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Niobium Nb

# Cost-efficient Steel Alloy Design with Niobium

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## Costs benefits

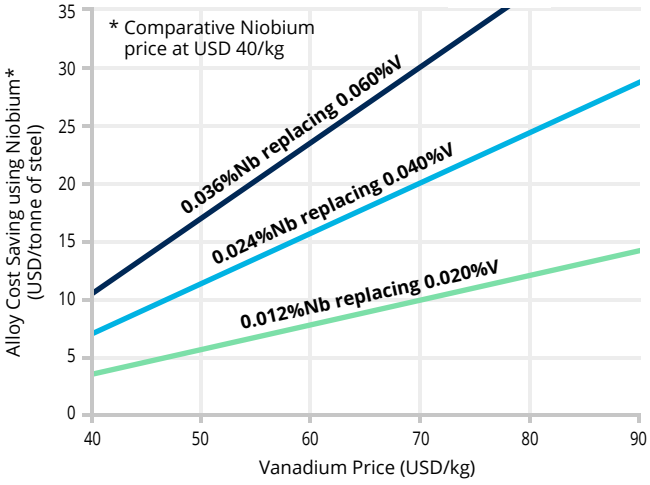
The price of raw materials used in the manufacturing of steel is largely market driven and most recently many ferroalloys have experienced substantial price increases as well as greater volatility. However, in comparison, the market price of niobium (supplied as a ferroalloy) has largely remained stable over several years. Furthermore, the availability of niobium has stayed consistent and importantly, secure.

Since 2016, steel producers have experienced some of the largest increases in price and volatility for alloying elements such as, vanadium and even manganese. Consequently, the industry is seeking alternative cost-efficient steel alloy design solutions and here niobium is a viable option, not only in the production of high strength steels but also some conventional steel grades.

The figure below highlights potential ferroalloy cost savings to be found in some common (300-350 MPa yield strength) and high strength steels (up to 420 MPa yield strength) when niobium is used as an alternative to vanadium for a given steel alloy design.

Note that the figure serves as a guide to the amount of alloy replaceable by niobium and that the relationship is not equal, i.e. one for one. The exact amount will depend upon the product type, final property requirements and steel-mill processing conditions. Nonetheless, typically 30% to 50% less alloy by wt.% is necessary to achieve the same strengths using only niobium.

As shown in the figure, with current market ferroalloy prices, savings of USD 10 per tonne of steel can easily be realized in most steel grades with a niobium steel alloy-design. For some lower strength steel products (e.g. plate and beams) where manganese levels of 1.40wt.% are typically seen it is also feasible to reduce this by 0.20 to 0.30wt.% using ≤0.010wt.% niobium and save approximately USD 1.20 per tonne of steel.



## Metallurgical benefits

Niobium (Nb) and vanadium (V) are alloying elements commonly used to increase strength in the production of high strength steels without the need for higher carbon content. In doing so they also improve other key properties, such as ductility. Unlike other popular alloying elements, such as manganese (Mn), the amounts applied are typically lower than 0.10wt.% and thus they are often referred to as 'microalloying' elements.

Vanadium, unlike niobium, experienced widespread usage several decades ago first being applied to tool steels. It is able to increase the strength of a steel via the metallurgical mechanism of precipitation hardening. However, despite increasing strength, this particular mechanism does not improve ductility and has a negative affect on toughness (impact) properties. In contrast, niobium gained popularity in the late 1960s after it was discovered that, unlike vanadium, it is primarily able to increase the strength of steel by a different metallurgical mechanism of grain refinement. The additional benefits of grain refinement are that it not only improves toughness but also steel ductility properties.

These attributes of microalloying with niobium were subsequently used to good effect in the production of large diameter oil and gas linepipe, offshore platforms and automotive parts that demanded higher levels of safety; and continue to do so today. In recent years, the benefits in properties when using niobium has also started to be experienced in the area of structural steels. This covers long products such as, beams, sections, rebar and wire rod, through to flat products such as, plate and strip (hot and cold rolled). As before, using niobium demonstrated excellent results for all these products leading to improved steel ductility, improved toughness as well as reducing the variability in overall properties when grain refinement is facilitated. Furthermore, as niobium can also enable steels to be produced with a lower carbon content, additional benefits are realized in fabrication and construction (i.e. better weldability).

## How to realize these benefits

For any steel-mill, the maximum amount of niobium that can be applied is defined by the 'solubility product'. This is a simple equation which takes into account the steel-mill's reheating furnace temperature and carbon content of the steel to calculate the maximum niobium that can be applied. The table below (in wt.%) provides some further guidance on this.

| | 1100 °C Reheat | 1150 °C Reheat | 1200 °C Reheat |
|---|---|---|---|
| 0.10 C | 0.025 Nb | 0.035 Nb | 0. 050 Nb |
| 0.15 C | 0.020 Nb | 0.030 Nb | 0.040 Nb |
| 0.20 C | 0.015 Nb | 0.025 Nb | 0.030 Nb |
| 0.25 C | 0.013 Nb | 0.020 Nb | 0.025 Nb |

In general, higher reheating temperatures and/or lower carbon content allow more niobium to be used. For most steel grades, additions above this level are not recommended. For conventional structural grades, additions of niobium below this maximum is usually enough to achieve to required properties.

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