V-Technology

A Vanitec Report on Technical Papers & Publications

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Vanitec is a technical and scientific committee, which brings together representatives of companies and organisations involved in the mining, processing, manufacture, research and use of vanadium and vanadium-containing products.

Vanitec establishes, collects and makes available information on vanadium, its use, availability, new scientific and technical developments and trends in its application. The object of V-Technology is to provide up to date information and to initiate discussion through the medium of short articles on subjects to the use of vanadium.

Recent Vanadium Related Publications Review

Vanadium Improves Mechanical Properties of Hot Stamped Boron Steel for Automotive Body Engineering Applications

The use of ultrahigh strength steel is one of the most effective ways to reduce car body weight while securing the required crashworthiness. However, forming of ultra-high strength steel at room temperature is limited by low formability and considerable springback. Therefore, hot stamping was developed in the 1970s in Sweden and is being increasingly used to produce lightweight ultra-high strength steel structural auto body parts. In the traditional direct hot-stamping process, the as-delivered strip of boron steel (most commonly used steel: 22MnB5) blank is heated in a furnace to its austenitisation temperature of around 900°C, formed in an internally cooled die set, and quenched under pressure to form a martensitic microstructure in the part, imparting high strength up to 1500 MPa. Ultra-high strength parts with complex geometries can be produced with hot stamping without the problem of springback. In recent years, many research works have been carried out to develop hot stamping steels with better performances. Taylor T. et al. published a paper "Effect of Carbon and Microalloy Additions on Hot-stamped Boron Steel" in Materials Science and Technology, vol. 33, no. 16, 2017, pages: 1964–1977 and it demonstrated that vanadium addition in hot-stamped boron steel results in ultimate tensile strength in excess of 1600 MPa combined with total elongation in excess of 11.0%.

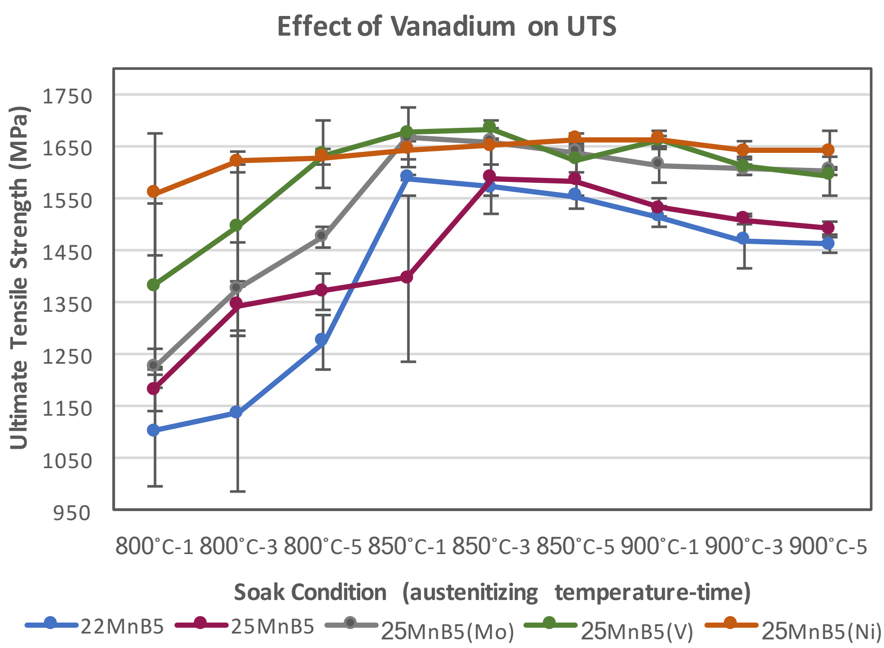

Fig. 1 The addition of vanadium results in higher ultimate tensile strength compared to the standard 22MnB5 and 25MnB5 steels

Laboratory hot stamping experiments were performed on eight boron steels including a conventional boron steel 22MnB5 and seven novel boron steels with variable carbon contents and microalloy additions of Mo, V and Ni in order to achieve higher tensile strength and higher elongation compared to 22MnB5. The steels were broadly classified into categories of XMnB5 and 25MnB5 (X) and the chemical compositions are shown in Table 1. Nine soak temperature (800°C, 850°C and 900°C) - time (1, 3 or 5 min) conditions were investigated for each steel.

Table 1 Chemical composition of the steels (wt.%)

	Steel	C	Mn	Si	P	S	Cr	V	Mo	Ni	Ti	B	N
XMnB5	22MnB5	0.225	1.229	0.211	0.018	0.008	0.289	0.000	0.001	0.000	0.037	0.0041	0.0049
	15MnB5	0.145	1.200	0.190	0.015	0.004	0.280	0.000	0.005	0.005	0.023	0.0030	0.0044
	29MnB5	0.291	1.260	0.179	0.017	0.007	0.195	0.000	0.001	0.000	0.030	0.0036	0.0061
	38MnB5	0.380	1.200	0.190	0.015	0.004	0.280	0.000	0.005	0.005	0.024	0.0030	0.0047
25MnB5(X)	25MnB5	0.245	1.195	0.178	0.021	0.009	0.251	0.000	0.001	0.000	0.033	0.0032	0.0040
	25MnB5(V)	0.255	1.200	0.190	0.016	0.004	0.280	0.097	0.005	0.005	0.024	0.0030	0.0047
	25MnB5(Mo)	0.257	1.180	0.202	0.016	0.005	0.280	0.000	0.218	0.000	0.029	0.0041	0.0072
	25MnB5(Ni)	0.255	1.310	0.190	0.014	0.004	0.280	0.000	0.005	0.500	0.024	0.0030	0.0050

Scanning electron microscopy (SEM) examination of the steels after the hot stamping showed that 46%-100% martensite was obtained in the steels and in each case where the martensite was less than 100%, the remainder of the microstructure was proeutectoid ferrite. For each steel, there was generally a positive correlation between soak time-temperature and martensite percentage. It is suggested that increasing soak time-temperature increases austenitic grain growth and results in less heterogeneous nucleation sites for proeutectoid ferrite transformation and higher quench hardenability, ultimately, increasing martensite percentage in the final quenched microstructure. For the XMnB5 steels, increasing carbon content led to a complete transformation to martensite at lower soak time-temperature condition. For the 25MnB5(X) steels, addition of molybdenum, vanadium or nickel demonstrated lower quench hardenability than the 25MnB5 steel.

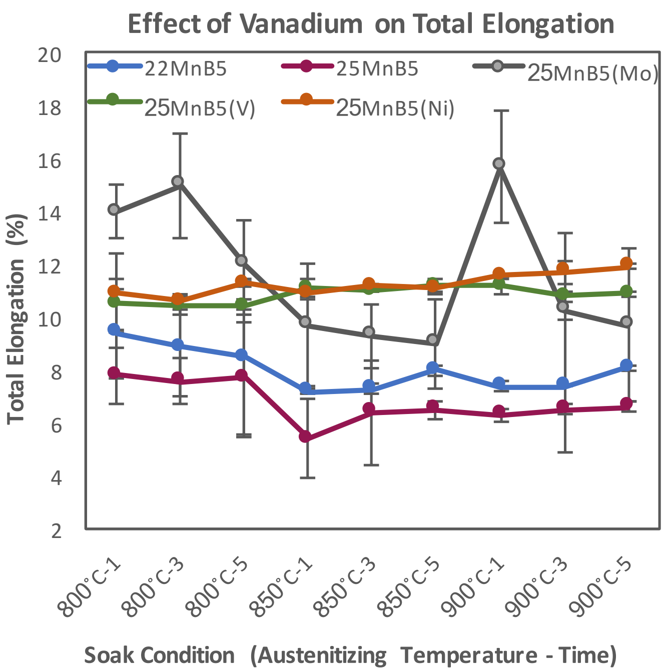

Fig. 2 The addition of vanadium improves the total elongation compared to the standard 22MnB5 and 25MnB5 steels

The tensile tests showed that increasing carbon content in the XMnB5 steels resulted in higher proof strength and higher ultimate tensile strength with comparable total elongation. It is suggested that the tensile strength gain could be attributed largely to interstitial solid solution strengthening and the insignificant loss of elongation could be due to greater autotempering of martensite during quenching. The higher carbon content of the 38MnB5 steel resulted in ultimate tensile strength in excess of 2000 MPa and the 38MnB5 steel could offer significant down-gauging and light weighting opportunities to anti-intrusive parts.

The addition of molybdenum, vanadium or nickel provided higher proof strength and higher ultimate tensile strength with improved total elongation over the standard 22MnB5 and 25MnB5 steels as shown in figures 1 and 2. The vanadium addition led to ultimate tensile strength in excess of 1600 MPa combined with total elongation in excess of 11.0%. It is considered that vanadium carbide precipitation have played a role in the increased tensile strength and vanadium addition is also beneficial to the elongation. It is concluded that the carbon and microalloy additions improve the mechanical properties in hot stamped boron steel for automotive body engineering applications.

Vanadium Microalloying is Beneficial for Microstructure Control of Medium-high Carbon Steels

Recently, there has been an increased demand for ultrahigh strength steels with good ductility and toughness. One of the potential solutions to achieve this is the use of a thermomechanical treatment – high temperature ausforming (modified ausforming). This process involves deformation at a temperature above A_{c3} (stable austenite region) prior to quenching to form martensite. The enhanced mechanical properties of high temperature ausformed steels are mainly attributed to the subcell structure introduced in austenite by the deformation and inherited by the martensite. In order to obtain the effect of high temperature ausformIng, it is essential to reserve the work-hardening of austenite after hot deformation before quenching. Therefore, inhibition of recrystallization is very important to obtain the optimum properties. Manabu Kubota, et al. of Nippon Steel & Sumitomo Metal Corporation have recently published a paper "Effects of Alloying Elements on Static Recrystallization Behavior of Work-Hardened Austenite of High Carbon Low Alloy Steel" in Materials Transactions, vol. 58, no. 2, 2017, pages. 186-195 and showed that vanadium microalloying is very effective to inhibit static recrystallization after hot deformation during high temperature ausforming process in the high carbon spring steels.

The authors systematically investigated the effect of microalloying elements (V, Nb, Ti) and the ausforming conditions on recrystallization behavior of work-hardened austenite of the SAE9254 spring steels with base composition of 0.55%C-1.5%Si-0.7%Mn-0.7%Cr, as shown in Table 2. Double-hit compression tests were carried out with a THERMECMASTOR-Z to investigate the recrystallization behavior of the steels. Specimens were heated at 1200°C, 1050°C or 950°C for 10 s. The applied strain at the first and the second hit was 0.3 and the strain rate was 2.5 s^{-1}. The deformation and holding temperature between the first hit and the second hit was 900°C, 850°C or 800°C. Optical microscopy, transmission electron microscopy (TEM) and atom probe tomography (APT) were used to examine the microstructure and precipitation of the steels.

Table 2 Chemical composition of the steels (wt.%)

Steel	C	Si	Mn	Cr	P	S	Al	V	Nb	Ti	N
SAE9254	0.55	1.49	0.68	0.72	0.015	0.010	0.002	-	-	-	0.0050
Nb(1)	0.55	1.51	0.69	0.72	0.014	0.011	0.002		0.002		0.0050
Nb(2)	0.56	1.50	0.68	0.72	0.014	0.010	0.002		0.010		0.0048
V(1)	0.55	1.50	0.68	0.72	0.015	0.009	0.003	0.02	-	-	0.0050
V(2)	0.56	1.50	0.68	0.72	0.016	0.010	0.003	0.10	-	-	0.0048
Ti	0.56	1.49	0.68	0.73	0.015	0.009	0.003	-	-	0.035	0.0049

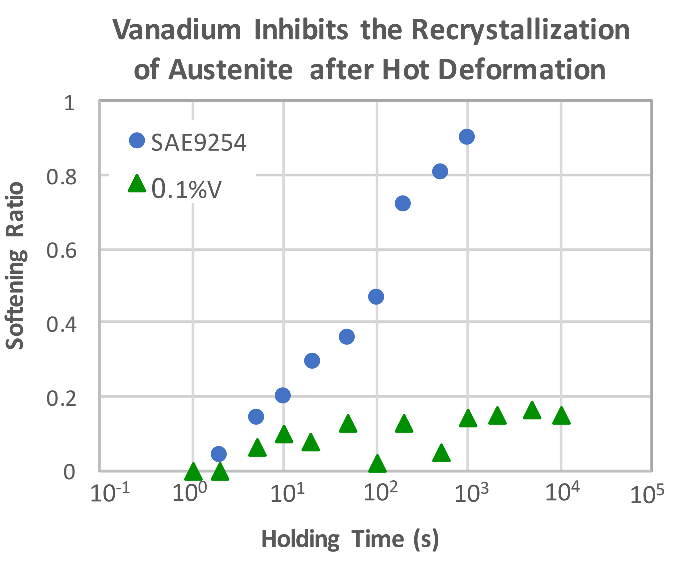

Fig. 3 Comparison of static softening behavior between SAE9254 and V(2)-0.1%V steel [1]

The authors showed that 0.1%V addition has significant inhibition effect on the recrystallization of the work-hardened austenite in the SAE9254 spring steel within a wide range of austenitizing temperatures, especially when the deformation and holding temperature is low. Figure 3 shows the effect of 0.1%V addition on the static recrystallization behavior, which was investigated by double-hit compression tests with austenitizing temperature of 1200°C and the deformation and holding temperatures of 800°C. After deformation and holding at 800°C for 10^4 s, the recrystallization was completed in the steel without vanadium, however, the softening ratio was less than 20% in the steel with 0.1%V addition. Fine VC precipitation was not detected by TEM or APT. It is suggested that the reason for the strong effect of vanadium on the inhibition of recrystallization is the interaction between V and C. C–V complexes or extremely fine VC clusters, which cannot be clearly identified by APT, may be responsible for inhibiting recovery and recrystallization.

The author also demonstrated that the effect of niobium or titanium addition on inhibiting recrystallization of austenite after the deformation in the SAE9254 spring steel was sharply decreased with decreasing in austenitization temperatures. This behavior is considered to be caused by the decrease in the solute contents of niobium or titanium at the initial austenitizing temperatures. When the austenitizing temperature is low, Nb or Ti mainly exist as undissolved coarse precipitates, which have a very weak recrystallization inhibition effect. In contrast, even when the austenitizing temperature is low, 0.1%V steel shows a relatively strong inhibition effect on recrystallization, as long as the deformation and holding temperature is low. It is concluded that vanadium is effective to inhibit recrystallization after hot deformation in medium-high carbon steels. On the other hand, niobium or titanium Is difficult to use in medium-high carbon steels, because of their low solubilities. The authors indicated that if niobium is used, austenitizatlon must be done at very high temperatures. However, this is not realistic in practical use, because decarburization would easily occur at high temperatures in medium-high carbon steels. The authors expected that this work would lead to an increase in the use of vanadium in ultrahigh strength medium-high carbon steels.

Ref. 1 Analysis of Recrystallization Behavior of Hot-deformed Austenite Reconstructed from Electron Backscattering Diffraction Orientation Maps of Lath Martensite, Manabu Kubota, Kohsaku Ushioda, Goro Miyamoto, and Tadashi Furuhara, Scripta Materialia, vol. 112, 2016, pp. 92-95.

Effect of V(C,N) Precipitation on the Mechanical Properties of High Manganese Steel

High manganese (Mn) steels have received great attention for automotive applications due to their excellent tensile strength and superior elongation. The attractive mechanical properties of high Mn steels are known to be closely related to their plasticity behaviors including dynamic strain aging and mechanical twinning. However, the relatively low yield strength of high Mn steels, especially when compared with existing advanced high strength steels is a critical problem limiting their use in structural parts of automobiles. Microalloying of high Mn steels is therefore considered as a way to increase the yield strength by grain size refining and precipitation strengthening. A recent publication (Precipitation Effect on Mechanical Properties and Phase Stability of High Manganese Steel, Cheoljun Bae, Rosa Kim, Un-Hae Lee, and Jongryoul Kim, Metallurgical and Materials Transactions A, vol. 48, no. 9, 2017, pp. 4072-4079) demonstrated that precipitation of fine V(C,N) in an austenite matrix improves the yield strength of high Mn steels.

The study was carried out on three high Mn steels, Ref., Ref.+V and Ref.+Ti and the chemical composition of the steels is shown in Table 3. The steel slabs were fabricated by vacuum induction melting. These slabs were homogenized for 2 hours at 1200˚C and then hot rolled to a thickness of 15 mm. The rolling temperature was controlled under the non-recrystallization temperature to induce the highly deformed austenite grains. These rolled plates were air-cooled to room temperature. Tensile tests were carried on the hot rolled plates. The phase change in the austenite matrix by plastic deformation was analysed with X-ray diffractometry (XRD). Microstructure and precipitation of the steels were examined by scanning electron microscopy (SEM), transmission electron microscopy (TEM) and electron backscatter diffraction (EBSD).

The tensile test results showed that vanadium addition to the Ref. steel increased the tensile strength from 1055 MPa to 1113.1 MPa and the yield strength from 465.9 MPa to 528.6 MPa without any significant change in elongation compared to the Ref. steel (figure 4). In contrast, the tensile strength, yield strength and elongation of the Ti added steel (Ref.+Ti) were severely reduced compared to the Ref. steel (figure 4).

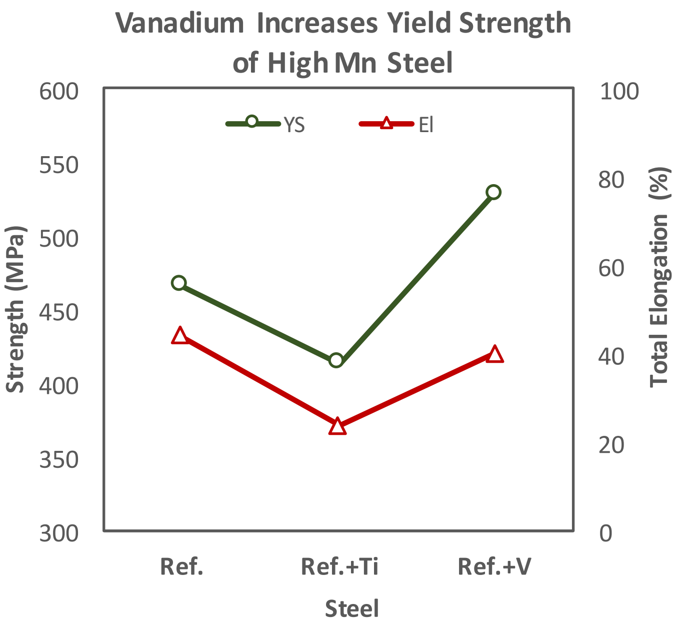

Fig. 4 Mechanical properties of the steels

Table 3 Chemical composition of the steels (wt.%)

Steel	C	Si	Mn	P	S	Ti	V	N
Ref.	0.4	0.1	18	<0.02	<0.01	-	-	0.015
Ref.+Ti	0.4	0.1	18	<0.02	<0.01	0.5	-	0.015
Ref.+V	0.4	0.1	18	<0.02	<0.01	-	0.5	0.015

SEM analysis and EBSD maps of the hot rolled plates revealed that the steels had similar average austenite grain size (Ref.: 36.92 μm; Ref.+Ti: 33.27 μm; Ref.+V: 34.52 μm), which was significantly decreased compared to the initial grain size at reheating temperature. In addition, a low-angle boundary is highly distributed in all samples. It is suggested that the changes in grain refinement strengthening are negligible with the microalloying additions. TEM analysis revealed a few coarse Ti(C,N) precipitates with a size of several hundred nanometers in the Ref.+Ti steel and many fine (10 nm) V(C,N) precipitates, which have a cube–cube orientation with the austenite matrix, in the Ref.+V steel. Figure 5 shows TEM micrographs of the V(C,N) precipitates, the corresponding selected area diffraction pattern and the orientation relationship between V(C,N) and the austenite matrix in the Ref.+V steel. The authors concluded the increased yield strength of the Ref.+V steel compared with the base Ref. steel is due to precipitation strengthening of fine V(C,N). However, the precipitation hardening effect was not achieved in steel containing titanium.

The study also showed that before the tensile tests, all samples had single phase of austenite, irrespective of the addition of vanadium or titanium. After the tensile tests, the austenite single phase was maintained in the Ref. and Ref.+V steels, but ε-martensite phase was detected in the Ref.+Ti steel. It is suggested the formation of ε-martensite phase is responsible for the decreased elongation in the Ref.+Ti steel. The stacking fault energy simulation and XRD analysis implied that the consumption of soluble carbon through the formation of coarse Ti(C,N) precipitates resulted in the formation of the ε-martensite in the Ref.+Ti steel after the tensile test. The authors indicated that in order to increase the yield strength without sacrificing the formability, it is critical to control the soluble carbon content in high Mn steels.

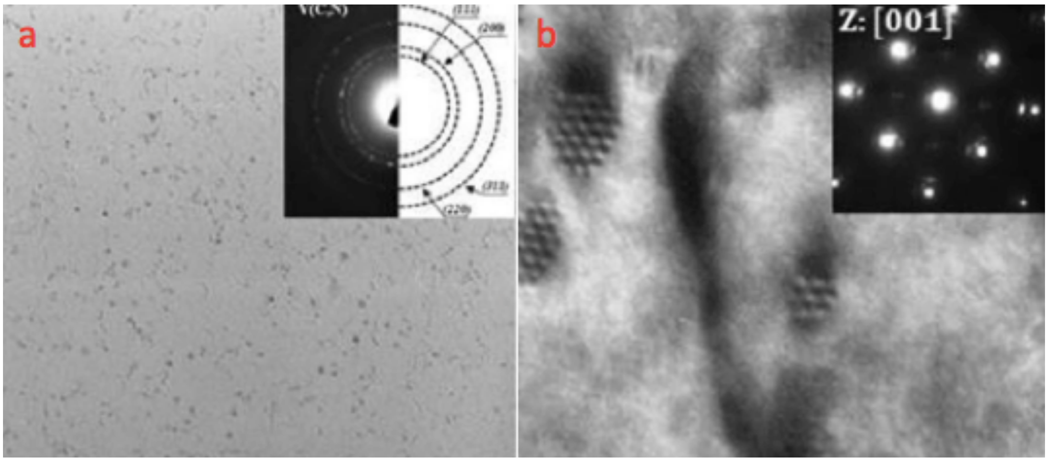

Fig.5 TEM micrographs showing (a) the characteristic of V(C,N) precipitates and the selected area diffraction pattern of the V(C,N); (b) the orientation relationship between V(C,N) and the austenite matrix

2017 Vanadium-Award Nominations

Effect of Cooling Rate on Precipitation Behavior and Micromechanical Properties of Ferrite in VN Alloyed Steel During a Simulated Thermomechanical Process, Jing Zhang, Fu-Ming Wang, Zhan-Bing Yang and Chang-Rong Li, Metallurgical and Materials Transactions A, vol. 48, no. 12, 2017, pp. 6142-6152.

Effects of Alloying Elements on Static Recrystallization Behavior of Work-Hardened Austenite of High Carbon Low Alloy Steel, Manabu Kubota, Yukiko Kobayashi, Kohsaku Ushioda and Jun Takahashi, Materials Transactions, vol. 58, no. 2, 2017, pp. 186-195.

Precipitation Effect on Mechanical Properties and Phase Stability of High Manganese Steel, Cheoljun Bae, Rosa Kim, Un-Hae Lee and Jongryoul Kim, Metallurgical and Materials Transactions A, vol. 48, no. 9, 2017, pp. 4072-4079.

Structure-properties Relationship of Ultra-fine Grained V-microalloyed Dual Phase Steels, C. P. Scott, F. Fazeli, B. Shalchi Amirkhiz, I. Pushkareva and S. Y. P. Allain, Materials Science and Engineering: A, vol. 703, 2017, pp. 293-303.

The Influence of Vanadium on Ferrite and Bainite Formation in a Medium Carbon Steel, T. Sourmail, C. Garcia-Mateo, F. G. Caballero, S. Cazottes, T. Epicier, F. Danoix and D. Milbourn, Metallurgical and Materials Transactions A, vol. 48, no. 9, 2017, pp. 3985-3996.

Recent Vanadium Related Publication List

A Model for Static Recrystallization with Simultaneous Precipitation and Solute Drag, Heinrich Buken and Ernst Kozeschnik, Metallurgical and Materials Transactions A, vol. 48, no. 6, 2017, pp. 2812-2818.

A Phase-field Model for Interphase Precipitation in V-microalloyed Structural Steels, Alireza Rahnama, Samuel Clark, Vit Janik and Seetharaman Sridhar, Computational Materials Science, vol. 137, 2017, pp. 257-265.

A Phase-field Model Investigating the Role of Elastic Strain Energy during the Growth of Closely Spaced Neighbouring Interphase Precipitates, Alireza Rahnama, Samuel Clark, Vit Janik and Seetharaman Sridhar, Computational Materials Science, vol. 142, 2018, pp. 437-443.

Application of V-N Microalloying in Ultra-high Strength Martensitic Sheet Steels for Hot-dip Galvanising, David Martin and Bevis Hutchinson, MS&T 2017 Conference & Exhibition, 8–12 October 2017, Pittsburgh, PA, USA.

Effect of Vanadium on Dynamic Continuous Cooling Transformation Behavior of Medium-carbon Forging Steels, Wei-jun Hui, Na Xiao, Xiao-li Zhao, Yong-jian Zhang and Yu-feng Wu, Journal of Iron and Steel Research, International, vol. 24, no. 6, 2017, pp. 641-648.

Effect of Carbon and Microalloy Additions on Hot Stamped Boron Steel, T. Taylor, G. Fourlaris and A. Clough, Materials Science and Technology, vol. 33, no. 16, 2017, pp. 1964-1977.

Effect of Carbon Content on Static Recrystallization Behavior of Work-Hardened Austenite in Low Alloy Steel and Its Mechanism, Manabu Kubota, Yukiko Kobayashi, Kohsaku Ushioda and Jun Takahashi, Materials Transactions, vol. 58, no. 2, 2017, pp. 196-205.

Effect of Composition and Isothermal Holding Temperature on the Precipitation Hardening in Vanadium-microalloyed Steels, Anish Karmakar, Subrata Mukherjee, Saurabh Kundu, Dinesh Srivastava, Rahul Mitra and Debalay Chakrabarti, Materials Characterization, vol. 132, 2017, pp. 31-40.

Effect of Cooling Rate on Precipitation Behavior and Micromechanical Properties of Ferrite in V-N Alloyed Steel During a Simulated Thermomechanical Process, Jing Zhang, Fu-Ming Wang, Zhan-Bing Yang and Chang-Rong Li, Metallurgical and Materials Transactions A, vol. 48, no. 12, 2017, pp. 6142-6152.

Effect of Microstructure on Mechanical Properties of a Novel High-Mn TWIP Stainless Steel Bearing Vanadium, Atef Hamada and Jukka Kömi, Materials Science and Engineering A, Feb. 2018.

Effects of Alloying Elements on Static Recrystallization Behavior of Work-Hardened Austenite of High Carbon Low Alloy Steel, Manabu Kubota, Yukiko Kobayashi, Kohsaku Ushioda and Jun Takahashi, Materials Transactions, vol. 58, no. 2, 2017, pp. 186-195.

Effects of Composition, Starting Microstructure, and Tempering Conditions on the Changes in Core Properties after a Simulated Nitride Thermal Cycle, Jonah Klemm-Toole, Robert Cryderman, Kip O. Findley and Michael E. Burnett, ASM Heat Treating Society 29th Annual Conference and Exhibition, 24-26 October 2017, Columbus, OH, USA.

Effects of Roughing on Finish Rolling Simulations in Microalloyed Strip Steels, S. A. J. Chalimba, R. J. Mostert, Waldo E. Stumpf, Charles Witness Siyasiya and K. M. Banks, Journal of Materials Engineering and Performance, vol. 26, no. 11, 2017, pp. 5294-5303.

Evolution of Microstructures and Mechanical Properties during Solution Treatment of a Ti–V–Mo-containing High−manganese Cryogenic Steel, Xiaojiang Wang, Xinjun Sun, Cheng Song, Huan Chen, Shuai Tong, Wei Han and Feng Pan, Materials Characterization, vol. 135, 2018, pp. 287-294.

High Dislocation Density–induced Large Ductility in Deformed and Partitioned Steels, B. B. He, Bo Hu, H. W. Yen, G. J. Cheng, Z. K. Wang, H. W. Luo and M. X. Huang, Science, vol. 357, no. 6355, 2017, pp. 1029-1032.

Hydrogen Diffusion and Trapping in V-microalloyed Mooring Chain Steels, Xiaobing Cheng, Xiaoying Cheng, Chaowei Jiang, Xiaoyan Zhang and Qunfeng Wen, Materials Letters, vol. 213, 2018, pp. 118-121.

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Investigating Nano-precipitation in a V-containing HSLA steel Using Small Angle Neutron Scattering, Y. Q. Wang, S. J. Clark, V. Janik, R. K. Heenan, D. Alba Venero, K. Yan, D. G. McCartney, S. Sridhar and P. D. Lee, Acta Materialia, vol. 145, 2018, pp. 84-96.

Kinetics and Microstructural Change of Low-carbon Bainite due to Vanadium Microalloying, Fateh Fazeli, Babak Shalchi Amirkhiz, Colin Scott, Muhammad Arafin and Laurie Collins, Materials Science and Engineering A, Feb. 2018

Microstructural Analysis of Ductility and Fracture in Fine-grained and Ultrafine-grained Vanadium-added DP1300 Steels, Javad Samei, Linfeng Zhou, Jidong Kang and David S. Wilkinson, International Journal of Plasticity, Jan. 2018.

Microstructural Characterization of a Vanadium Microalloyed High Carbon Wire Steel, S. L. Kaster and E. De Moor, Interwire 2017, 9 May 2017, Atlanta, Georgia, USA.

Modeling of Work Hardening During Hot Rolling of Vanadium and Niobium Microalloyed Steels in the Low Temperature Austenite Region, Stephen Akonda Chalimba, Roelf Mostert, Waldo Stumpf, Charles Siyasiya and Kevin Banks, Journal of Materials Engineering and Performance, vol. 26, no. 11, 2017, pp. 5217-5227.

Precipitation Effect on Mechanical Properties and Phase Stability of High Manganese Steel, Cheoljun Bae, Rosa Kim, Un-Hae Lee and Jongryoul Kim, Metallurgical and Materials Transactions A, vol. 48, no. 9, 2017, pp. 4072-4079.

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Structure-properties Relationship of Ultra-fine Grained V-microalloyed Dual Phase Steels, C. P. Scott, F. Fazeli, B. Shalchi Amirkhiz, I. Pushkareva and S. Y. P. Allain, Materials Science and Engineering A, vol. 703, 2017, pp. 293-303.

The Influence of Vanadium on Ferrite and Bainite Formation in a Medium Carbon Steel, T. Sourmail, C. Garcia-Mateo, F. G. Caballero, S. Cazottes, T. Epicier, F. Danoix and D. Milbourn, Metallurgical and Materials Transactions A, vol. 48, no. 9, 2017, pp. 3985-3996.

Theoretical and Experimental Nucleation and Growth of Precipitates in a Medium Carbon–Vanadium Steel, Sebastián F. Medina, Inigo Ruiz-Bustinza, José Robla and Jessica Calvo, Metals, vol. 7, no. 2, 2017: 45.

Thermodynamic Properties of Vanadium, J. W. Arblaster, Journal of Phase Equilibria and Diffusion, vol. 38, no. 1, 2017, pp. 51-64.

Twinning-induced Plasticity (TWIP) Steels, Bruno C De Cooman, Yuri Estrin and Sung Kyu Kim, Acta Materialia, vol. 142, 2018, pp. 283-362.

Calendar of Technical & Trade Conferences

Date & Place	Vanitec Events
9-12 April 2018, São Paulo, BRAZIL	94th Vanitec Meeting
9 July 2018, Lausanne, SWITZERLAND	4th Vanitec ESC Meeting
Fall, 2018, London, UK	95th Vanitec Meeting
Date & Place	**Steel Related Events**
25-27 April 2018, Wuhan, CHINA	2018 International Symposium on Thin Slab Casting and Direct Rolling
7-10 May 2018, Philadelphia, USA	The Iron & Steel Technology Conference and Exposition (AISTech2018)
3–6 June 2018, Orlando, USA	2nd International Symposium on The Recent Developments in Plate Steels
24-29 June 2018, Croatia, ŠIBENIK	13th International Symposium of Croatian Metallurgical Society Materials and Metallurgy (SHMD)
8-13 July 2018, Paris, FRANCE	THERMEC'2018
29-31 August 2018, New Delhi, INDIA	12th International Exhibition and Conference Minerals, Metals, Metallurgy & Materials
14-18 October 2018, Columbus, USA	Materials Science & Technology (MS&T) 2018
16 – 19 October 2018, Stockholm, SWEDEN	3rd International Conference on Ingot Casting, Rolling and Forging (ICRF 2018)
Date & Place	**Energy Storage Related Events**
27-28 February 2018, London, UK	Energy Storage Summit
13-15 March 2018, Düsseldorf, Germany	Energy Storage Europe
15 March 2018, Telford, UK	Battery Tech Expo UK
27-29 March 2018, Beijing, China	Energy Storage China (ESC) 2018
2-4 April 2018, Beijing, China	7th Energy Storage International Conference and Expo
11-12 April 2018, Berlin, GERMANY	Energy Storage Innovations Europe 2018
24-24 May 2018, Adelaide, AUSTRALIA	Australian Energy Storage Conference and Exhibition
20-22 June 2018, Munich, GERMANY	ees Europe 2018
10-12 July 2018, Lausanne, SWITZERLAND	The International Flow Battery Forum (IFBF2018)

Date & Place	Trade Events
25-28 February 2018, Cape Town, SOUTH AFRICA	5th International Ferro-Alloys Congress (Infacon XV)
27 February-2 March 2018, London, UK	Argus Metal Week 2018
13-15 March 2018, Leshan, CHINA	2018 China (Leshan) Vanadium Industry Summit Forum
20-22 March 2018, Hong Kong	19th Asian Ferroalloys Conference
18-20 April 2018, Wuhan, CHINA	2018 FerroAlloyNet Vanadium Products Summit
06-07 June 2018, Düsseldorf, GERMANY	7th CRU Ryan's Notes Ferroalloys Europe
21-23 October 2018, Orlando, USA	CRU Ryan`s Notes Ferroalloys Conference 2018

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