BENEFITS OF STAINLESS STEELS FOR UTENSILS

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History

Harry Brearley is usually credited with the invention of stainless steel. However, it wasn't until 1911 that the importance of a minimum chromium content was discovered by Germans P. Monnartz and W. Borchers.

In metallurgy stainless steel, also known as inox steel or inox, is defined as a steel alloy with a minimum of 10.5% chromium content by mass

Stainless characteristic of these steels are achieved through formation of an adherent, a very thin layer of about 130 Å chromium-rich oxide film on the surface due to higher affinity of chromium for oxygen. This layer is passive, tenacious and self healing.

Genesis of 200 Series

- Chrome-manganese grades were first developed in the early 1930s.
- 15Cr-12Mn-1.5Ni Stainless steels were in use in Germany in 1940's. Major applications were in dairy industry, beer industry and household appliances

- In early 50's during Korean War US Govt. put restriction of 1% Ni max for stainless steel in certain applications
- Following grade developed by Allegheny, for the manufacture of railcars, termed as IA 201

C	Mn	Cr	Ni	N
0.15	15	14.5	0.99	0.25

Post Korean War Scenario

- Softer alloys preferred
- Half of Nickel only replaced by Mn and N
- AISI Designation in 1955 to 201 and 202

Grade	C	Mn	Cr	Ni	N
201	0.15 max	5.5-7.5	16-18	3.5-5.5	0.25 max
202	0.15 max	7.5-10	17-19	4-6	0.25 max

History of 200 series in India

- Started in early 1990's
- Various steels with different Ni content from 6% to 0.2%.
- The development was initiated to cater the domestic market of utensils, with low cost stainless steel.
- The technical theme behind development of these grades was mainly to substitute the costly nickel with manganese and nitrogen to achieve the austenitic structure.
- With the growing popularity and increased knowledge on the in-service properties of such steel across India, this steel could also find high-end applications in the field of consumer durables, catering and food processing industry, architecture, transport, building and construction.

Role of alloying elements

Manganese

Manganese is added to steel to improve hot working properties and increase strength, toughness and hardenability. Manganese has THREE main effects to aid the stability of stainless steel:

- promotes the formation of austenite
- combines with the sulfur to form manganese sulfides
- increases the solubility of nitrogen

Nickel

The reason for Nickel addition is to promote an austenitic structure. Nickel generally increases ductility and toughness. It also reduces the corrosion rate and is thus advantageous in acid environments.

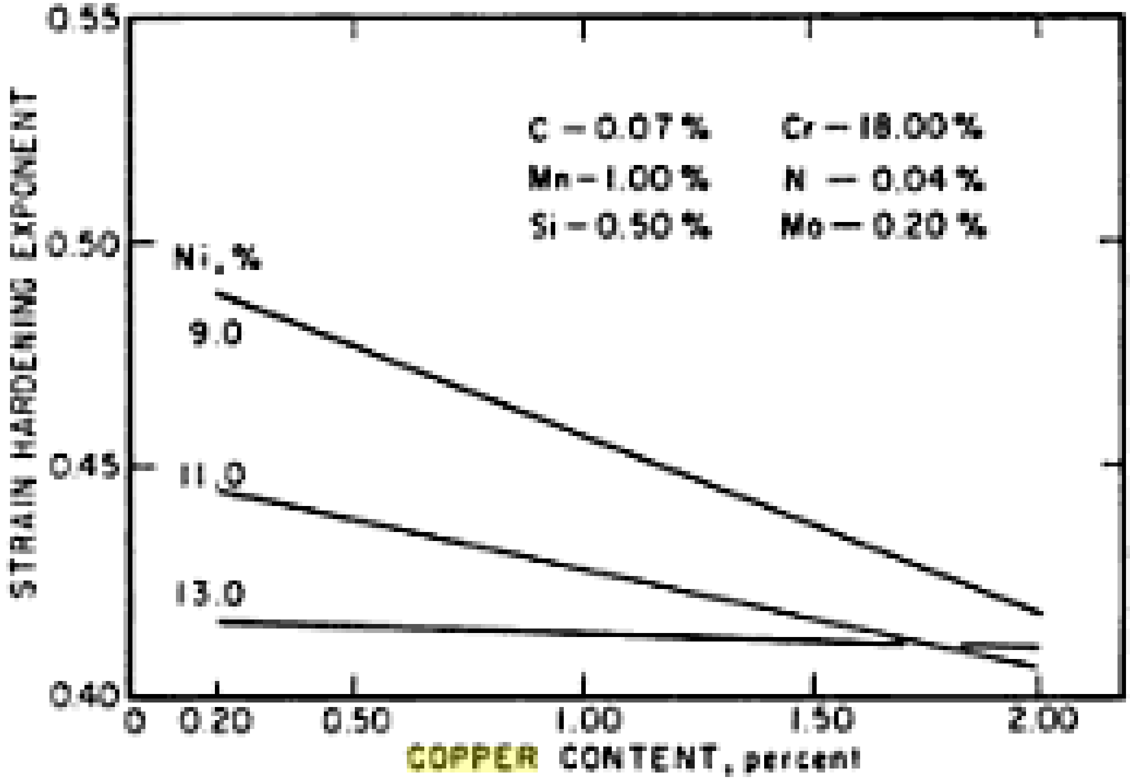
Chromium
Most important alloying element in stainless steels, it provides stainless steels basic corrosion resistance. It also increases the resistance to oxidation at high temperatures.

Nitrogen
Nitrogen is a very strong austenite former. It also substantially increases the mechanical strength. Moreover, Nitrogen inproves the resistance to pitting.

Copper
Copper enhances the corrosion resistance and stress corrosion cracking resistance in certain acids and promotes an austenitic structure. Presence of copper also increases ductility.

Improvement in drawability of AISI 201 by alloying with Cu

By addition of 1.5-2% Cu to AISI 201, a stainless steel with superior drawability was evolved



Effect of Cu on strain hardening exponent of stable austenitic stainless steel at several Ni levels

With the development of

- **Argon Oxygen Decarburisation**
- **Ladle Refining**
- **Continuous Casting**
- **Rolling Temperature Control**

Leaner alloys produced successfully with controlled N, P and S.

These alloys are endowed with high strength, good drawability, weldability and corrosion resistance.

Chemical Composition:

GRADE	%C (max)	%Mn	%S	%P	%Si (max)	%Cr	%Ni	%N	%Cu
X10Cr15Mn9Cu 2Ni1N	0.12	8.5-10.5	0.03	0.08	0.75	14.5-16.0	1.0-2.0	0.08-0.2	1.5-2.5
X8Cr16Mn8Cu2 Ni2N	0.1	6.5-9.0	0.03	0.07	1	15.5-17.0	1.5-3.5	0.1-0.25	2.0-4.0
X8Cr16Mn7Cu2 Ni4N	0.09	6.0-8.0	0.03	0.07	0.75	16.0-17.5	4.0-6.0	0.05-0.15	1.5-2.5

Mechanical Properties:

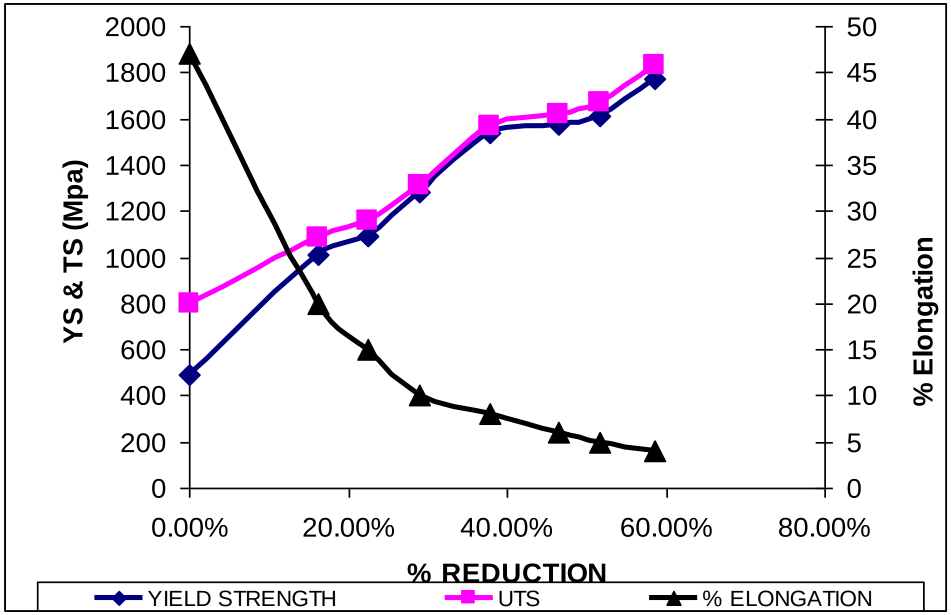
GRADE		YS (Mpa)	UTS (Mpa)	% El
X10Cr15Mn9Cu2Ni1N (9Mn1Ni)	IS 15997:2012	345	650	40
	Typical	480	860	50
X8Cr16Mn8Cu2Ni2N (8Mn2Ni)	IS 15997:2012	310	650	40
	Typical	415	795	52
X8Cr16Mn7Cu2Ni4N (7Mn4Ni)	IS 15997:2012	275	600	40
	Typical	310	665	55

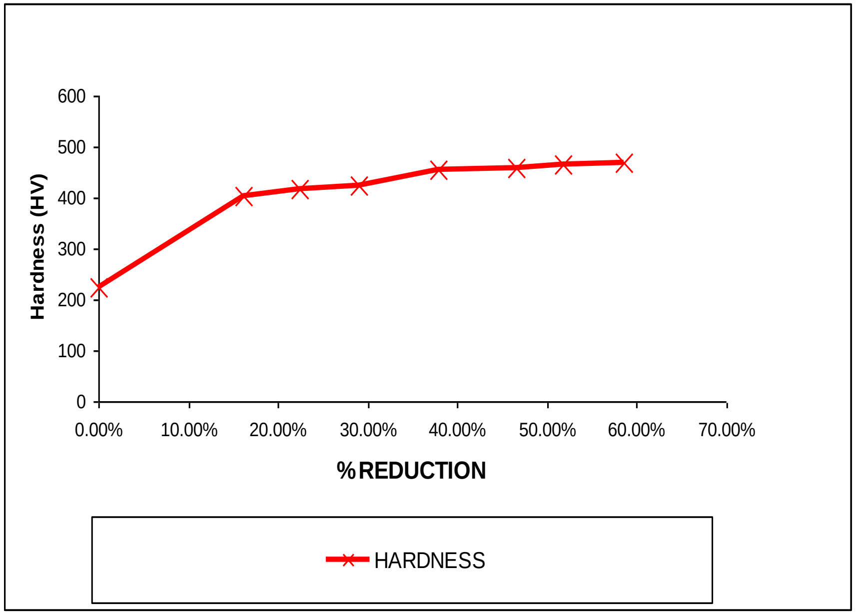
Physical Properties:

Physical properties	Density Kg/m^3	Heat Capacity At 23-100^oC J/Kg.K	Electrical resistivity μΩ.m	Thermal conductivity W/m.K(100^oC)
9Mn1Ni	7850	496.5	0.699	14.98
8Mn2Ni	7850	496.5	0.763	15.03
7Mn4Ni	7850	496.5	0.699	14.98
304	7910	500	0.72	16.3

9Mn1Ni/EN 1.4616

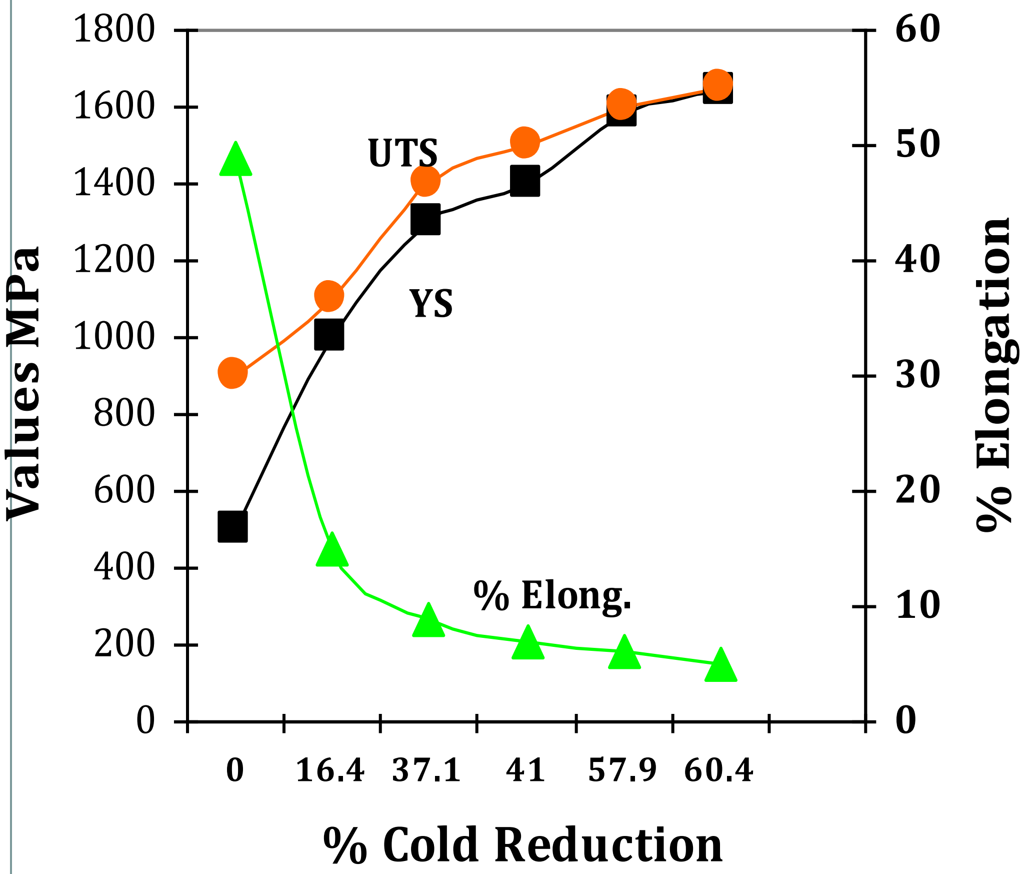
Work hardening curves:

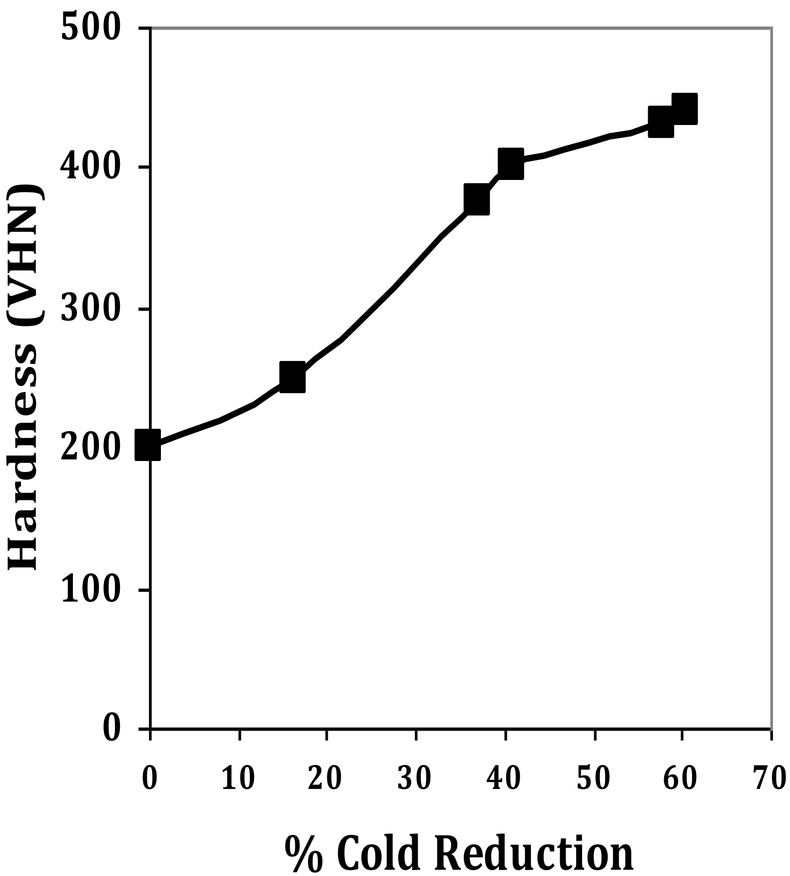




8Mn2Ni/UNS20430

Work hardening curves:





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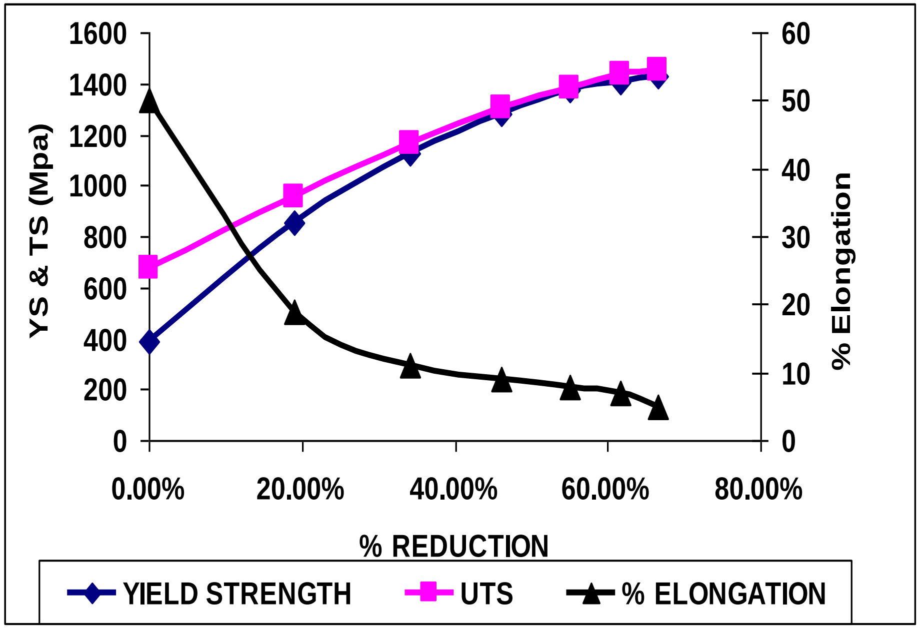
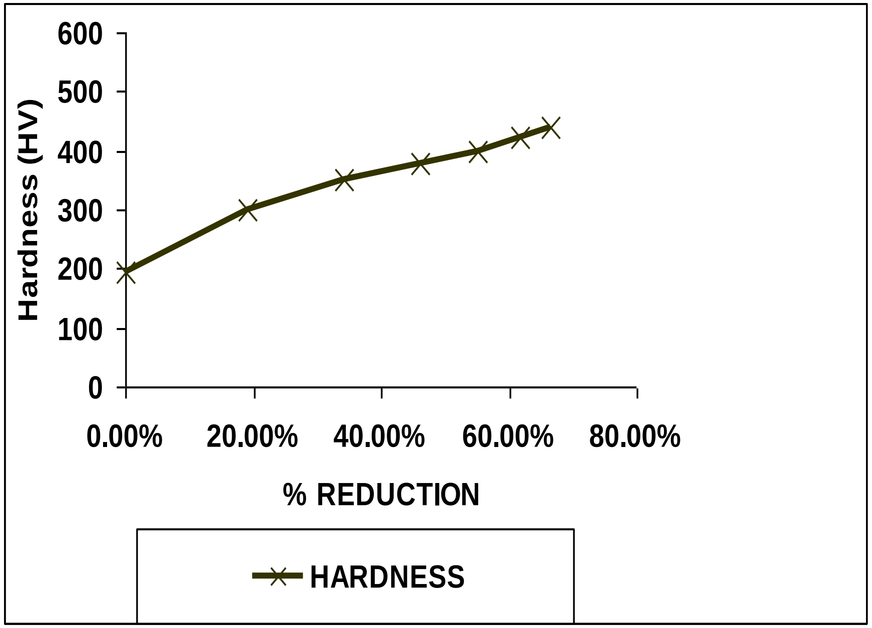
7Mn4Ni

7Mn4Ni is very tough and ductile and readily amenable to deep drawing, bending, stretch forming and spinning. After heavy cold working, it is only mildly magnetic like 304.

Work hardening curves for 7Mn4Ni:





Corrosion in Food Application Media

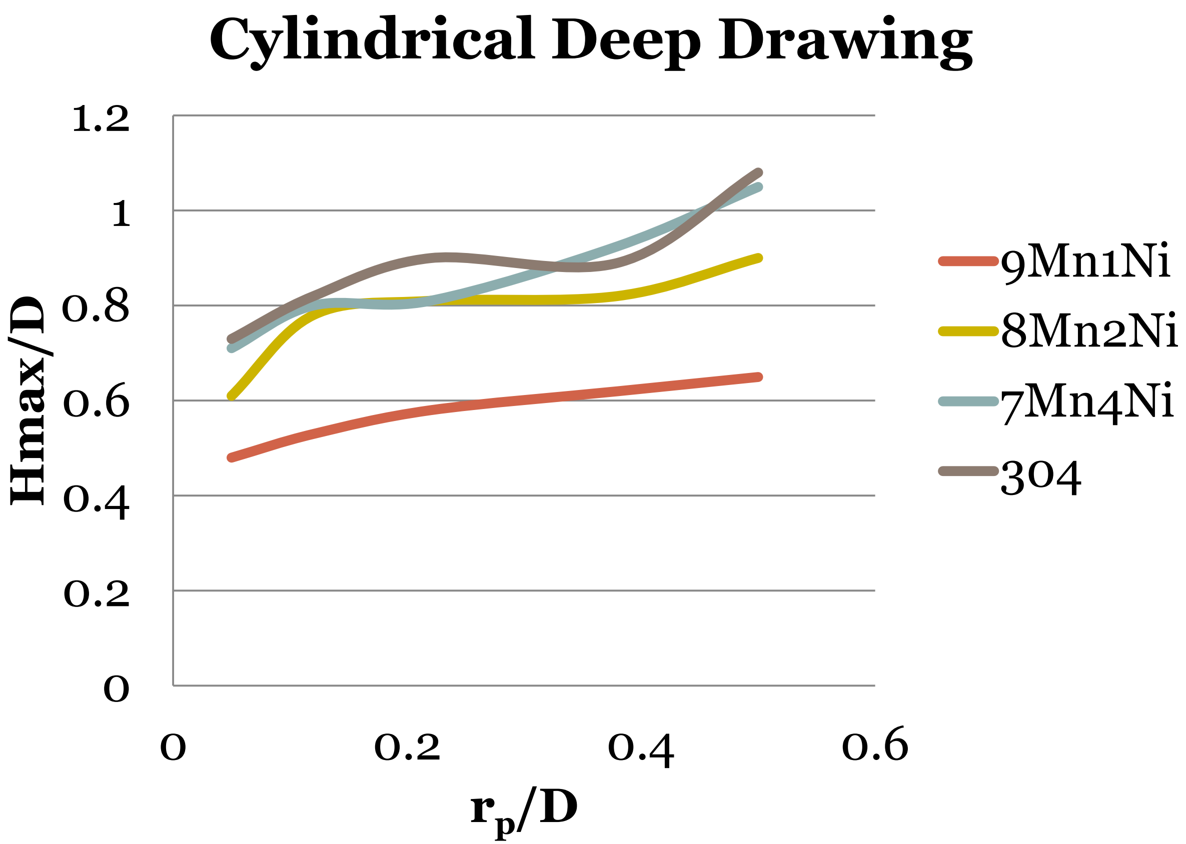
Test Media	Corrosion Rate (mmpy)			
	9Mn1Ni	8Mn2Ni	7Mn4Ni	304
3% NaCl for 720 hrs at RT (25° C)	A	A	A	A
3% NaCl for 100 hrs at Boiling Temperature.	A	A	A	A
0.5% Citric + 0.5 % Tartaric for 720 hrs at RT	A	A	A	A
0.5% Citric + 0.5 % Tartaric for 100 hrs Boiling	A	A	A	A
0.5% Acetic + 0.5% Lactic for 720 hrs at RT	A	A	A	A
0.5% Acetic + 0.5 % Lactic for 100 hrs at Boiling Temperature.	A	A	A	A

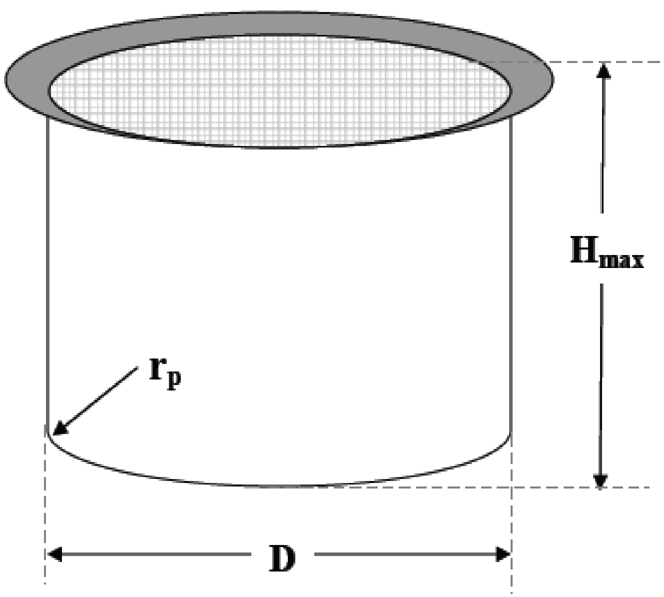
A < 0.1 mmpy; B : 0.1-1.0 mmpy; C: 1-3 mmpy

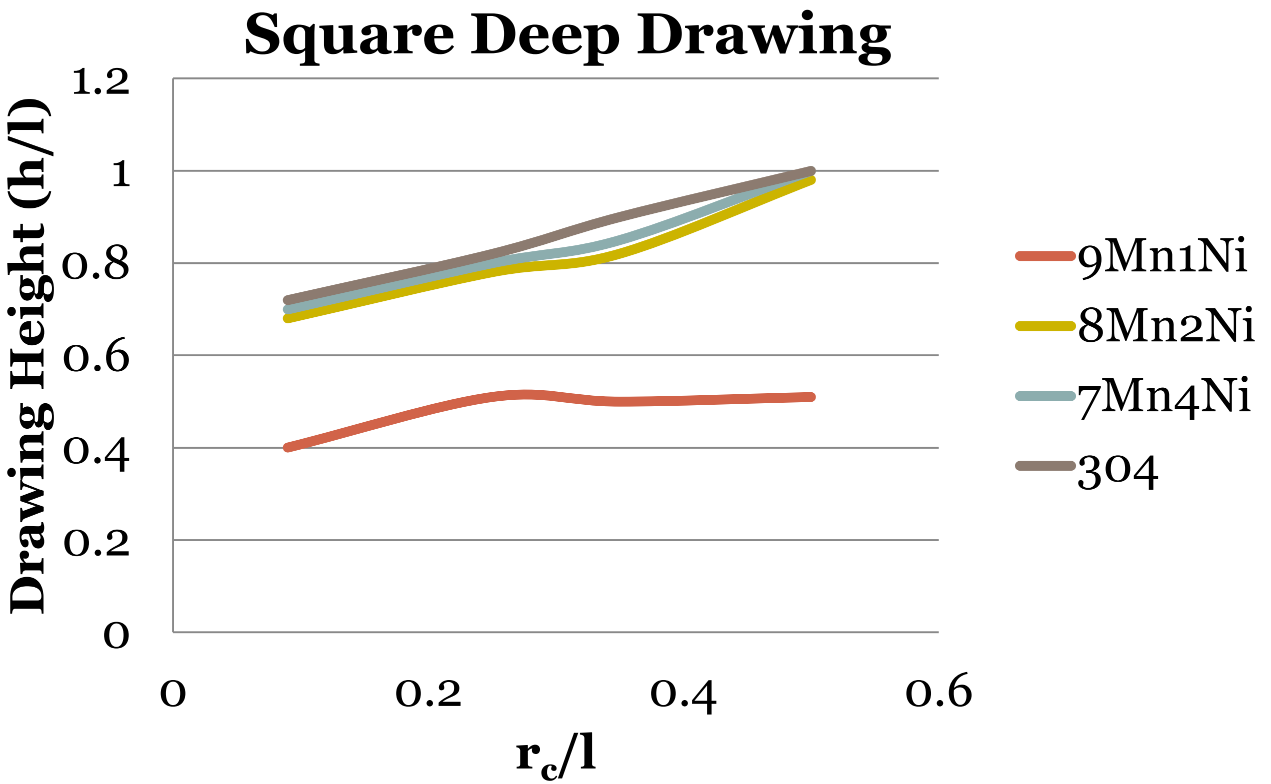
Intergranular Corrosion Test as per ASTM 262 – Practice E

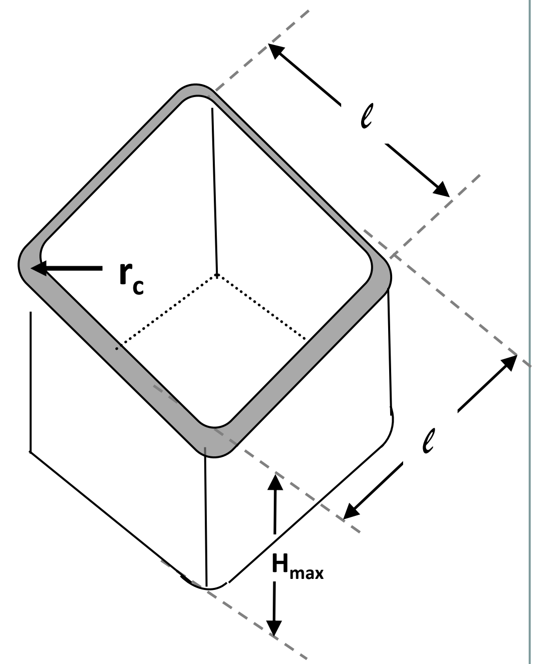
Test Media	9Mn1Ni	8Mn2Ni	7Mn4Ni	304
$Cu-CuSO_4$ + 16% H_2SO_4	Passed	Passed	Passed	Passed

Drawability Analysis









Limiting Drawing Ratio & Erichsen Cupping Value:

Grade	Limit Drawing Ratio (LDR)	Erichsen Cupping Value
9Mn1Ni	1.7	11.5 mm
8Mn2Ni	2.1	12.1 mm
7Mn4Ni	2.1	13.0 mm

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Suitability for Food Equipment/ Contact Material

- 8Mn2Ni with 16%+ Cr fully conforms to American National/ International Standard **'NSF ANSI 51'** for food equipments/contact material.
- It is suitable for this purpose as per policy statements of **'Council of Europe'** and **'Ministere de L'Economie des Finances et de L'Industrie'** of French Republic.
- It meets stipulation of **Minister's Decree 21.3.73** and successive updates of **26.4.93** and **28.10.94** in Italy for suitability as material for utensils in contact with food substances.

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The X-factors

- Good ductility along with high strength
- Scratch Resistance
- Better Polishability

Application of 9Mn1Ni

Shallow/medium drawn utensils

Cutlery

In-house Water tanks

Applications of 8Mn2Ni

Deep drawn utensils

Ice & Water Dispensers

Milk cans

Industrial kitchen equipments

Cookware

Water Filters

Applications of 7Mn4Ni

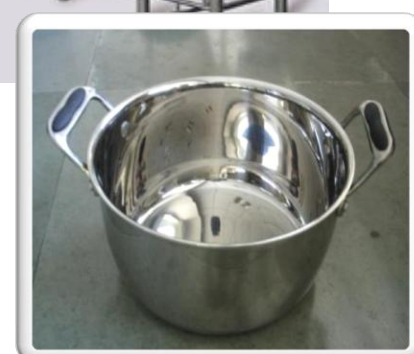
Extra Deep drawn utensils

Pressure Cookers

Hot Food Wells

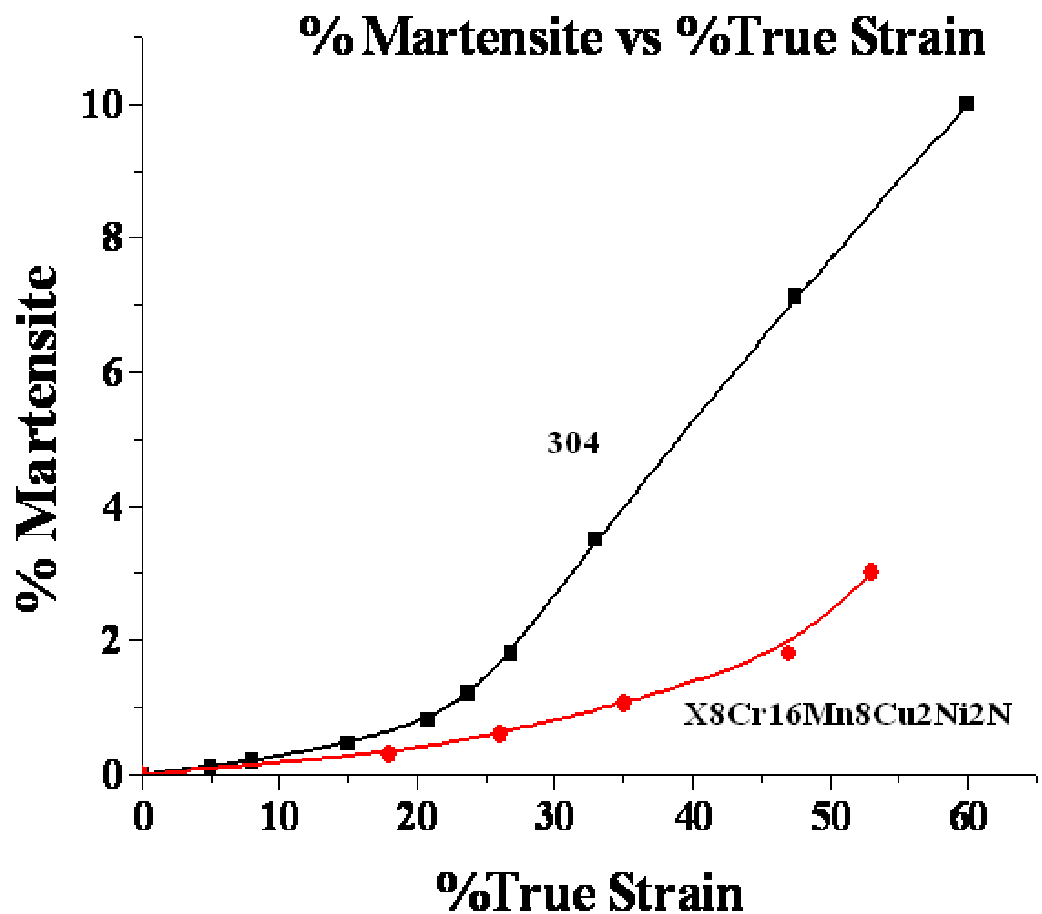
Cook line

Beverage Dispensers



METASTABILITY

- Like 304, 8Mn2Ni is fully austenitic in annealed condition.
- Martensite formation in 8Mn2Ni2 on cold working is much less compared to 304.
- Work hardening rate of 8Mn2Ni is lower as compared to AISI 201.



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Conclusion

Performance		304	7Mn4Ni	8Mn2Ni	9Mn1Ni
Strength		Good	V. Good	V. Good	V. Good
Formability		V. Good	V. Good	V. Good	Good
Weldability		V. Good	V. Good	Good	Good
Corrosion	Crevice	Slightly better	Good	Good	Good
	Pitting	Slightly better	Good	Good	Good
Economy		Fair	V. Good	Better	Better

Thank You...

Consumer Durables

Dish Washer

Dust bin

Microwave ovens

Corrosion in Food Application Media

- Corrosion tests have been conducted in NaCl solution and organic food media.
- Sodium chloride solution was selected as one of the media as chloride ion is notorious for its ability to penetrate passive films and cause pitting. Sodium chloride is also a common ingredient in food preparations. Brackish water which carries 3% NaCl, which is selected for immersion tests.
- Acetic acid is present in vinegar and it is common to use vinegar in kitchen. When milk deteriorates, lactic acid is produced. Hence a mixture of lactic acid and acetic acid was chosen as second medium.
- Citric acid is commonly present in fruit juices and tartaric acid is an ingredient in tamarind extracts. Hence, the concentration of 10000 ppm (1%) of a mixture of two acids was chosen to get accelerated results.