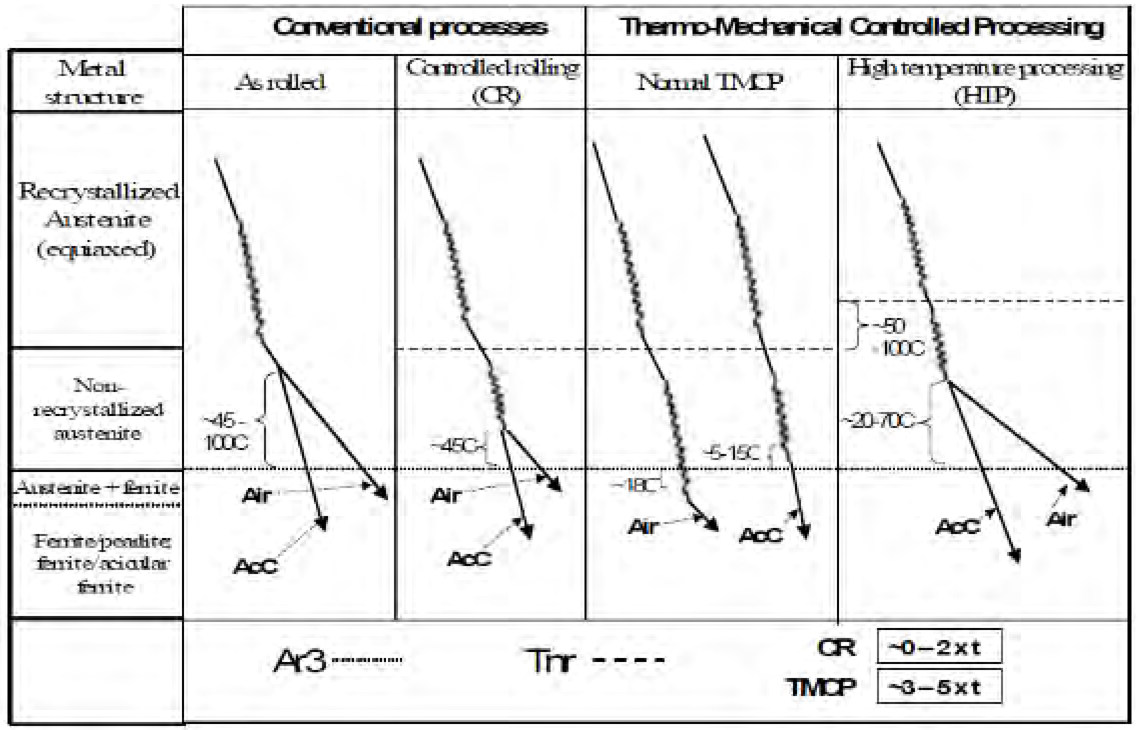
Up to 0.10%Nb added to API pipeline steels

INCREASES PRODUCTIVITY AND DECREASES COSTS OF THE PIPE MILL PRODUCTION

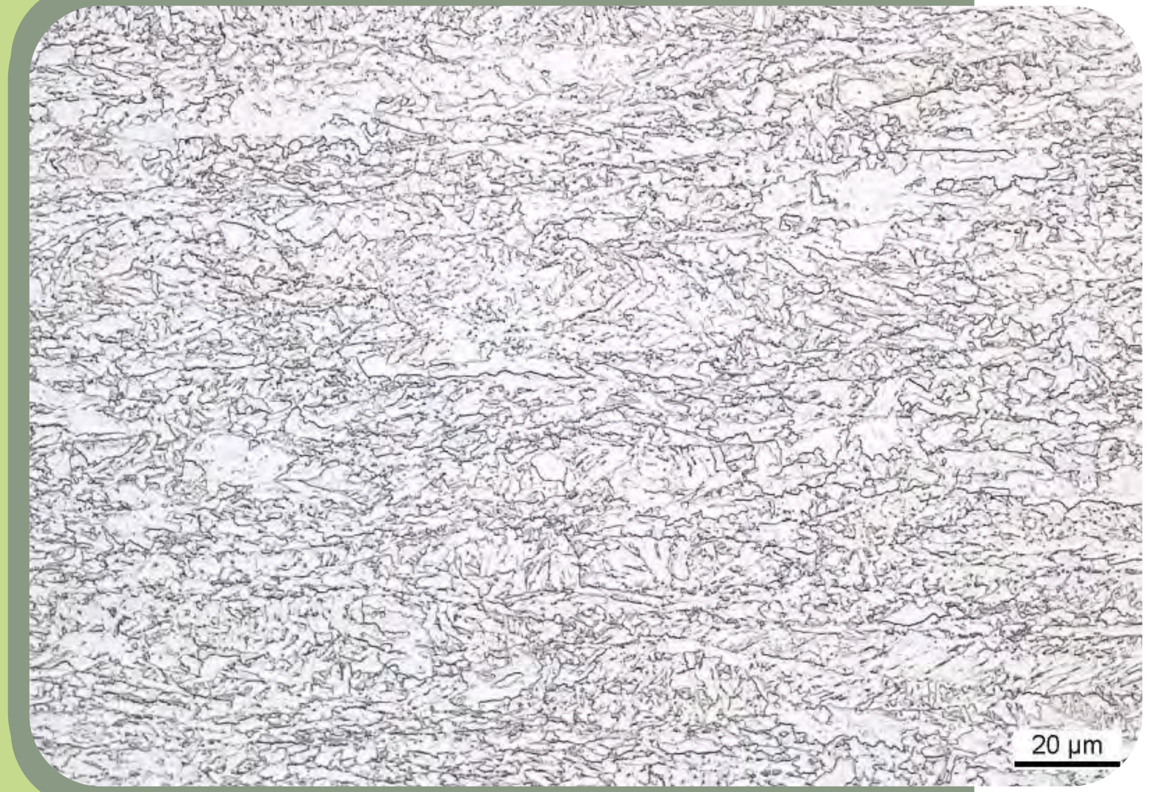
The use of up to 0.10% Nb in API steels **allows TMCP rolling at higher finishing temperatures.**
Higher finishing processing enhances plate/coil production process and still achieves excellent final cross-sectional API microstructure, resulting in

OPTIMUM MECHANICAL PROPERTIES



Niobium increases Tnr temperature, hence retarding recrystallization, allowing hot rolling at higher temperatures without the risk of recrystallizing and growing the deformed grains. The result is a homogeneous and fine austenitic grain size and an austenite with more strain accumulation at the end of the hot rolling process.

D. G. Stalheim; K.R.Barnes; D.B.McCutcheon – Alloy designs for high strength oil and gas transmission linepipe steels, International Symposium on Microalloyed Steels for the Oil and Gas Industry, TMS, 2007.



Acicular ferrite, bainite and carbide precipitates

Finer and deformed austenite (higher strain accumulation) transforms into finer, more desired API microstructures compared to when austenite recrystallizes and grows during rolling.

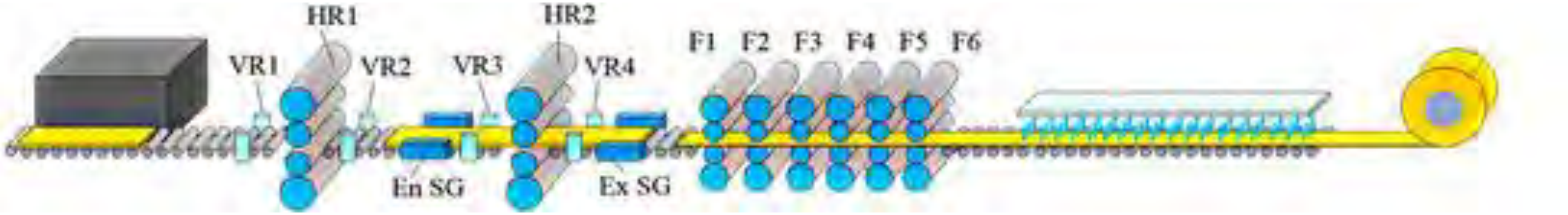
Volker Flaxa, Franz M.Knoop - Hot-rolled strips of up to 19 mm in thickness and their processing to helically welded large diameter pipes of grade X80, BAC2010, China, 2010.

Higher hot rolling temperatures provide

FINER AND HOMOGENEOUS GRAIN SIZE

Illustration based on the concepts presented by:
Han-Kai Hsu and Jong-Ning Aoh, The Mechanism of Position-Mode Side Guide in Correcting Camber in Roughing Process of a Hot Strip Mill, https://www.mdpi.com/2075-4701/9/5/504/htm

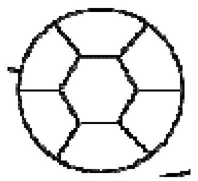
FURNACE	ROUGHING MILL		FINISHING MILL		LAMINAR COOLING	DOWN COILER

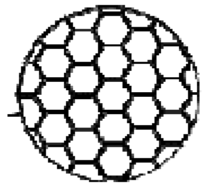


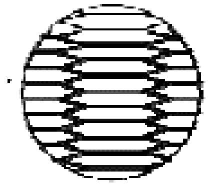
ROLLING DIRECTION →

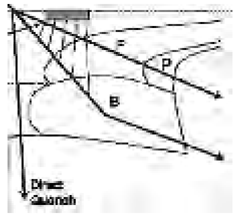
Main features

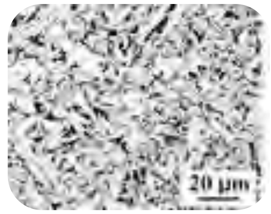
Temperature (ºC)











Furnace	Roughing mill		Finishing mill		Laminar cooling	Down coiler
Slab thickness 200 mm	Thickness after 40% reduction 60mm	T_{nr} (non recrystallization) 1.020ºC	Strip thickness 22 mm	A_{r3} (start γ to α transf.) 770 C°₀	Cooling speed between 2ºC/s to 20ºC/s	
Ti(C,N) particles plus Niobium in solid solution; Austenite grain size 80/90 μm	Nb,Ti (C,N) particles and Nb atoms at grain boundaries; Austenite grain size 20/30 μm		Pancake shaped austenite Nb(C,N) particles and some Niobium in solution			Acicular ferrite, bainite Grain size 2/5 μm
Soaking 1.250ºC	Roughing 1.200/1.050ºC		Finishing 1.000/840ºC		Laminar cooling 840/600ºC	Coiling 600/400ºC

UP TO 0.10% Nb IN API STEEL IS

THE BEST ANSWER

for improving the productivity and reducing the costs of pipe mills since they have a more homogenous cross-sectional microstructure/grain size, reducing the overall residual stress state.

In a UOE pipe mill, pipe forming is easier and more stable with a properly processed API plate steel containing up to 0.10% Nb due to excellent homogeneity of the fine cross-sectional microstructure and corresponding properties.

As mentioned by Doug Stalheim during his experience with the production of pipes for the Cheyenne Plains project utilizing a properly processed plate steel containing up to 0.10% Nb, ***"the overall non-prime percentage on this project was one of the lowest recorded. In addition, the pipe productivity was 15-20% better than the original forecast."***

The non-prime percentage refers to any kind of defect that results in a downgrade or material cut away as a cylinder. Non-prime events during pipe mill production creates "bottlenecks" that slow processing throughout the mill and, in some cases, can stop forming altogether. Pipe may be rerouted and reworked, but overall flow is reduced compromising productivity, increasing cost, and potentially delaying pipe delivery.

Douglas G. Stalheim, The use of high temperature Processing (HTP) Steel for High Strength Oil and Gas Transmission Pipeline Applications, Research Gate

An example of an occurrence that can reduce productivity is during UOE forming where there is high, uneven residual stress states in the as-rolled plate due to non-homogeneous cross-sectional microstructure/grain size. The high residual stress can cause variability in the gap between the edges after forming is complete. Since the width of the gap is essential to the tack welding process, high residual stress can lead to tack welding failures and geometric deviations (such as peaking at the weld) beyond the allowable tolerance of the specification. If significant peak is carried through the final DSAW ID/OD welding process and subsequently expanded, per the normal UOE process, **there is potential for the weld to crack during expansion causing more delays increasing processing time and cost.**

Similar problems can occur with coils destined for spiral forming mills as well. The excess residual stress in hot rolled coils can create forming/tack welding issues **that result in burn throughs and broken tack welds.** These conditions are potentially dangerous and the pipe must be reworked before final welding to remove or repair the defect once again increasing production time and cost.

Douglas G. Stalheim, CBMM internal communication, 2020.

Plate after cold leveling on line to pipe forming. Note the bow up from excess residual stress even after cold leveling.

Pipe gap after UOE forming. The width and uniformity of the gap is directly related to the overall residual stresses in the as-rolled plate for a given pipe forming set-up. Ideally, the gap would be narrow and uniform in width down the entire length to allow for defect free tack welding.

Excess pipe tack weld peaking from residual stress/forming gap issues prior to mechanical expansion.

Internal diameter weld cracking after expansion of the final welded pipe due to excess peaking.

HOW CAN NIOBIUM UP TO 0.10% HELP?

Douglas G. Stalheim, The use of high temperature Processing (HTP) Steel for High Strength Oil and Gas Transmission Pipeline Applications, Research Gate

With the ability to use higher finishing rolling mill temperatures you can get:

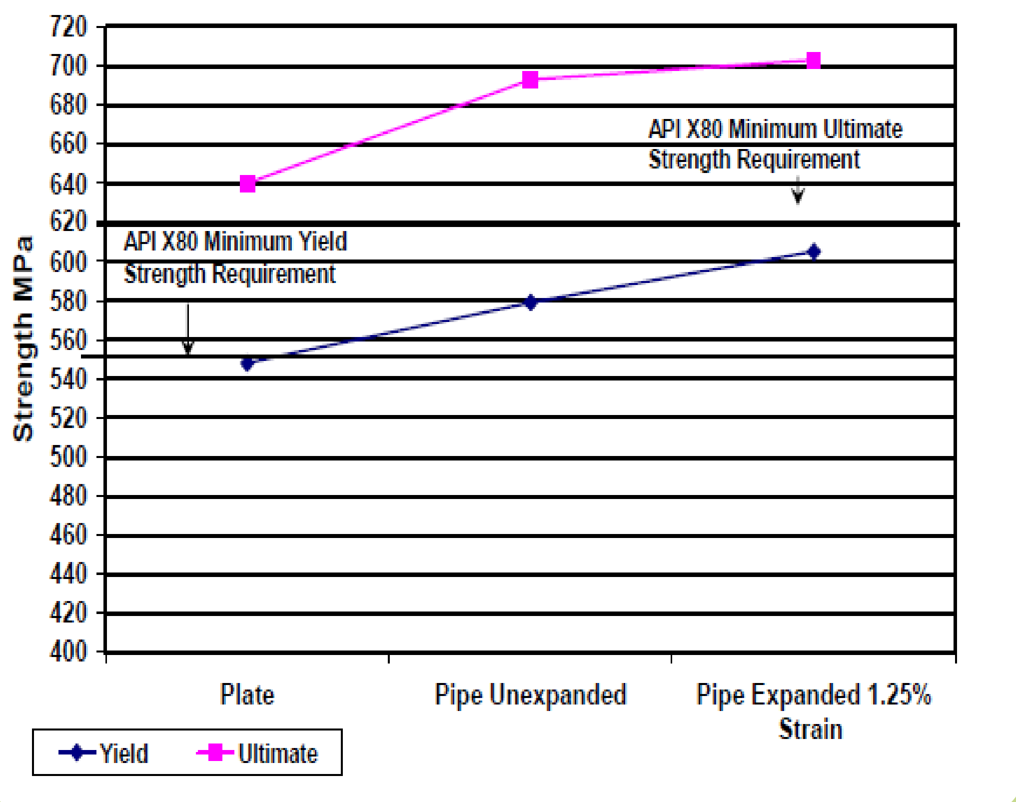
- Lower Mill Loads
- Finer and Homogeneous Microstructures
- Lower and More Homogenous Final Plate/Coil Residual Stresses
- Better flatness/shape, minimizing flatness/shape problems compared to those observed with the traditional API X80 alloy design
- Optimum mechanical strength and toughness

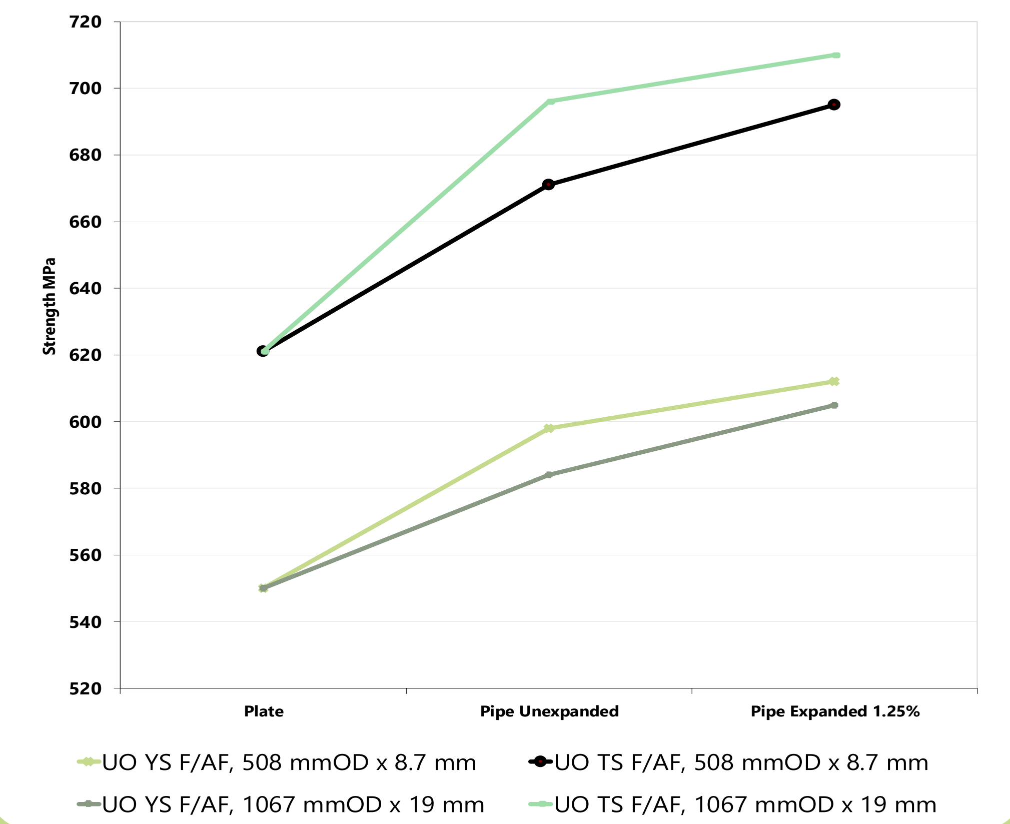
The more homogenous cross-sectional microstructure/grain size reduces the overall residual stress state. With smaller and balanced residual stresses it is easier to make flatter plates. These plates will have less residual stress. Starting material with stable properties, good flatness, and lower residual stresses will lead to a significant reduction in forming defects and improved edge preparation, thus reducing rework, **increasing productivity, and reducing production costs.**

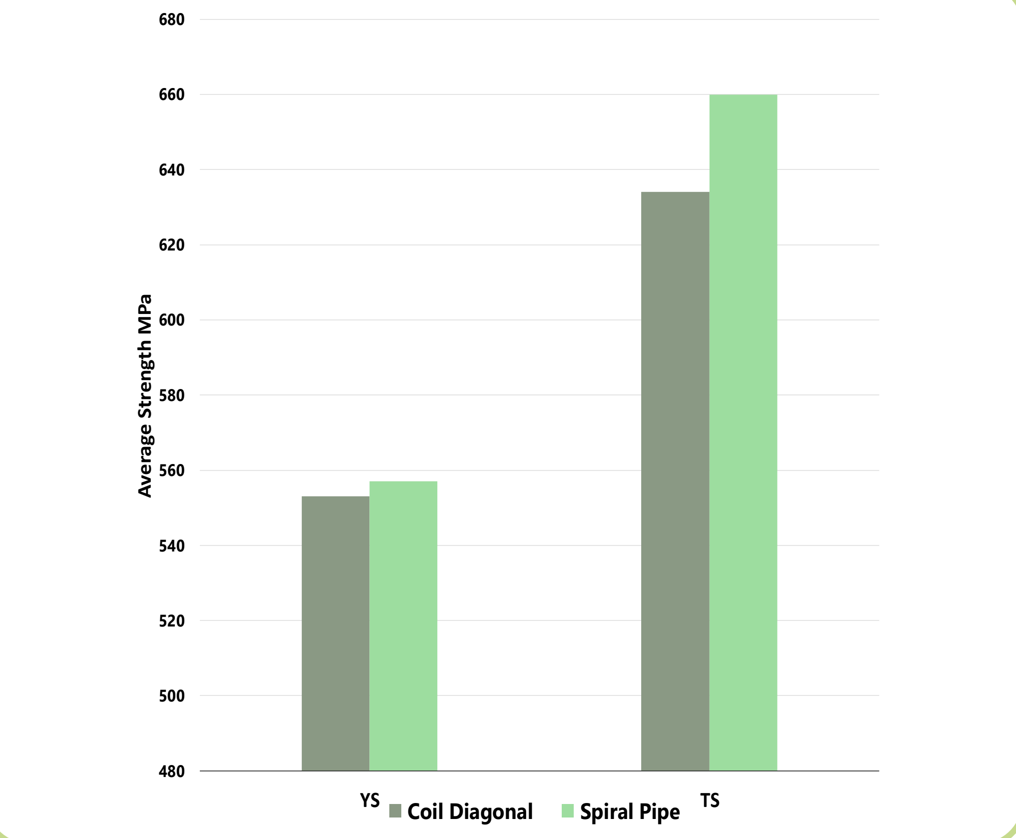
RELIABILITY

OF PIPE QUALITY IS ANOTHER BENEFIT

During pipe forming, yield strength of the steel changes due to work hardening (Bauschinger Effect). This change can be better controlled by using up to 0.10%Nb steel, improving reliability of the process and increasing productivity of the pipe mills.

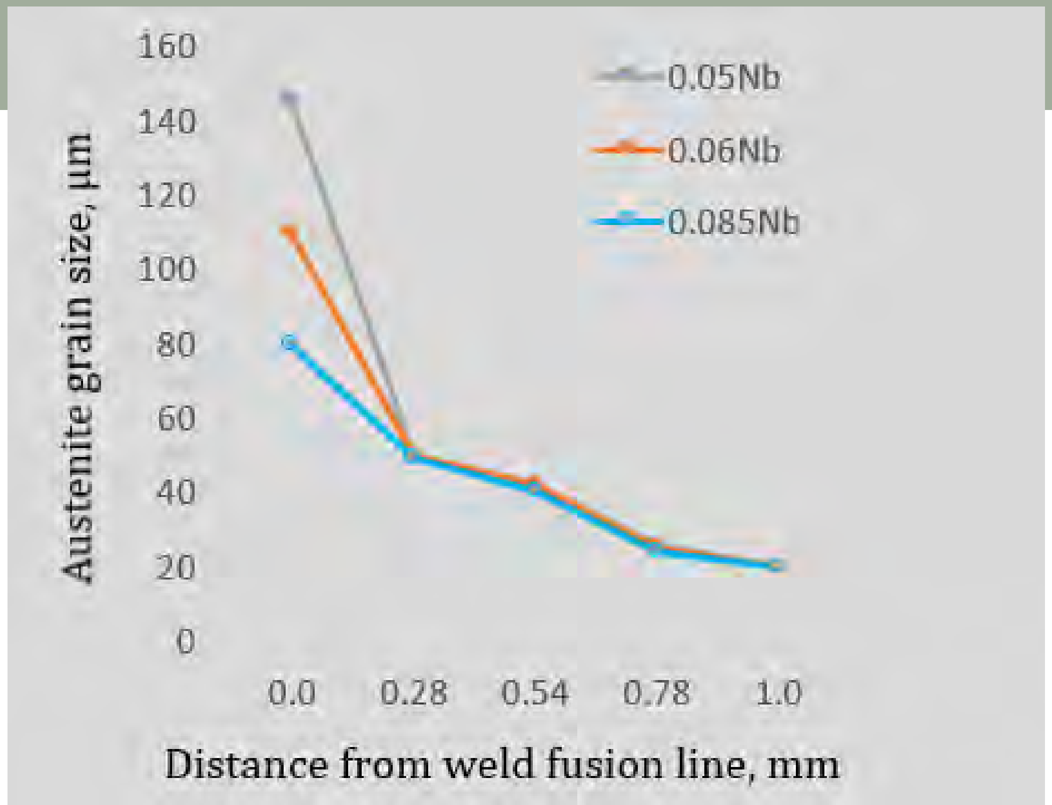






Douglas G. Stalheim, Keith R. Barnes, Dennis B. McCutcheon – Alloy Designs for High Strength Oil and Gas Transmission Linepipe Steels, International Symposium on Microalloyed Steels for the Oil and Gas Industry, TMS, 2007.
Douglas G. Stalheim, J Malcolm Gray, Fulvio Siciliano – Alloy Design Concepts for High Strength Coil for Gas Transmission Spiral Pipe, Proceedings of X80 & HGLPS 2008 International Seminar on X80 and Higher Grade Pipe Line Steel 2008, Xian, China, 2008

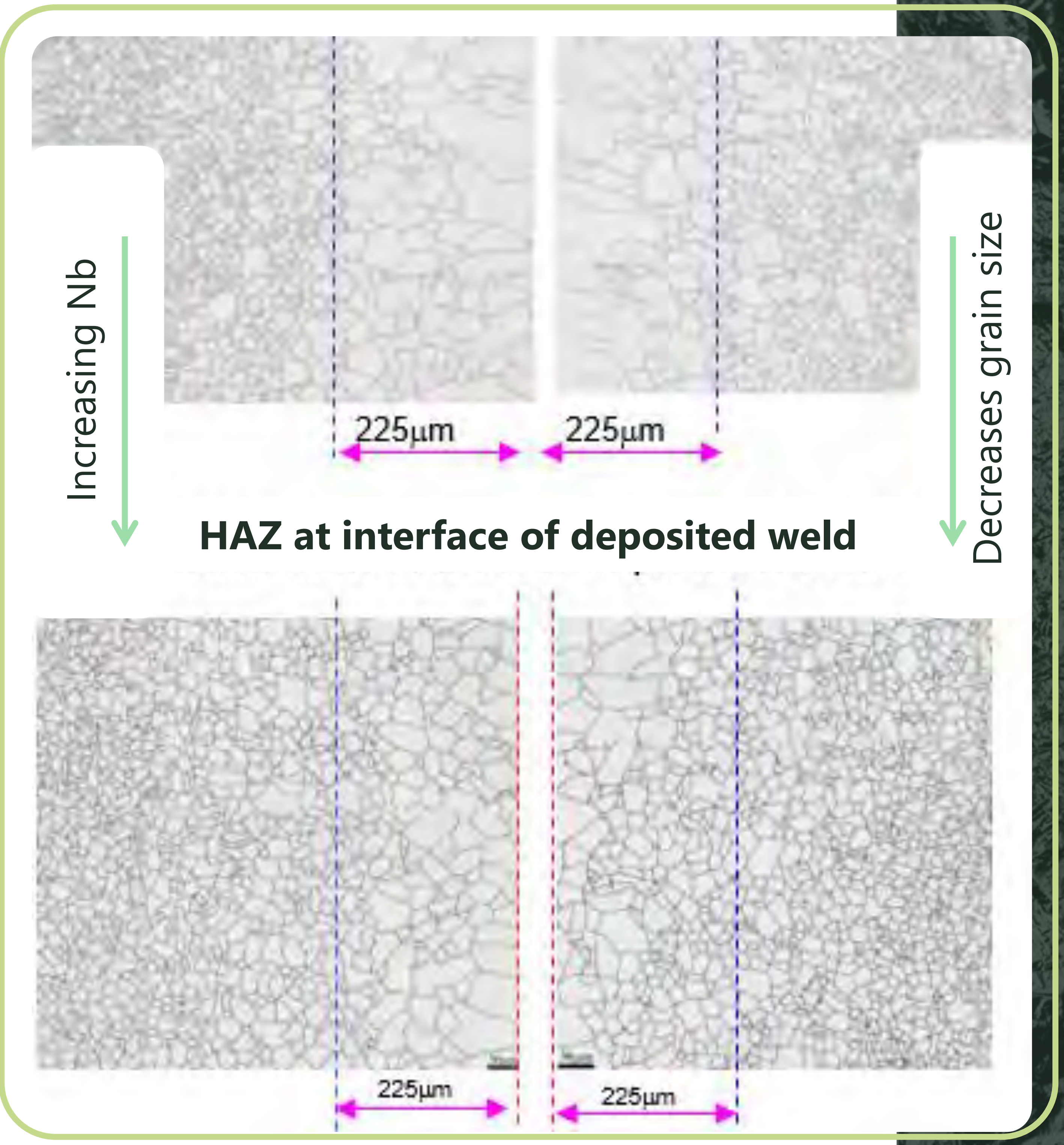
UP TO 0.10% NIOBIUM STEELS ARE LESS SENSITIVE TO HEAT INPUT ALLOWING TO INCREASE WELDING PRODUCTIVITY



Development and application of heavy gauge X -80 coil with optimization processing , Zhang Yongqing, Niu Tao and Bi Zongyue

Control of weld HAZ properties in modern high strength pipeline steels-IPC 2014, Calgary- Canada , F.J Barbaro et al.

LOOKING AT THE HEAT AFFECTED ZONE, HAZ



Niobium together with Titanium promotes grain refinement in the HAZ. The effect is very pronounced when Niobium content is in the range of 0.08 to 0.11%. As a direct consequence of grain refinement a remarkable increase in toughness occurs.

The state of the art of long distance gas pipeline in China
Chengjia Shang – IGRC – Rio 2017

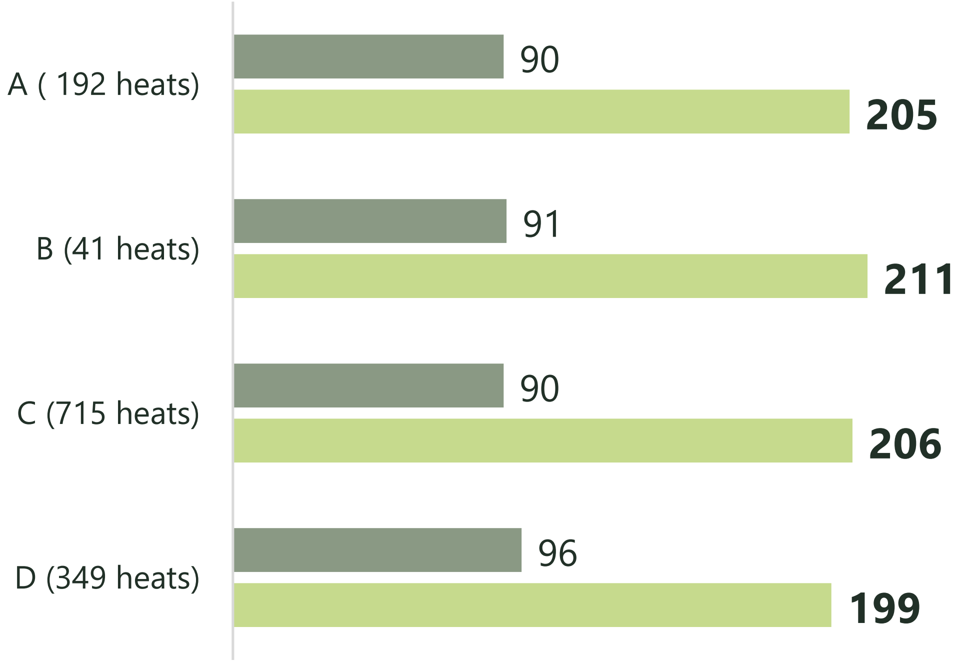
PROVEN RESULTS
IN ACTUAL PIPES

1,297 heats of X80 HTP steels were produced by 4 Chinese steel plants for the production of SAWH pipes with 1,219 mm in diameter and 18.4 mm thickness. **They were applied in the 2nd West-East Gas Pipeline, CNPC.**

STEEL:
C - 0.05 - 0.06%
Mn - 1.83%
Nb - 0.08 - 0.10%
(Mo, Ni, Cr, Cu)
Ti - 0.02%
Pcm =0.19

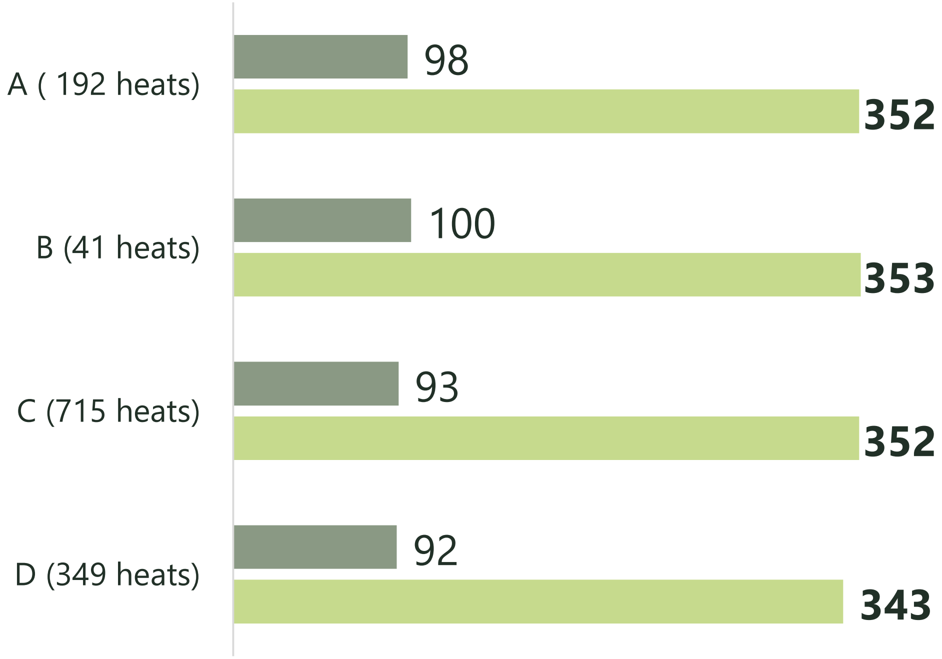
Heat Affected Zone, HAZ

Single ≥60J, Average ≥ 80J
Single ≥ 30%, Average ≥ 40%



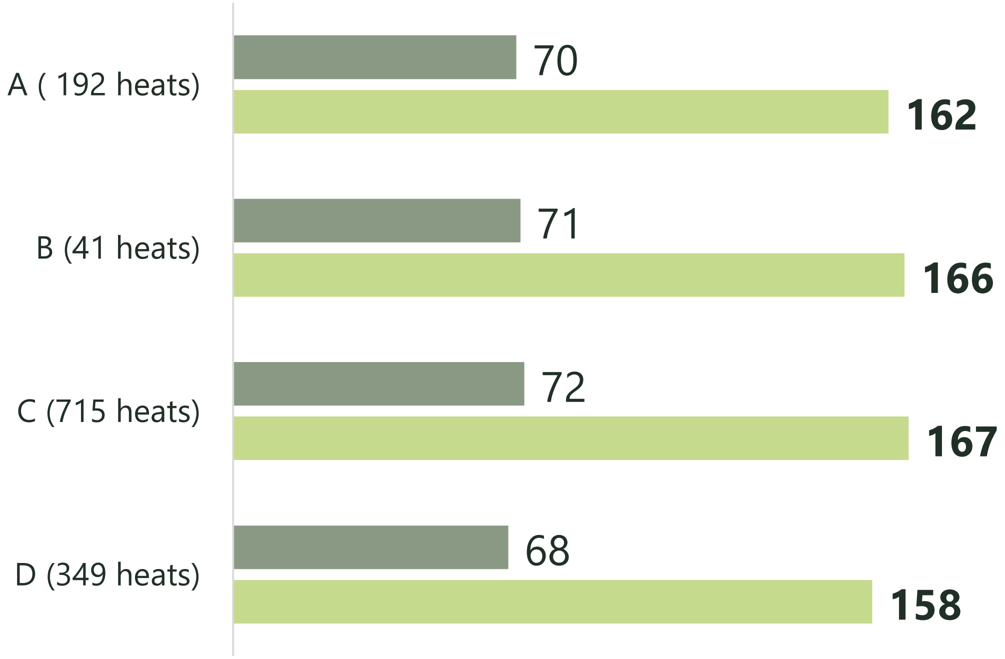
Base metal

Single ≥170J, Average ≥ 220J
Single ≥ 80, Average ≥ 90



Weld Seam

Single ≥60J, Average ≥ 80J
Single ≥ 30%, Average ≥ 40%



Shear area (%) Impact energy (J)

Shang, C., Guo, F. - The state of the art of long distance gas pipeline in China.
https://www.gas-for-energy.com/fileadmin/G4E/pdf_Datein/g4e_1_18/gfe1_18_fb_ShangGuo.pdf

CBMM | Niobium Nb

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Further information can be obtained at
www.niobium.tech/energy

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