Abstract
The market for steel products has widely changed since the end of the China Boom in 2008 and not recovered yet. Worldwide overcapacities – especially for commodity steel products such as carbon steel flats and rebar – sustainably put pressure on prices and decrease the possibility to generate sufficient profits for steelmakers around the globe. The steel industry’s sandwiched position between two well-consolidated industries in the steel value chain further sharpens this situation. To generate a competitive advantage over regional and international competitors, steel producers and foundries have to differentiate and develop into new markets and business models.

This paper presents a possible way to escape the low-margin trap by consequently specializing into growing, high-margin niche markets like tooling, aerospace & other high demand materials. The technological and organizational prerequisites to enter these markets are explained and suitable production concepts are derived from the findings. The paper compares the traditional EAF-LF-VD/VOD route with ALD’s innovative VID-route – a production concept, specially tailored to economically produce small-batch, high-grade materials from various raw materials at minimum losses on precious alloying elements. The concepts are compared on technological and economical base to lay a substantial foundation for decision-makers to think about future strategy and investments.

VID is, however, only the entry stage into ultra-high grade steelmaking, only to be exceeded by vacuum melting and pouring (VIM-VIDP), electro slag remelting (ESR) and vacuum arc remelting (VAR). Therefore, VID is to be seen as a first step into specialty steelmaking – especially interesting for SMEs that want to enter the market for elevated quality steel products.

ALD Vacuum Technologies is a world-leading supplier of machinery and services for production, heat treatment and coating of high-value, specialized metals. We serve customers around the globe with our extensive expertise from strategy planning, machine design and turnkey plant construction, towards production ramp-up and support.

1. Introduction
Steel degassing and ladle metallurgy and remelting are state of the art in modern iron- and steel industry. In the face of increasingly difficult markets, the efficient use of the perfectly fitting equipment setup is essential to win in the long run. Western steelmakers and foundries have gone through numerous cost-cutting rounds in the past decades where they harvested the low-hanging fruits. Further cost excellence has to focus on improved equipment to target the most interesting markets and increase the topline while maintaining an optimized bottomline.

The efficient use of primary and secondary raw materials, as well as ferroalloys, consumables and of course energy and workforce is a must to stay competitive. Improvement of any of these drivers may mean investments in the short run, but will pay out soon in the struggle for a place among premium-quality producers. Cost effectiveness is the catch phrase for this next wave of operational cost improvement. Even in countries with low labour and energy cost, efficient use of these valuable resources increasingly gains importance.

Furthermore, entry into growing niche markets for high-alloyed special steels and superalloys...
demands high expertise and technological excellence to achieve the demanded material cleanliness, super-fine grain structure and superior homogeneity of the materials to be used in aerospace, tooling and other high-quality applications.

These technologies are of course only the entry into the art of making ultra-premium grades for the highest requirements in aerospace turbine components, oil & gas exploration equipment, special tooling and others, that explicitly demand a higher amount of treatment, such as melting and pouring under vacuum, electro-slag-remelting and vacuum-arc-remelting in a row, the so-called triplemelt process. But since this is the latest stage of development and – due to long-lasting, expensive and complicated certification routines and a need for a very high amount of metallurgical know-how – not easy to enter, we will focus on the entry into premium steelmaking, the degassing. We will explore the metallurgical boundary conditions caused by the desired grades and derive the technological needs for the equipment to be used to successfully conquer the specialty steel market.

2. Market development in the steel industry

Since the China boom ended in 2008, steel industry suffers from low prices due to high buyer power from downstream industries, such as automotive, construction, energy and others. These industries profit from oversupply in most commodity-near materials like carbon steel flats and rebar. On the other side, the even more consolidated raw material producers – especially iron ore miners – increase prices and lower margins even further. As a result, steel producers find themselves in a sandwiched position without much market power.
This situation leaves steelmakers with low profits that can barely return their capital cost. A possible way out of this dilemma is to specialize in niche markets that are hard to address for large-scale steelmakers due to small order batch size, high quality requirements, large product dimensions and high market entry hurdles such as investment in specialized equipment and super-strict certifications. Possible niches with good growth projections and complicated, high-value products that still generate high margins are aerospace, tool- and die making.

These applications’ increasing demand in cleanliness (absence of non-metallic inclusions), narrow analytical and mechanical property ranges, material isotropy and homogeneity and strict definition of the applied production route make it very hard for large scale producers to integrate these products into their product portfolio. This is why in these markets the high overcapacity in the market is absent, leading to good margins and high utilization rates for producers who manage to enter these niches.

Additionally, these industries often demand small batch sizes of 30mt or less, making it hard to produce for the demand with traditional machinery that has continuously grown over the last decades.

3. Requirements for machinery to produce special steels
To step into these niche markets and also derive high returns, a well-sized and specifically fitted production route is needed.

Requirements include:

1. Variable batch sizes of up to 30t max.
2. Variability in alloying concept over a wide range from batch to batch
3. High reliability and process stability (reproducibility)
4. Very high product cleanliness and isotropy
5. High raw material efficiency

Possible process routes are:

1. EAF – LF – VD/VOD
2. EAF – VID –
3. Induction Furnace – VID
These concepts are to be compared along the defined criteria:

<table>
<thead>
<tr>
<th>Criteria</th>
<th>VDI/VOD</th>
<th>EAF - VD/VOD</th>
<th>EAF - VID</th>
<th>Ind. Furn.</th>
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<td>Variable batch sizes of up to 30t max.</td>
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<td>Variability in alloying concept over a wide range from batch to batch</td>
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Figure 4: Evaluation criteria for technological assessment of VID vs. EAF-LD-VD/VOD

The following table explains in more detail the advantages of the VID system for different steel grades and process steps:

Figure 5: Detailed evaluation of different technological drivers to produce high-value steels

As shown above, the VID process offers optimal process conditions for a wide range of different steel grades and great flexibility.

ALD’s VID systems can be equipped with furnace bodies in different sizes to expand the flexibility in batch size. It can also be fitted for oxygen blowing for ULC grades. In any case, the possibility to control the melt temperature throughout the process without aggregate change (as between LF and VD/VOD) without entrapment of oxygen due to inductive heating instead of electric arc heating improves process reproducibility.

4. The VID-process

For less than 30 t one has to consider the heat losses after superheating the melt in the LF within the vacuum treatment (20 min), soft Argon rinsing (10-15 min), transport time (15 min total) and casting (casting speed, appr. 20 to 30 min). Heat losses of 1 – 2 K/min in small ladles have to be calculated. In some cases the melt is reheated after VD due to excessive temperature drop of the melt with result of undesired pick up of Hydrogen.

As an attractive alternative of VD-treatment of smaller heats of less than 30 mt the VID (Vacuum-Induction-Degassing) has been developed for special applications in the ferrous and non-ferrous metal industry. Whenever pouring under vacuum is not specified or required for metallurgical reasons, this type of furnace with teeming under atmosphere or protective gas is recommended.

Smaller steel shops and foundries will be able to produce with the VID furnace within one step high quality vacuum treated steels, whereas larger steel shops realize these grades by conventional secondary metallurgy route (LF/VD). The temperature losses during degassing treatment are compensated by induction heating with the VID-process during the whole treatment time.
Figure 6: General layout of a VID system

Figure 6 shows a general lay-out of a VID-system. This process can be used as well as furnace with solid scrap additions or as liquid charging out of an EAF. This can be adapted and tailor made to customer’s needs.

An advantage of a liquid transfer out of an EAF is the use of scrap without any specific requirements like analysis and shape. Especially for higher P-content the VID – system is limited and the EAF-process for creating the mother heat is recommended.

A typical process is as follows:

- Charging in air or liquid material input
- Meltdown under air/inert gas/vacuum
- Degassing under vacuum
- Refining under vacuum
- Sampling
- Temperature measurement
- Alloying/fine trimming
- Inert gas purging with lance and/or porous plug
- Tapping into a ladle or direct casting

VID machinery properties are:

- Melting capacity: max. 30 mt steel
- Melting power supply: up to 8,000 kW
- Melt and refining time: approx. 3 – 4 hrs
- Specific power consumption: Approx. 650 kWh/mt

In case of a liquid transfer the power supply will in the range of 2,000 kW for 20 mt of steel capacity. The cycle time will be for the VID-treatment less than 30 min. Figure 7 shows different sizes of VID systems offered by ALD.

Figure 7: Technical data of different VID sizes offered by ALD

5. Process cost comparison

Since the best process cannot bear exhaustive cost, the VID process of course has to compete with the EAF-LF-VD/VOD route.

A comparison of a 20 mt heat by the traditional route LF-VD and VID is shown in Figure 8:

Figure 8: Process comparison between VID, VID for liquid charging and the EAF route

Three versions have been checked:

1. VID solid charging
2. EAF – liquid transfer to VID
3. EAF – LF – VD
The equipment prices based on European basis have been evaluated and for an EAF the investment will be in the range of 4.5 Mio € and the LF/VD in a range of 4.0 Mio € (without building, auxiliaries, infrastructure).

For a 20 mt VID installation the estimated investment are for solid charging with higher melting power are in the range of 5.5 Mio € and for liquid charging 4.8 Mio € [6].

Given this calculation, the installation of a VID system is economically competitive.

- **High flexibility due to continuous heating and exchangeable furnace body optimizes cost for each heat**
- **VID offers cost advantage over LF-VD/VOD setup across the complete size range up to 30t furnace size and 35kt annual capacity**
- **Solid and liquid charge possible – process route connectable to existing EAF or other melting devices**
- **High reproducibility with low dust, gas and noise emissions increase process stability and workplace safety**
- **Comparatively low investment and operational cost**

ALD has extensive experience in supply of equipment for special steelmaking, but we do not stop here. Our mission is to assist our customers in each phase of the product’s life cycle, from business case development until...
production support, maintenance and revamping. Therefore we offer:

- **Business case development**: Fitting the equipment into the existing environment and the desired outcome

- **Turnkey planning and execution**: Development of the complete production facility including all workshop halls, equipment auxiliaries and media supply

- **Construction supervision** from the foundation until hot testing

- **Ramp-up support, teaching and recipe development**: Our dedicated and experienced metallurgists, software developers and commissioning engineers are on the ground from day.

- **Production support**: If you want us to, we stay on site until all certification is done and the production runs in full scale.

- **Implementation of new materials**: We offer recipe development throughout the whole equipment lifetime.

- **Maintenance**: Our service team is always on hold, our induction coil workshop makes certain, that your material will always reach up to our premium standard.

- **Revamp**: As any equipment comes to age, we update our machinery if necessary to keep you up to date.

- **Production extension**: Upgrade of existing production setups to extend the footprint into higher grades and more demanding markets.

7. **References**


If we caught your interest, please do not hesitate to contact us on booth XXX or directly:

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