THE OPTIMAL TOOL STEEL SOLUTIONS FOR AHSS

a comprehensive focus on Uddeholm Vanadis 4 Extra, Vanadis 8, and Vancron SuperClean

The increasing use of Advanced High-Strength Steels (AHSS) in modern manufacturing, particularly within the automotive industry, places significant demands on tooling materials. High forming forces, accelerated wear mechanisms, and risks of chipping and galling necessitate advanced solutions.

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This article explores the performance of Uddeholm Vanadis 4 Extra SuperClean, Vanadis 8 SuperClean, Vancron and Caldie – four high-performance tool steels tailored for cold work applications involving AHSS.

AHSS (Advanced High-Strength Steel) is a group of steels with high strength and good formability, with a typically yield strength above 440–500 MPa. It's mainly used in automotive applications to reduce weight while improving safety.

By leveraging powder metallurgy (PM) and advanced alloying techniques these steels offer superior resistance to abrasive wear, adhesive wear (galling), and fatigue cracking while maintaining adequate ductility and dimensional stability. Vanadis 4 Extra balances toughness and wear resistance, Vanadis 8 excels in extreme wear conditions, Vancron integrates galling resistance, all with the ability to extend the tool life even further by adding a PVD coating on top.

Through detailed analysis, including mechanical properties, failure mechanisms, and real-world case examples, this article highlights how selecting the appropriate tool steel can enhance tool life, reduces downtime, and optimizes productivity in demanding AHSS forming and blanking operations.

Advanced High-Strength Steels

Sustainability, efficiency, and safety are at the heart of today's global manufacturing priorities, particularly in the automotive industry. Advanced High-Strength Steels (AHSS) play a critical role in achieving these goals, offering unmatched weight reduction while maintaining high strength and crash performance. By reducing vehicle weight while maintaining high strength, AHSS enables manufacturers to produce safer and more fuel-efficient vehicles, which contributes to lower CO_2 emissions, which in turn reduces emissions and the overall environmental footprint.

The use of AHSS is expanding rapidly, driven by strict emission regulations and the need for cost-efficient lightweight designs. It has become a cornerstone material in producing automotive structural components such as B-pillars, crash beams, and battery enclosures for electric (EVs) and hybrid vehicles. Globally, this trend is accelerating, where sustainability goals and government directives are reshaping the automotive landscape.

However, AHSS is not without its challenges. Its high strength and advanced microstructure make it more demanding to process, particularly in cold work applications such as forming, blanking, and punching. These challenges manifest in several critical ways:

Abrasive Wear: The high hardness of AHSS causes increased tool wear, where the tough steel being formed acts like sand-paper, rapidly scratching and grinding down the tool surface. This leads to tools wearing out quickly, becoming dull, and losing effectiveness during forming and punching operations.

Adhesive Wear (Galling): When forming coated or stainless AHSS, severe friction between the tool and the material can cause material to stick to the tool surface. This creates rough, pulled out areas and damages both the tool and the workpiece.

Chipping and Cracking: The intense mechanical loads required to process AHSS can lead to chipping – where small pieces break off from the tool's edges – and cracking, where small cracks form and spread under repeated stress. This often occurs during blanking or stamping operations, reducing tool lifespan and precision.

Plastic Deformation: Under high contact pressures during AHSS forming and blanking operations, standard tool steels can bend or dent permanently. This changes the tool geometry and precision, leading to poor-quality parts and increased maintenance needs.

The strength of AHSS dictates whether a tool will hold its shape or succumb to plastic deformation, but it's the unique micro-structures within AHSS that define how the material interacts with the tool during production. Each phase – whether ferrite, martensite, bainite, or austenite – brings its own challenges, influencing tool performance through wear, sticking, or deformation.

Typical AHSS sheets and its Structure		
AHSS Type	**Structure**	**Typical Strength** (MPa)
Dual Phase (DP)	Ferrite + Martensite	500–1000
Complex Phase (CP)	Ferrite + Bainite + Martensite	780–1000
Martensitic (MS)	Martensite	1100–1400
Ferritic-Bainitic (FB)	Ferrite + Bainite	600–800
TRIP	Ferrite + Bainite + Austenite	500–700
TWIP	Austenite + Twinning	900–1200

AHSS sheet type and their microstructure.

Ferrite: causes sticking which causes Galling, which leads to Adhesive Wear

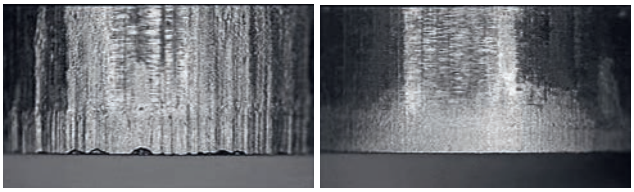
Martensite: causes abrasive wear and edge chipping.

Bainite: contributes to a mix of Abrasive and Adhesive wear. Also, somewhat sticky

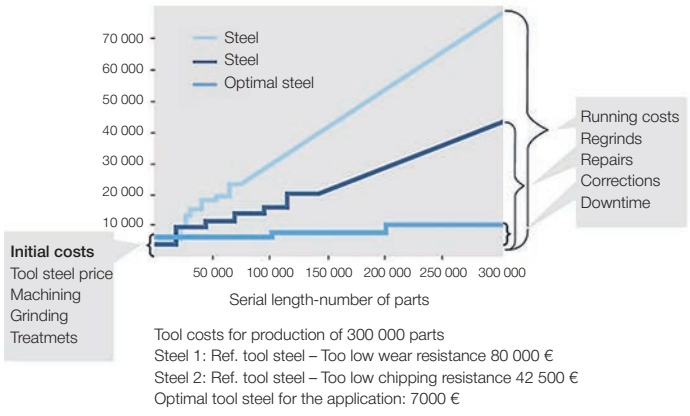
Austenite: especially in TRIP and TWIP steels, causes Plastic deformation and localized stress damage due to work hardening.

Understanding these relationships helps manufacturers select the appropriate solution, which often requires an optimal combination of hardness, wear resistance, ductility, and dimensional stability.

Below is an example where Uddeholm Vanadis 4 Extra after blanking of a typical AHSS sheet in a thickness of 1.5 mm. Traditional steels struggle to meet the increasing demands of AHSS, and often leading to costly tool failures, downtime, increased maintenance efforts and poor part quality.



Edge comparison between AISI D2 (left) and Uddeholm Vanadis 4 Extra (right) after stamping 50,000 parts.



Total tool cost considerations. Steps in lines indicates cost for refurbishment.

Strong Tools for Stronger Materials

Working with Advanced High-Strength Steels (AHSS) puts extreme demands on tooling. To handle these challenges, Uddeholm offers high-performance powder metallurgy (PM) tool steels. Vanadis 4 Extra, Vanadis 8 and Vancron are three key grades, each with properties tailored to different wear and toughness requirements.

Thanks to the PM process, these steels have a fine, even microstructure with well-distributed hard phases. This results in excellent wear resistance and durability and are crucial for applications like blanking and forming AHSS. By continuously developing advanced materials, Uddeholm helps ensure efficient and reliable production in a rapidly evolving industry.

Uddeholm Vanadis 4 Extra SuperClean
The composition of Vanadis 4 Extra, an optimized alloying of chromium, molybdenum, and vanadium that creates a microstructure with evenly distributed carbides. This carefully controlled PM process results in a material that provides:

High Abrasive and Adhesive Wear Resistance: The presence of finely dispersed carbides ensures strong resistance to wear mechanisms that dominate in blanking and forming operations with AHSS.

Exceptional Ductility and Chipping Resistance: Where brittle failure can be catastrophic, Vanadis 4 Extra demonstrates elevated ductility, significantly reducing the risk of chipping or cracking, particularly under high cyclic loading conditions.

Dimensional Stability: Minimal distortion during heat treatment and minimal aging effect during operation ensures precision and consistency in tool performance, a critical factor for high-accuracy applications.

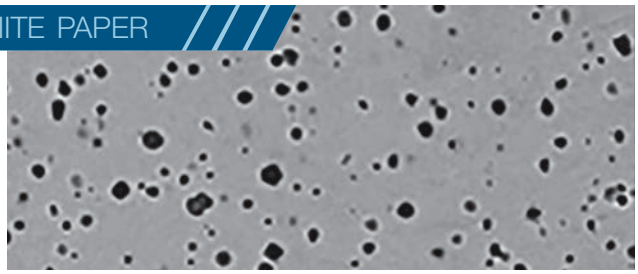
Manufacturability and Practicality
From a production perspective, Vanadis 4 Extra offers significant advantages in machinability and grindability, properties not always associated with high-alloy tool steels. This facilitates efficient tool production and finishing, enabling manufacturers to maintain tight tolerances without excessive processing costs.

Vanadis 4 Extra is particularly well-suited for applications where AHSS imposes severe conditions on tooling materials, such as:

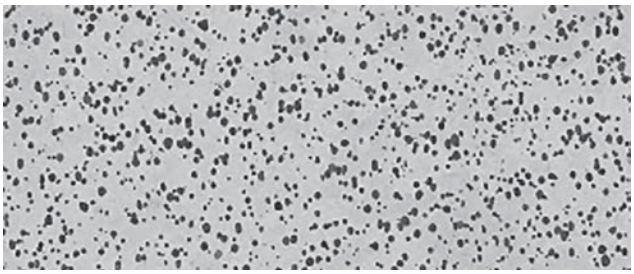
- Tools subject to high cyclic loading where wear resistance must be balanced with ductility to prevent early failure.
- Tools that face high mechanical stresses during shaping and must resist both plastic deformation and fatigue cracking.
- The ability to maintain performance in these demanding environments makes Vanadis 4 Extra a durable versatile steel grade where traditional high-speed steels often fail to deliver sufficient durability.

Uddeholm Vanadis 8 SuperClean
The composition of Vanadis 8, with its high vanadium content and optimized composition, results in a tool steel with a fine and uniform carbide distribution. This advanced microstructure provides superb performance in terms of wear resistance, making it particularly suited for demanding applications with long production runs and abrasive conditions.

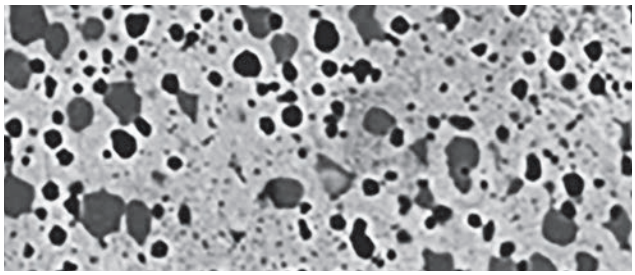
Uddeholm Vanadis 4 Extra, the top bar, absorbs significantly more deformation before cracking compared to standard high-speed steel. Its fine PM micro-structure and unique composition can be crucial for demanding applications and safety under extreme stress. Both grades at 60-62 HRC.



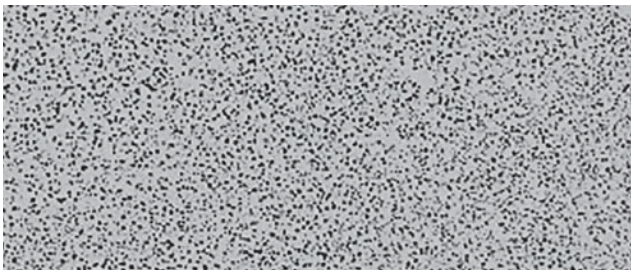
Vanadis 4 Extra ~8 % V+C Vanadium Carbides



Vanadis 8, ~15% MC carbides



PM 10 type that contains ~13% (9% MC+ 3% M7C) mixed size carbides



Vancron ~16% MCN V+C+N = Vanadium Carbonitrides

How the Carbide Structure Increases Tool Life

The high proportion of fine vanadium carbides in Vanadis 8 provides maximum resistance to abrasive wear, which is critical when working with hard, abrasive materials like AHSS. The fine carbides act as a protective barrier, resisting the micro-cutting, that occurs when hard particles slide against the tool surface.

Tools made from Vanadis 8 maintain their sharp cutting edges and dimensional accuracy for far longer. While large, coarse, and mixed carbides in high-speed steels can create stress concentrations and initiate chipping and cracks, the fine, evenly distributed carbides in Vanadis 8 minimize this risk.

At the same time, its homogeneous and SuperClean structure enhances the steel's ductility, allowing it to absorb higher loads without chipping or cracking.

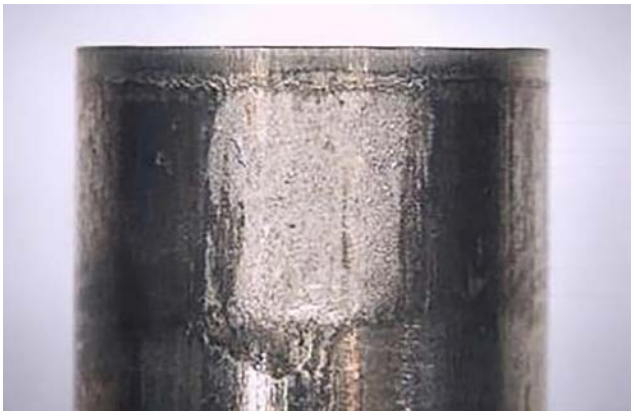
High hardness of the small carbides improves resistance to premature edge wear, ensuring longer tool life under heavy loads.

This combination makes Vanadis 8 the ideal tool steel for long production runs where tools are subjected to extreme wear and high stresses, such as in blanking and punching operations for AHSS.

By leveraging the hardness and stability of vanadium carbides, Vanadis 8 not only extends tool life but also improves overall manufacturing efficiency, reducing the need for tool maintenance and replacement.

Uddeholm Vancron SuperClean

Vancron is a nitrogen-alloyed PM tool steel that stands out among high-performance tool steels because of its unique nitrogen-rich composition, achieved through advanced Powder Metallurgy (PM) technology. This advanced micro-structure introduces a balance of wear resistance and galling resistance, making Vancron particularly effective in forming and blanking applications where adhesive wear, such as galling, is a dominant challenge.

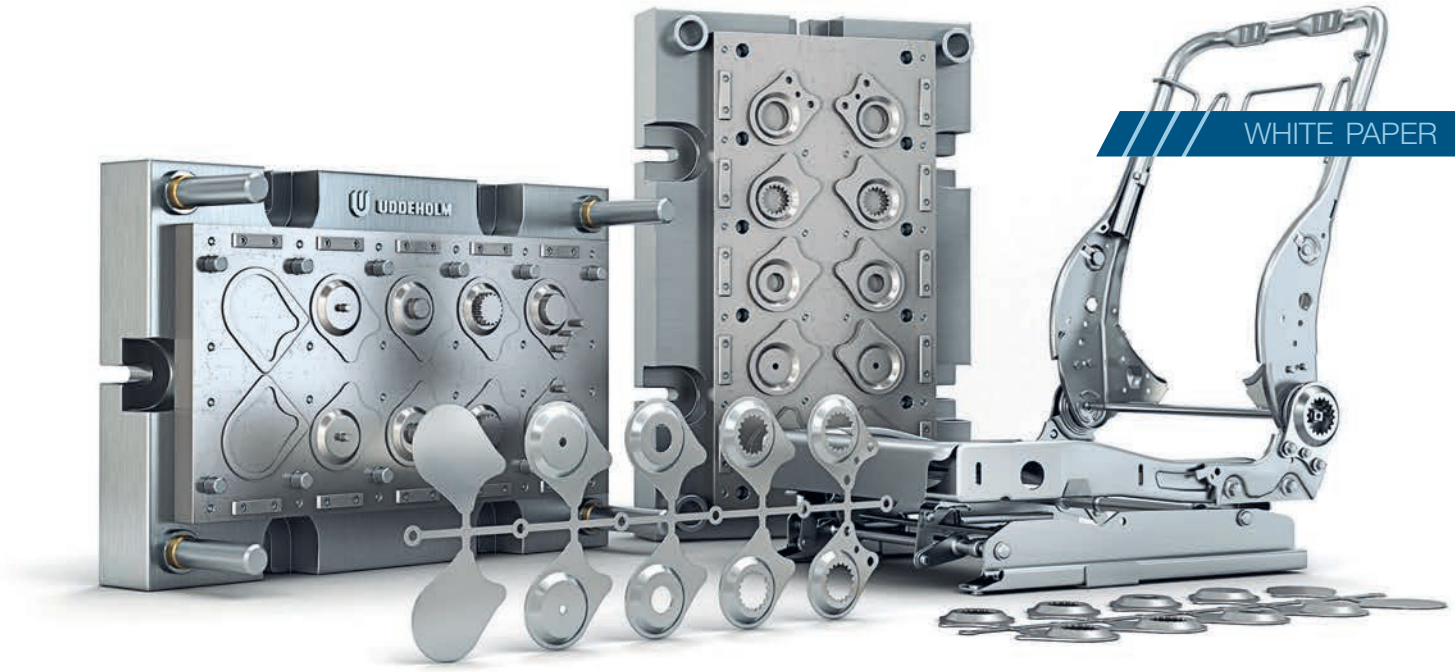


Stamping punch suffered severe galling.

Nitrogen-Rich Carbonitrides – Built-In Galling Resistance

The nitrogen alloying process leads to the formation of nitrogen-rich carbonitrides, which provide a naturally low-friction surface within the steel matrix in combination with its small nitro carbides. Unlike external coatings, which can wear off or delaminate over time, this property is inherent to the material itself. The smooth, low-friction surface minimizes metal-to-metal adhesion, reducing the risk of galling under high contact pressures and sliding conditions, particularly when working with coated AHSS (e.g., hot or electro galvanized).

In addition to its galling resistance, finely distributed vanadium carbonitrides, deliver excellent abrasive wear resistance. This ensures tools retain their edge integrity and performance over long production runs, even in highly abrasive environments.



Uddeholm Vancron is particularly well-suited for applications where reliable, long-term tool performance is essential:

- Forming tools for coated AHSS, such as galvanized (GI/GA) or aluminized sheets.
- Blanking and punching tools requiring low friction and high wear resistance and a sharp edge.
- Complex stamping and forming operations with high sliding pressures and surface contact.

By eliminating the need for additional coatings, Vancron simplifies tooling maintenance while delivering consistent performance. Self-lubricating properties provide a unique solution for applications where the work material sticks to the tool and takes away the risk of premature tool failures and replacements.

Conclusion

The increasing use of Advanced High-Strength Steels (AHSS) in modern manufacturing presents significant challenges, particularly for tooling materials exposed to abrasive wear, galling, and chipping. Uddeholm's high-performance tool steels – Vanadis 4 Extra SuperClean, Vanadis 8 SuperClean, and Vancron – are specifically developed to address these issues and extend tool life in demanding cold work applications.

Uddeholm Vanadis 4 Extra SuperClean provides an excellent balance of wear resistance and toughness, making it the versatile choice for applications requiring both durability and resistance to chipping.

Uddeholm Vanadis 8 SuperClean excels in environments dominated by abrasive wear, offering superior edge retention and tool life for long production runs.

Uddeholm Vancron SuperClean, with its nitrogen-rich carbonitrides, offers inherent galling resistance and reduces the need for coatings, making it particularly effective for forming coated AHSS.

By selecting the appropriate tool steel for specific challenges – whether galling, abrasive wear, or chipping – manufacturers can enhance productivity, reduce downtime, and achieve consistent, high-quality results when working with AHSS materials.

By leveraging the unique properties of these advanced tool steels, manufacturers can optimize tooling performance and address the diverse challenges posed by AHSS materials.

When to use Uddeholm Vanadis 4 Extra, Vanadis 8, and Vancron

Tool Steel	Primary Strength	Applications	Ideal for
Vanadis 4 Extra SuperClean	Balanced toughness and wear resistance	Blanking, forming, and stamping tools for AHSS	Applications requiring a balance of toughness and wear resistance to prevent early failure.
Vanadis 8 SuperClean	Exceptional abrasive wear resistance	High-volume blanking and punching of AHSS	Environments with extreme abrasive wear where maximum edge retention is critical.
Vancron SuperClean	Superior galling resistance, low friction	Forming tools for coated AHSS (e.g., galvanized)	Environments with extreme adhesive wear (galling) dominates, edge retention is critical and coatings are impractical.

Uddeholm solutions in different environments.