: IMOA; Metals Week Dealer Oxide Price
Molybdenum Market: Demand Change and Price

Source: IMOA; Metals Week Dealer Oxide Price
New Primary Molybdenum Mine Projects

<table>
<thead>
<tr>
<th>Mine</th>
<th>Country</th>
<th>Expected Annual Capacity (Million lb Mo)</th>
<th>Status</th>
<th>Production Start Indicated</th>
</tr>
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<tbody>
<tr>
<td>Roca Mines - Max Moly</td>
<td>Canada</td>
<td>2.5</td>
<td>Under construction</td>
<td>??</td>
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<tr>
<td>Bluepearl Davidson</td>
<td>Canada</td>
<td>5 to 10</td>
<td>Feasibility study</td>
<td>end 2007</td>
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<td>PD Climax mine</td>
<td>USA</td>
<td>20 to 30</td>
<td>Conditionally approved</td>
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<tr>
<td>Mt. Hope Nevada</td>
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<td>35</td>
<td>Currently being permitted</td>
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<tr>
<td>Adanac - Ruby Creek</td>
<td>Canada</td>
<td>10</td>
<td>Feasibility study</td>
<td>2009</td>
</tr>
</tbody>
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A comprehensive list of new molybdenum projects, including a number of by-product expansions, can be found under www.infomine.com

Source: Company Reports
Western Roasters: Utilization of Available Time

Source: Climax Molybdenum, presented at Ryans’s Notes Conference 2005
Projection of Western Roasting Capacities

Source: IMOA, Company Reports
Global Molybdenum Reserve Base

- Southamerica: 16%
- Northamerica: 8%
- China: 43%
- CIS & Mongolia: 33%

Total 19 million metric tons Mo ctd. – worth 100 years of present use

Source: US Geological Survey 2006
World Stainless Production & Molybdenum Use

Source: IMOA; Adams Metals
Everything that glitters is stainless – and moly is happy to be part of it.

Thank you.