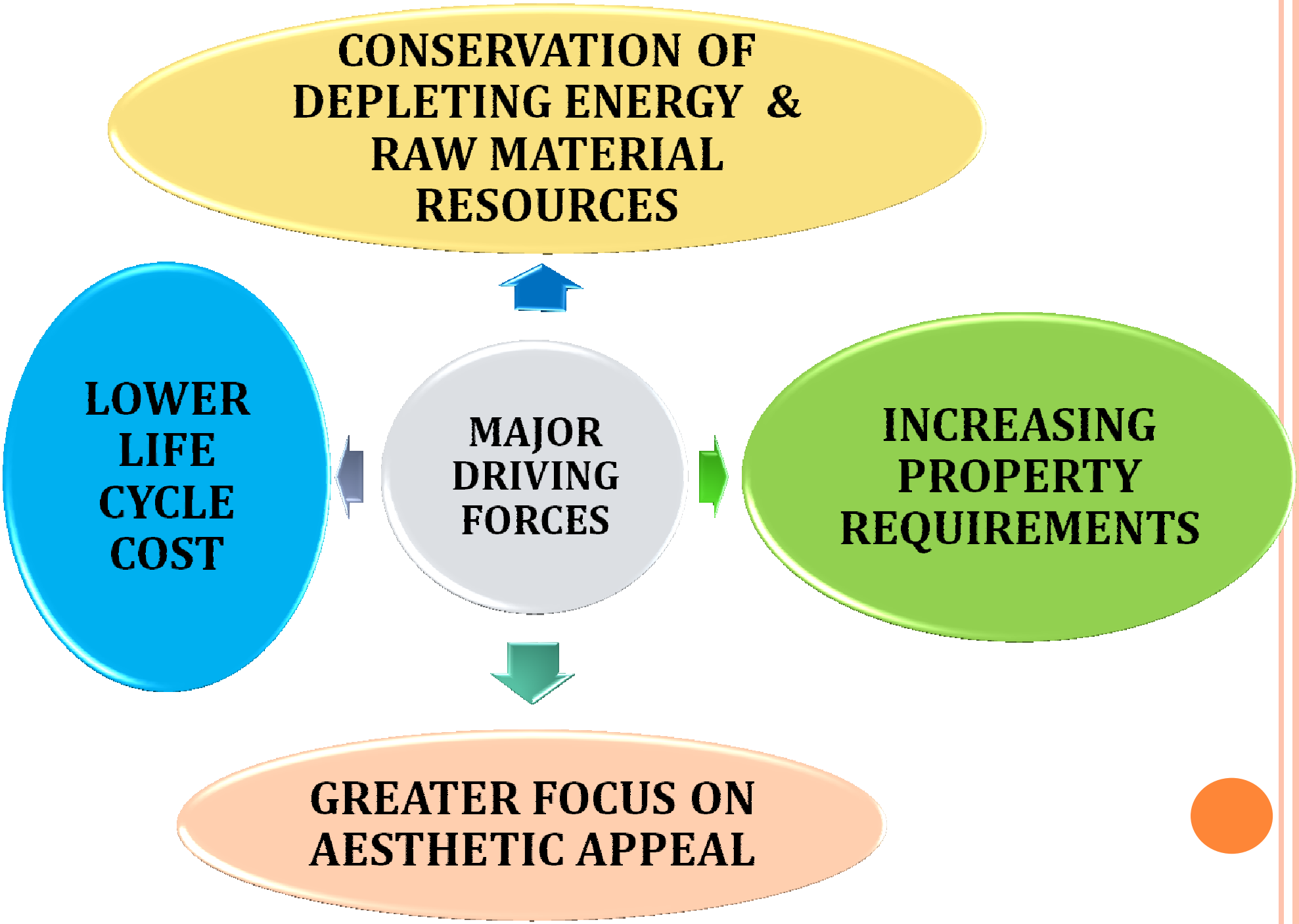
ADVANCES IN SPECIAL STEEL PRODUCTS INCLUDING STAINLESS STEELS

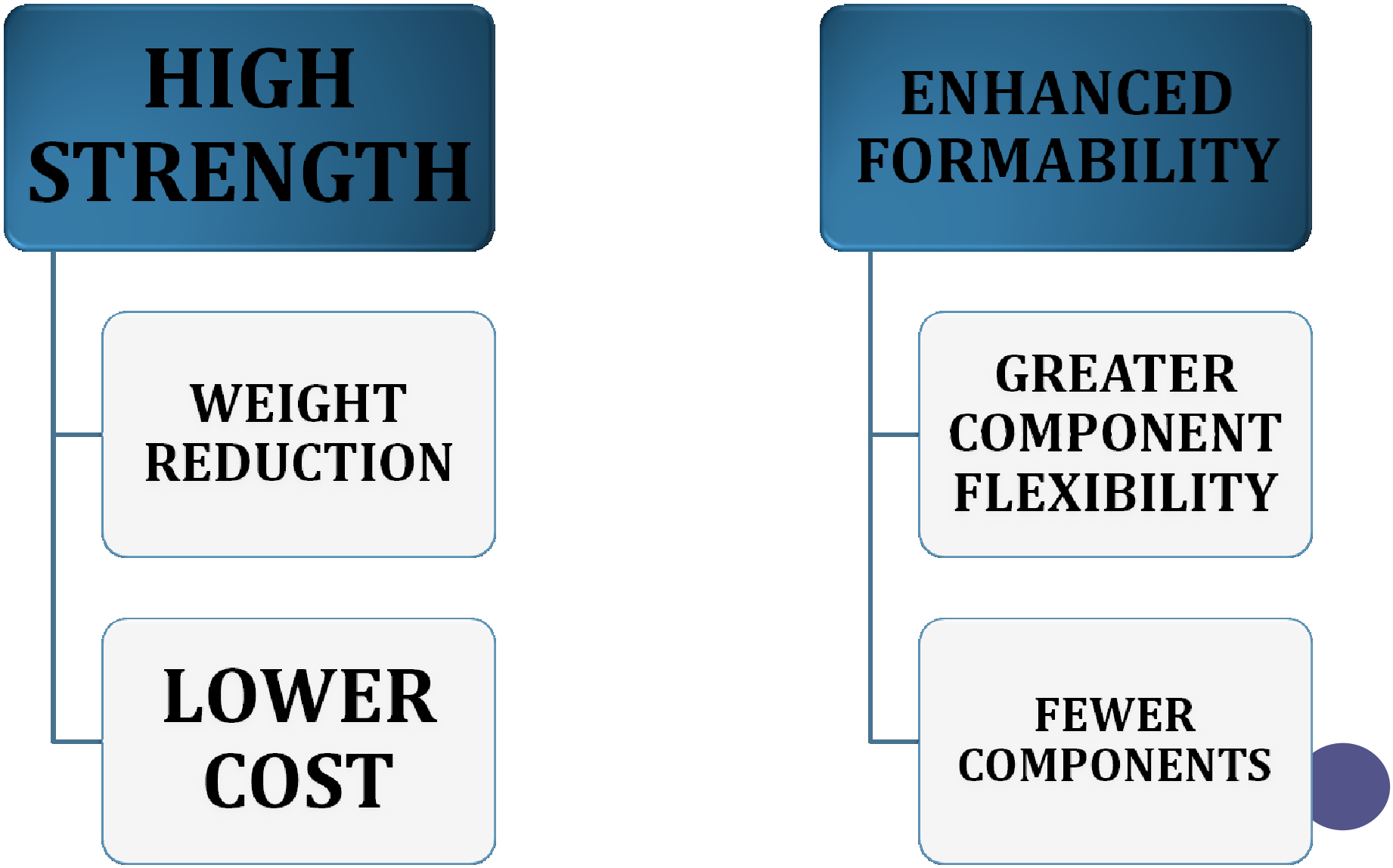
DR.L.K.SINGHAL

AMRITRAJ BHANJA

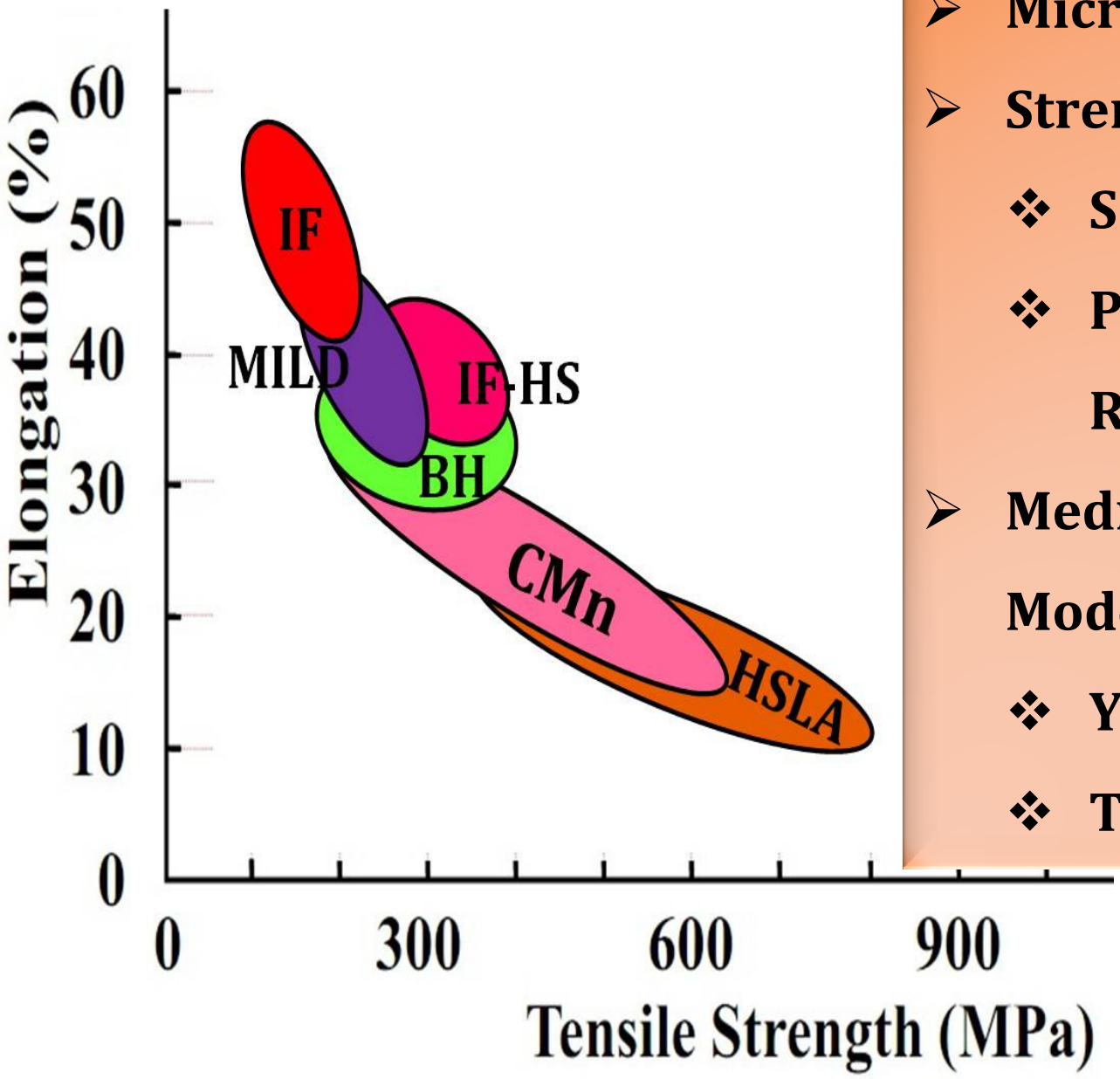
JSL STAINLESS LTD


CONSERVATION OF DEPLETING ENERGY & RAW MATERIAL RESOURCES
LOWER LIFE CYCLE COST
MAJOR DRIVING FORCES
INCREASING PROPERTY REQUIREMENTS
GREATER FOCUS ON AESTHETIC APPEAL

ADVANCED HIGH STRENGTH STEELS

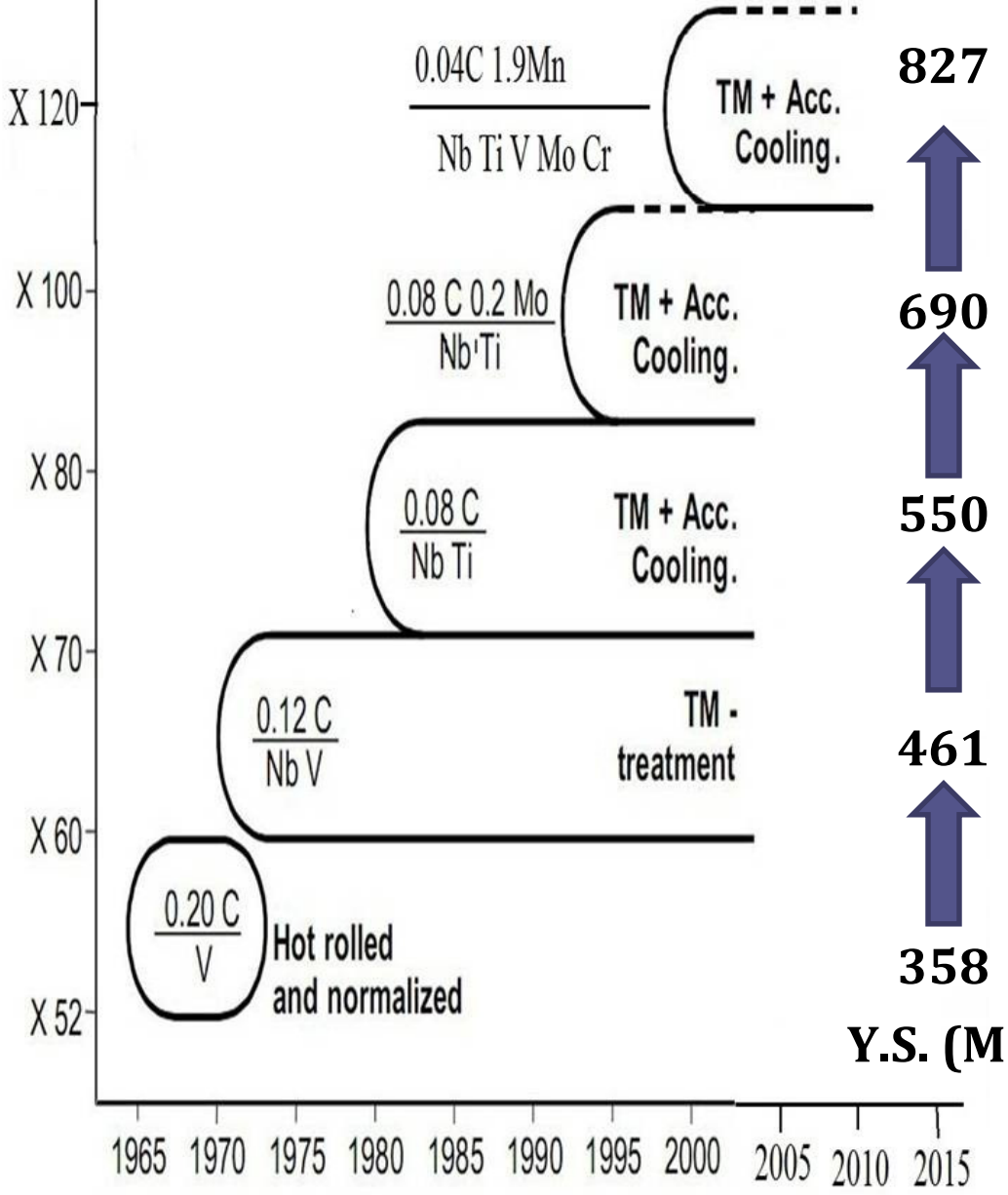


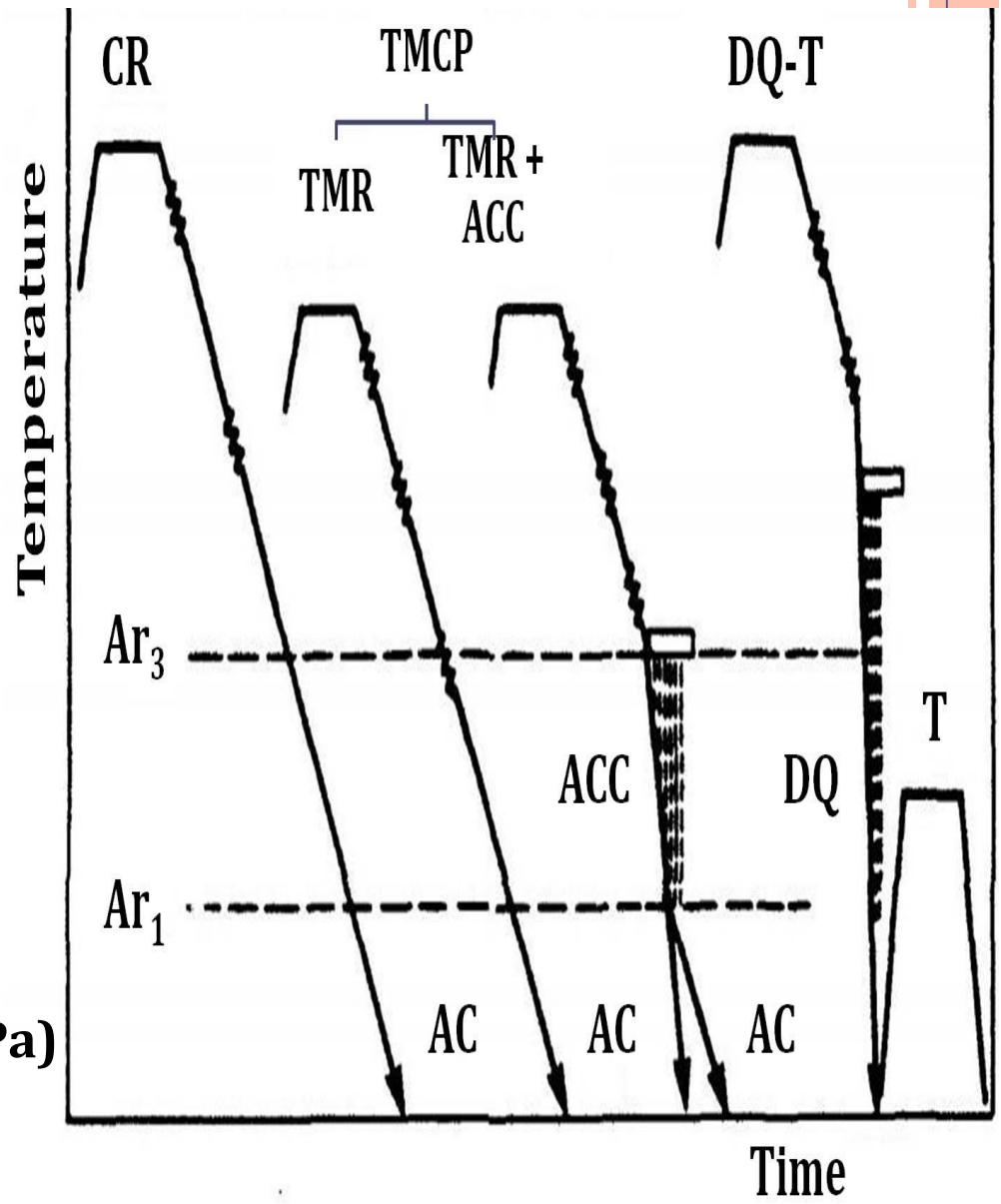
MICRO-ALLOYED STEEL (HSLA)



- Micro-alloying of V, Nb, Ti
- Strengthening
  - Solid Solution (P, Mn, Si)
  - Precipitation & Grain Refinement (Nb, V)
- Medium & High Strength, Moderate Formability
  - YS: 250-700 MPa
  - T-El: 20-35 %.

DEVELOPMENT OF HIGH STRENGTH MICRO-ALLOYED PIPELINE STEELS





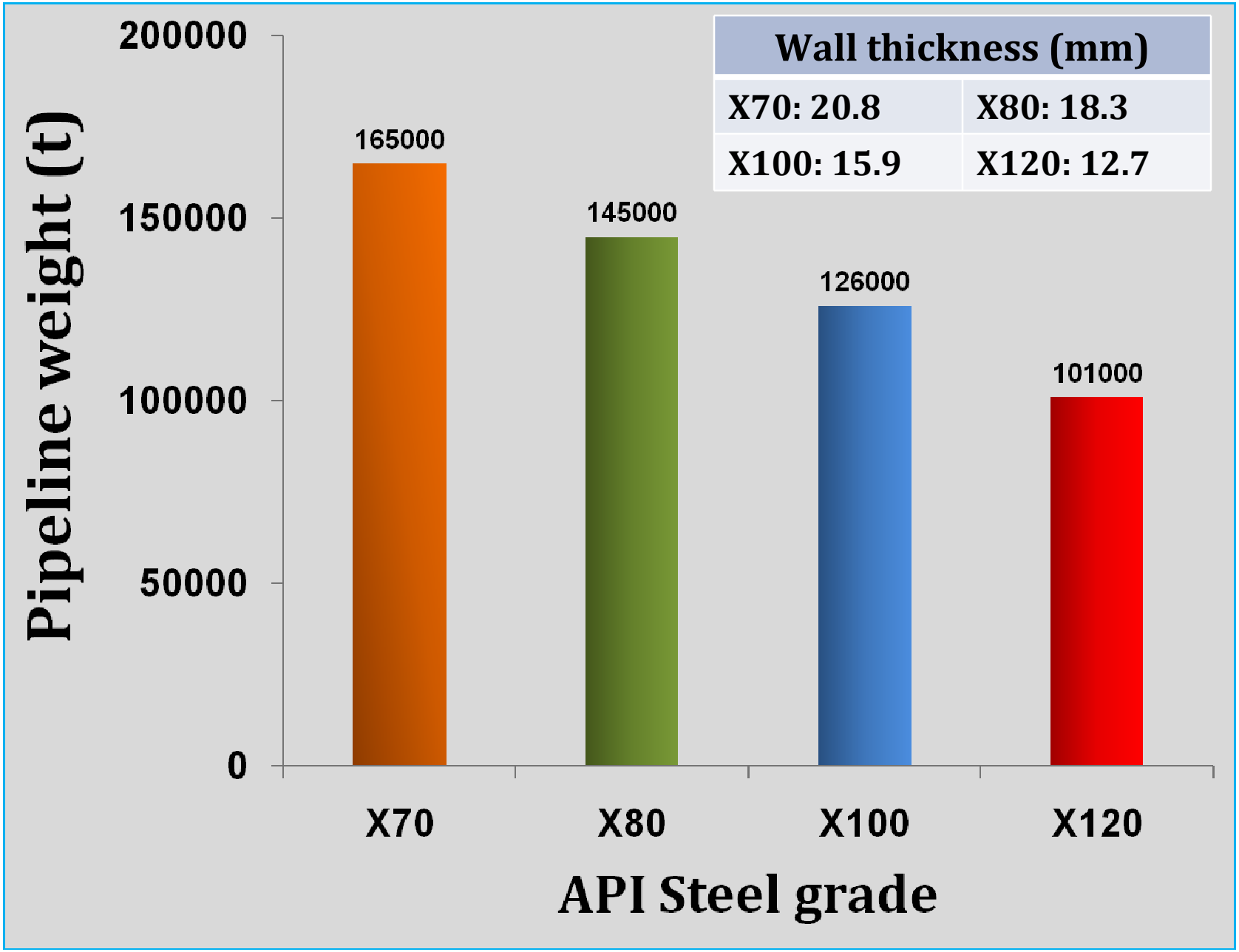
MICRO-ALLOYED STEEL APPLICATIONS

LINEPIPES (GAS/OIL)	BUILDING STRUCTURES
HEAVY DUTY VEHICLES	MINING & AGRI INDUSTRY
TRANSMISSION TOWERS	SHIP BUILDING

PIPELINES

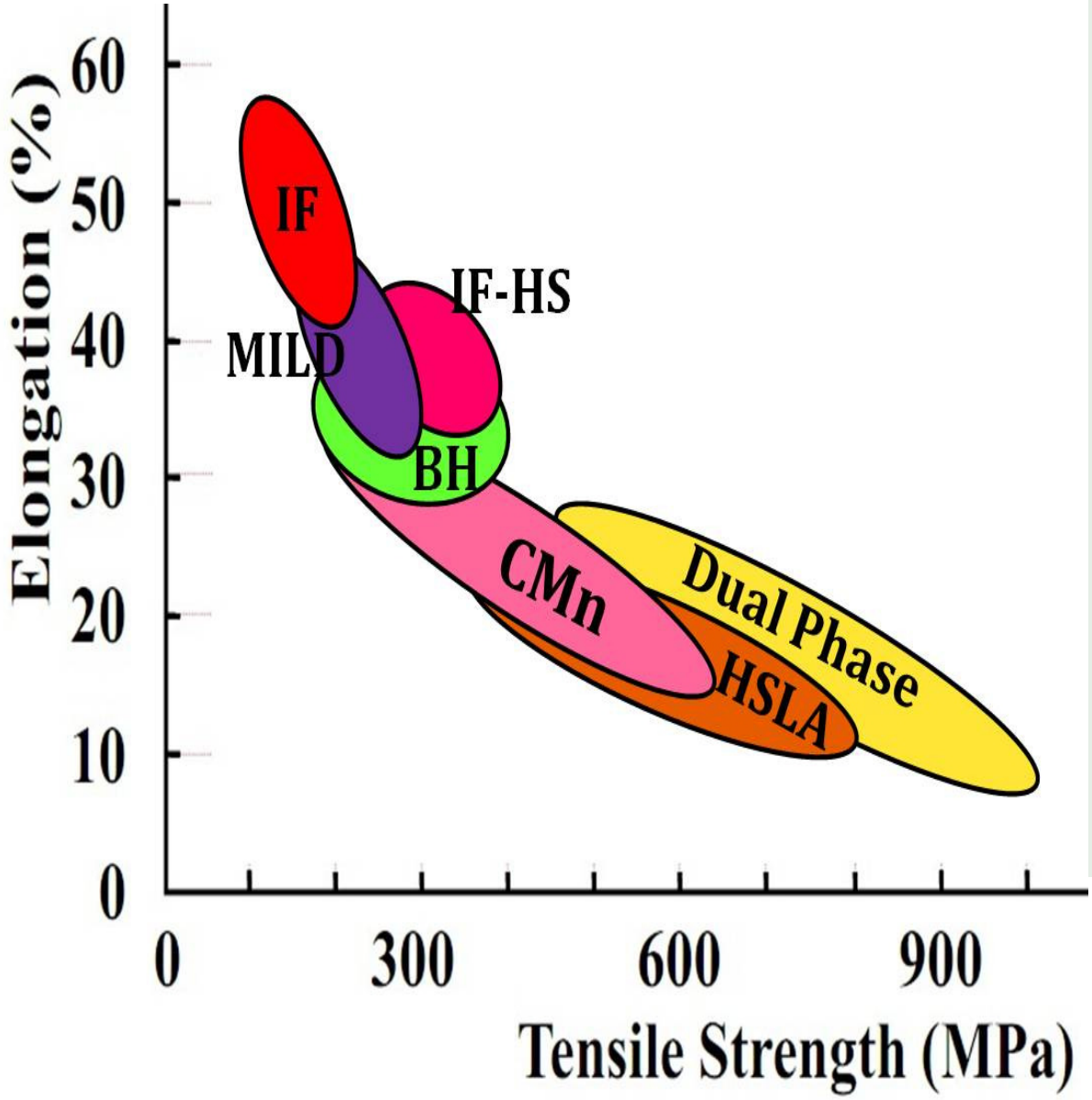
HIGH RISE BUILDING STRUCTURES

MATERIAL SAVING



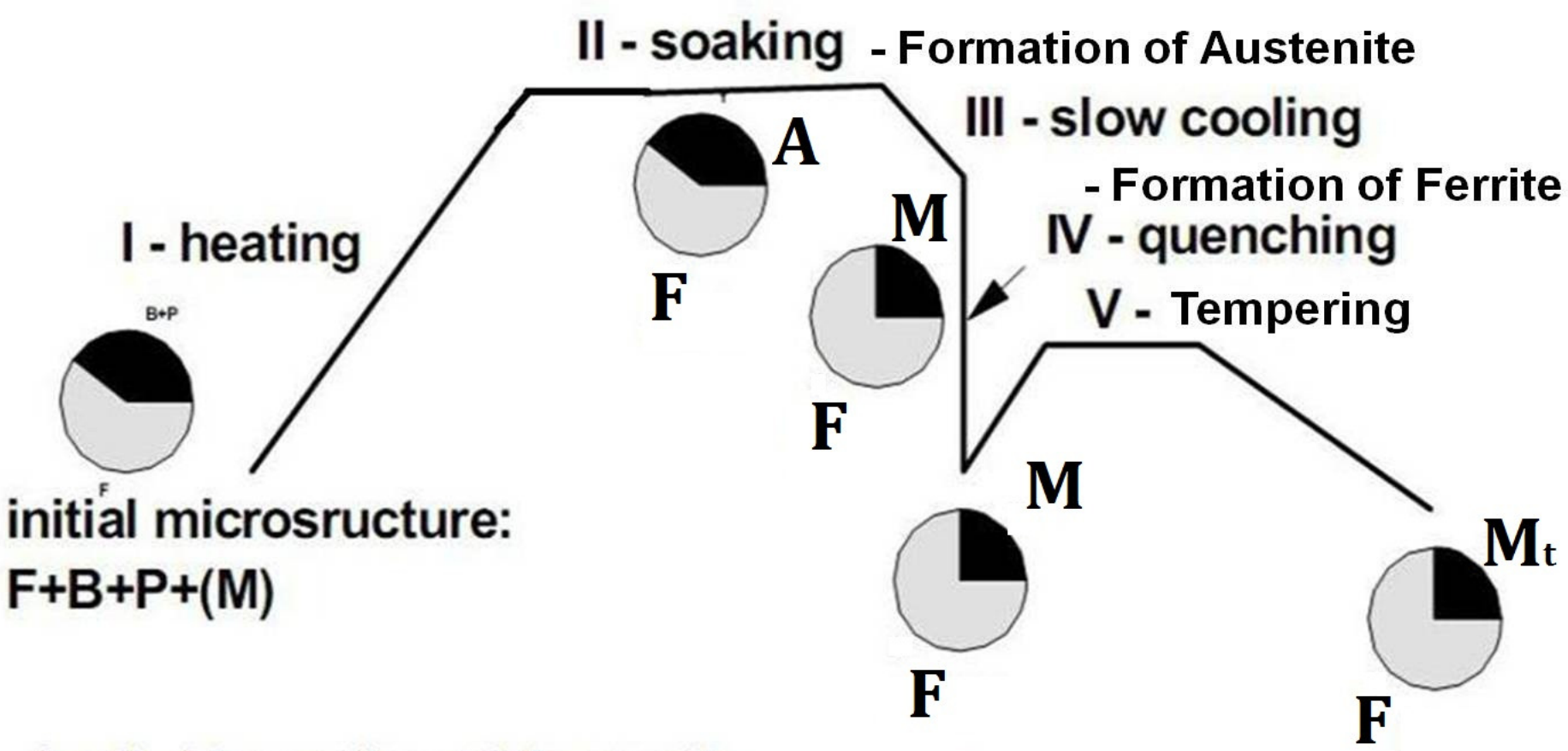
Overall Project Cost

DUAL PHASE STEEL



- Alloying with Mn, Si, Cr, Mo etc.
- Coiling at Low Temperature
- Islands of Martensite in Ferrite.
- Grain Refinement and Precipitation Strengthening (Nb, Ti, V etc.)
- Solid solution strengthening (Mn, P, Si etc.)

METALLURGICAL ASPECT TO OBTAIN DP STEEL

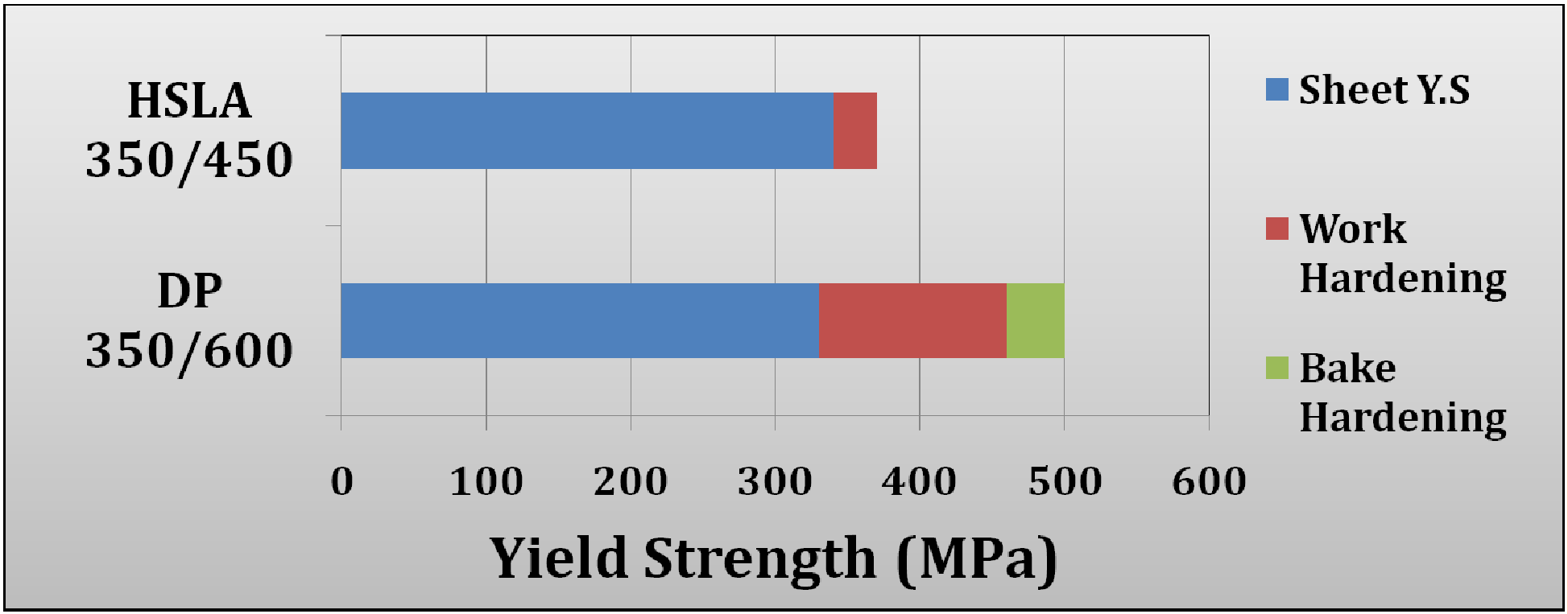


I + II - Formation of Austenite

III - Formation of Ferrite

IV - Formation of Martensite/Bainite

V - Tempering of Martensite/Bainite



- **DP STEELS ARE BAKE-HARDENABLE.**
- **INCREASE IN YIELD STRENGTH IN DP STEELS OF ABOUT 140 MPa AFTER FORMING & BAKING.**
- **LIMITED INCREASE IN YS BY WORK HARDENING IN HSLA DUE TO HIGH YS/TS RATIO.**

DUAL PHASE STEEL APPLICATIONS

REINFORCEMENTS. | STRUCTURAL PARTS

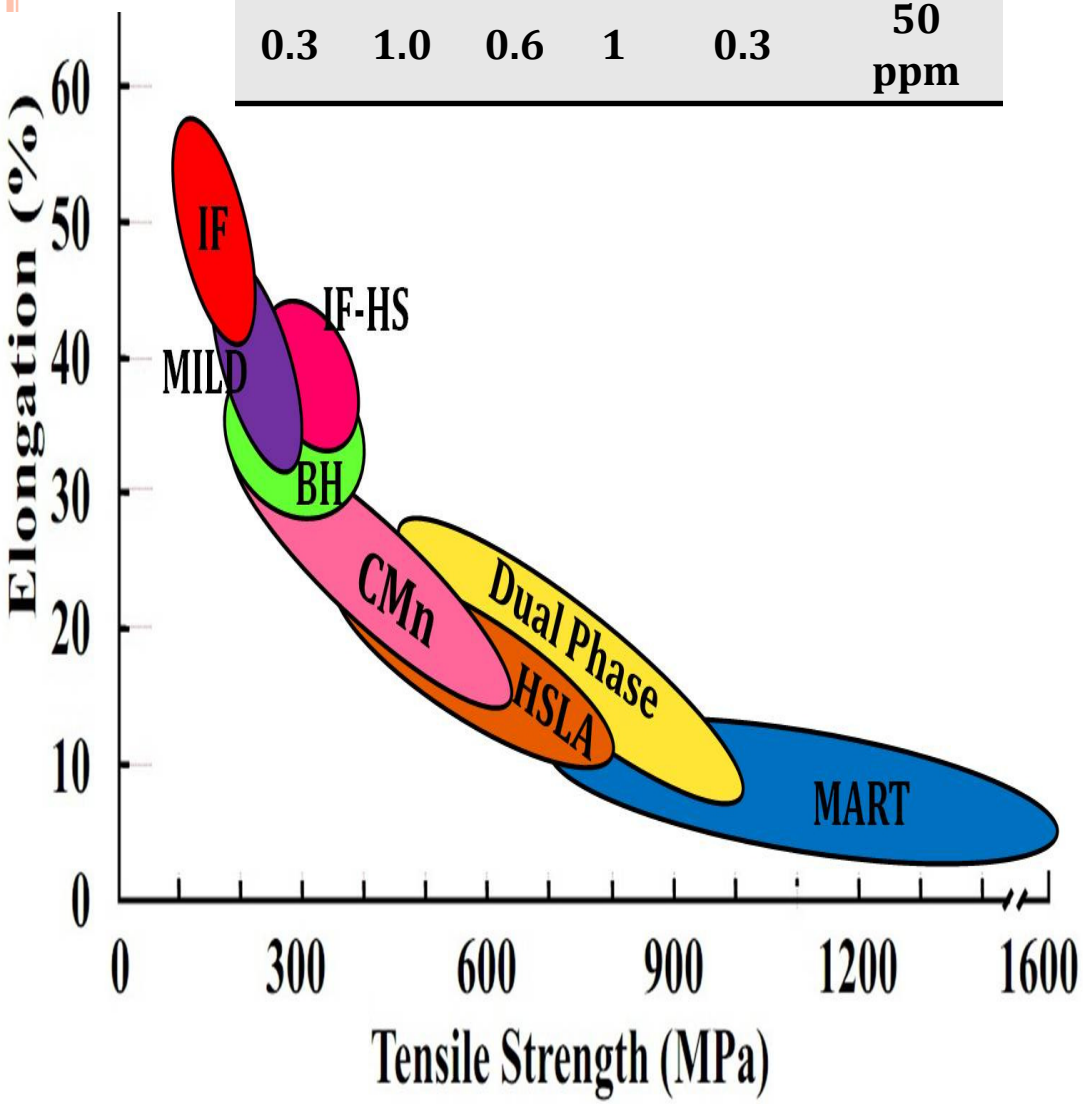
AUTOMOBILE WHEEL

Steel type	C	Si	Mn	P	Nb (Cb)	Cr
Dual Phase	0.08	0.30	0.50	0.07	-	0.5
	0.07	0.49	1.59	-	0.038	1.59

B-PILLAR REINFORCEMENT

MARTENSITIC STEEL

ARMOUR STEEL					
C	Mn	Si	Cr	Mo	B
0.3	1.0	0.6	1	0.3	50 ppm



- Y.S. – ~1450 MPa
- T.S. – ~1650 MPa
- % Elongation (min) – 8

APPLICATIONS

TANKS

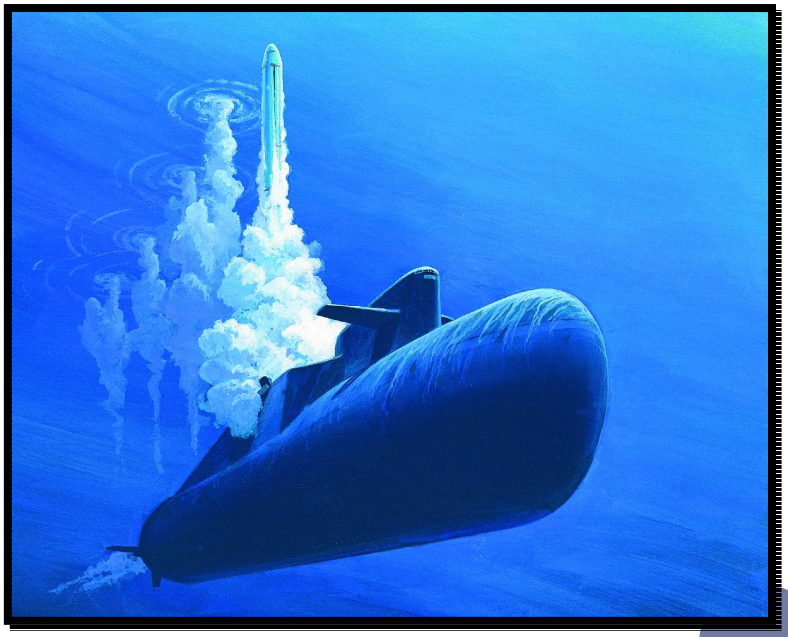
TRENDS IN MARTENSITIC STEEL

- INITIALLY HIGH CARBON CONTENT (QUENCHED & TEMPERED)
- ALLOYING WITH Ni, Mo FOR STRENGTH & TOUGHNESS (QUENCHED & TEMPERED)
- PART SUBSTITUTION BY Mn, Cr, B (QUENCHED & TEMPERED)
- MICRO-ALLOYING (V,Nb,Ti) – THERMO-MECHANICALLY CONTROLLED PROCESSING

Based on TMCP & Tempered Martensite

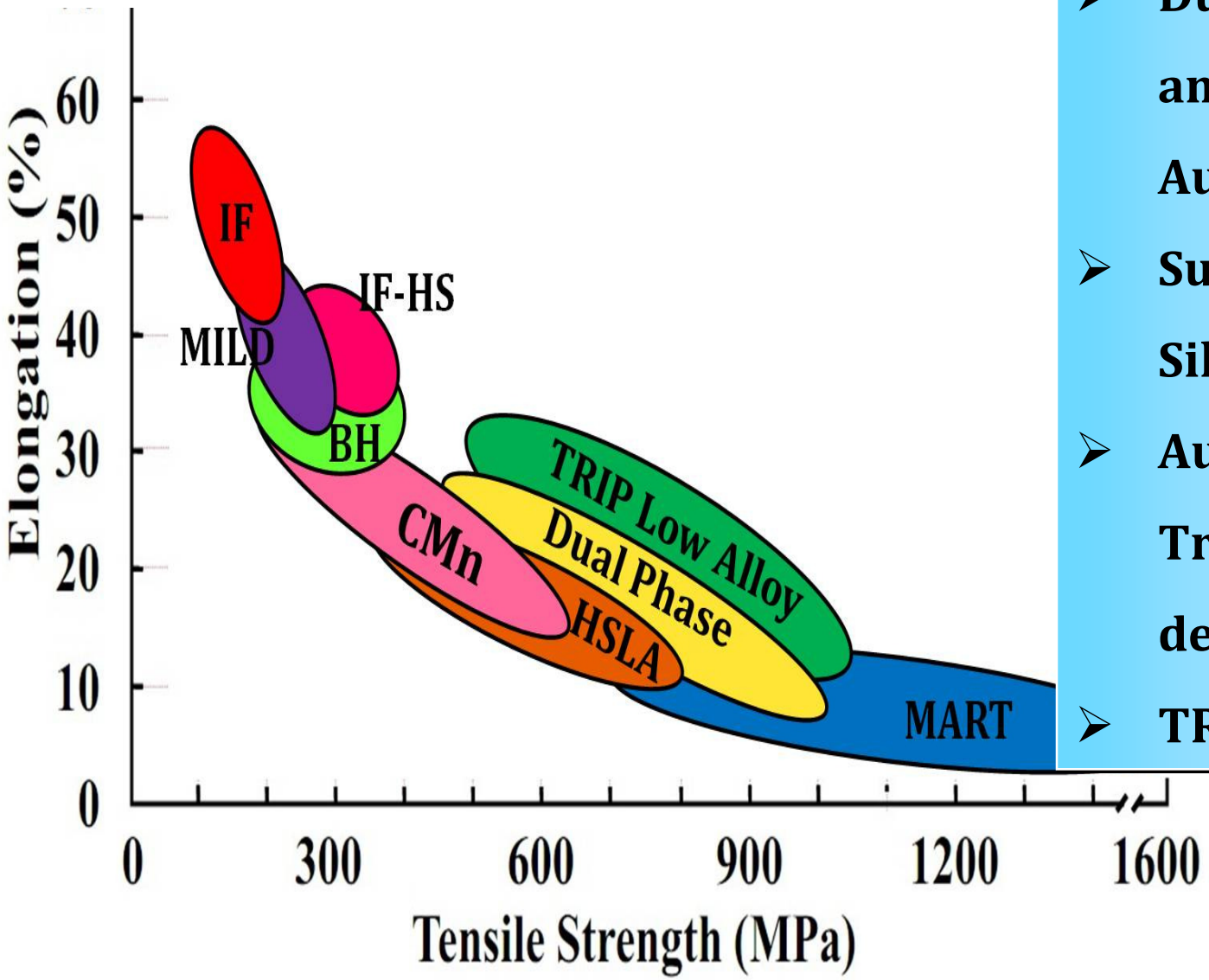
	C	Ni	Cr	Mo	V	Ti	P	S
HY 80	0.15	3	1.5	0.5	0.03	0.02	<0.015	<0.008

- Y.S. – 551 MPa (min.)
- % Elongation (min) – 20
- Charpy Impact – 47.5 Joules @ -49 ^{0}C



SUBMARINES

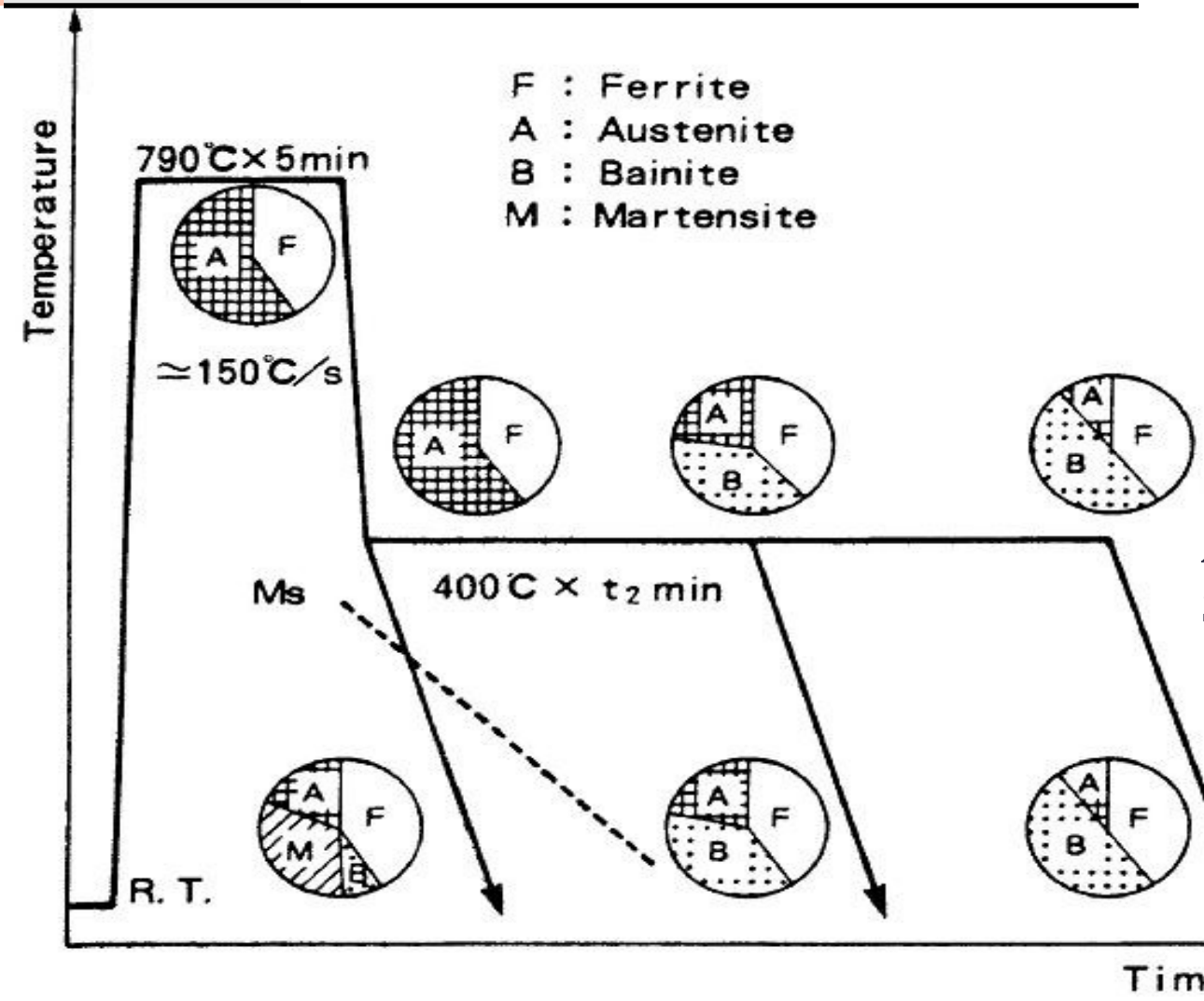
TRIP STEEL



- Suppress Pearlite by rapid cooling.
- During inter-critical anneal, Carbon in Austenite increases.
- Suppress Cementite by Silicon addition.
- Austenite retained - Transforms during deformation
- TRIP 590/690/780

METALLURGICAL ASPECT TO OBTAIN TRIP STEEL

Steel type	C	Si	Mn
TRIP Steel	0.2	1.2	1.2
	0.14	1.95	1.65

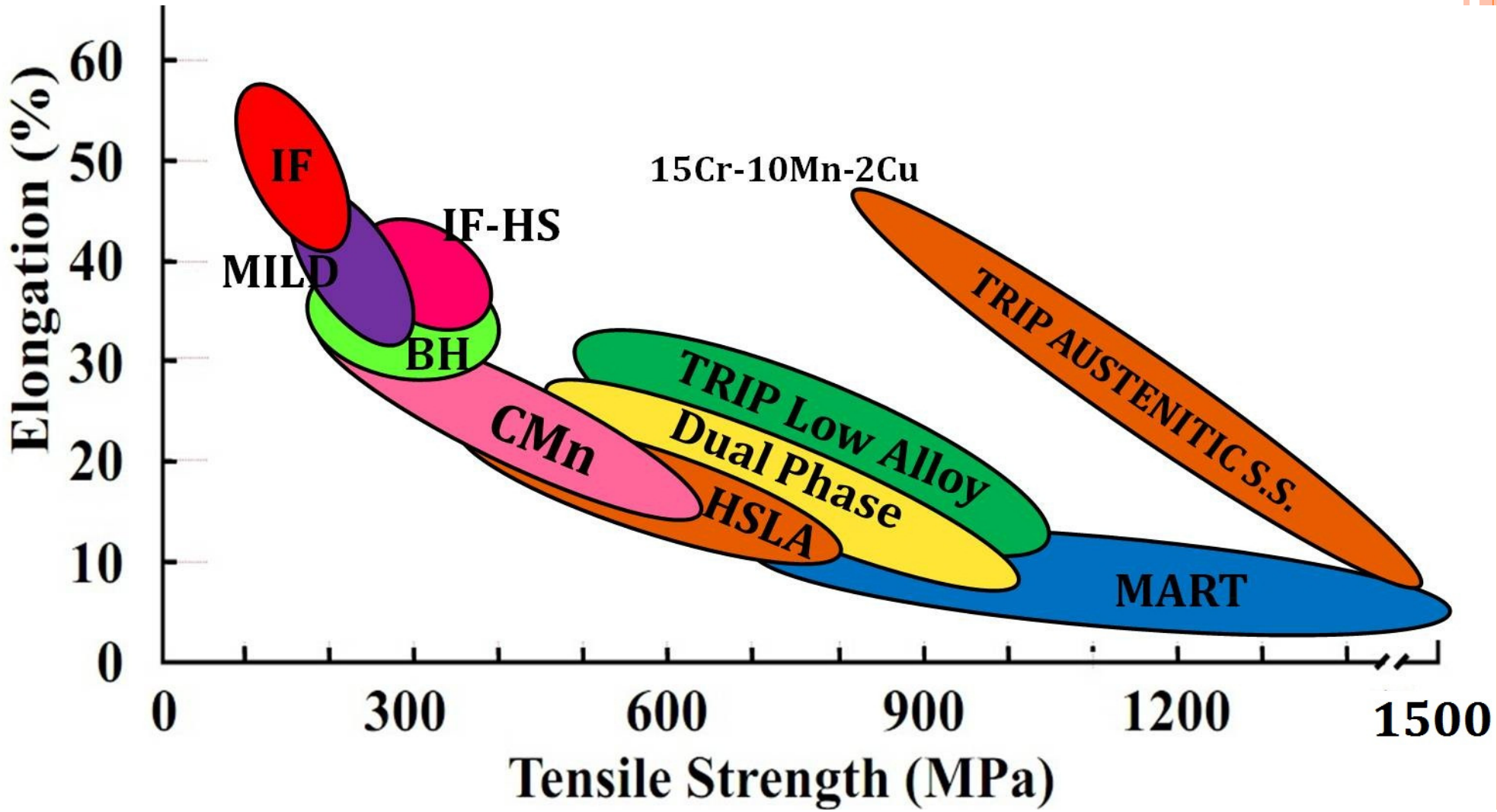


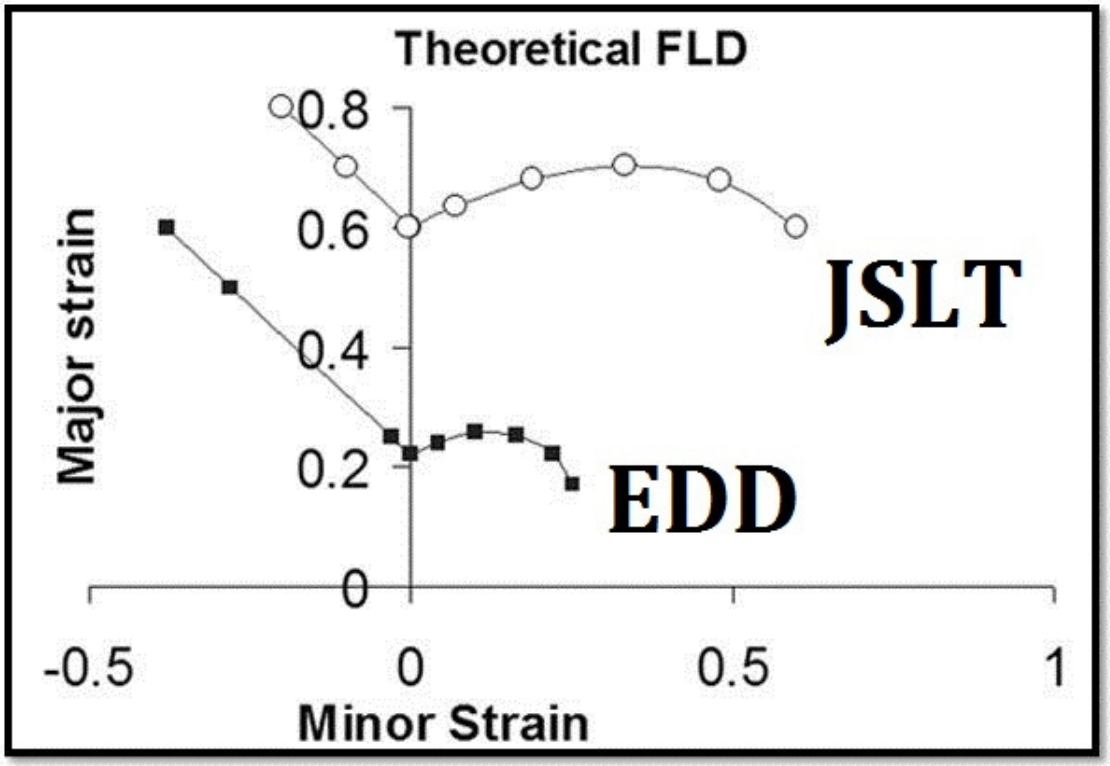
AUTOMOBILE STRUCTURAL & SAFETY PARTS:

- Cross members.
- Longitudinal beams.
- B-pillar reinforcements.
- Sills and bumper reinforcements

HIGH STRENGTH AUSTENITIC STAINLESS STEELS - METASTABLE

Grade	C	Cr	Mn	Cu	S	N
JSLT	≤ 0.1	15.0-16.0	9.0-10.0	1.5-2.0	≤0.01	0.1-0.2

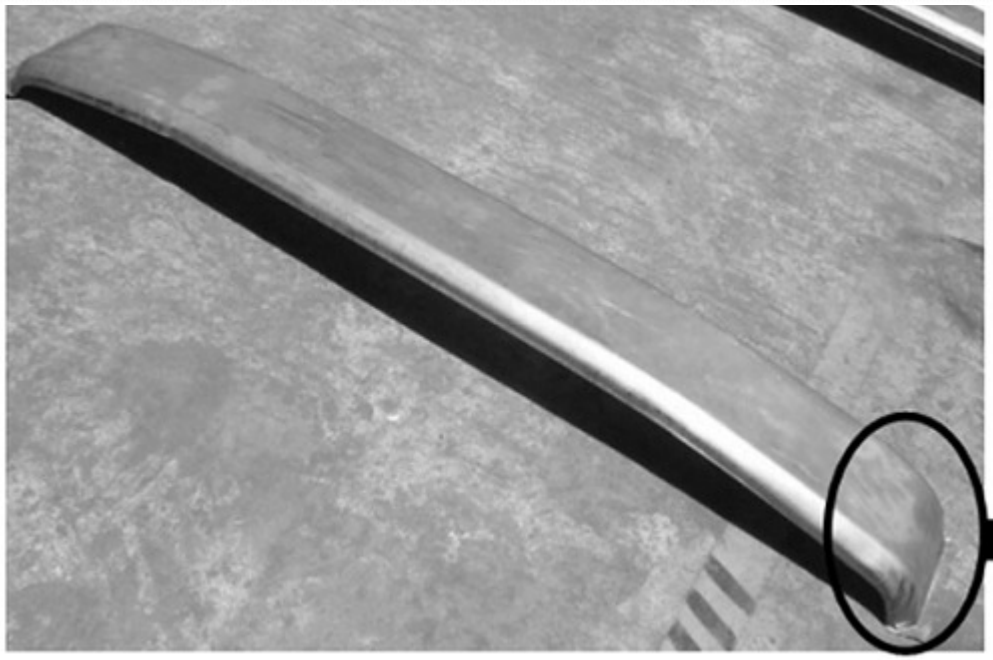


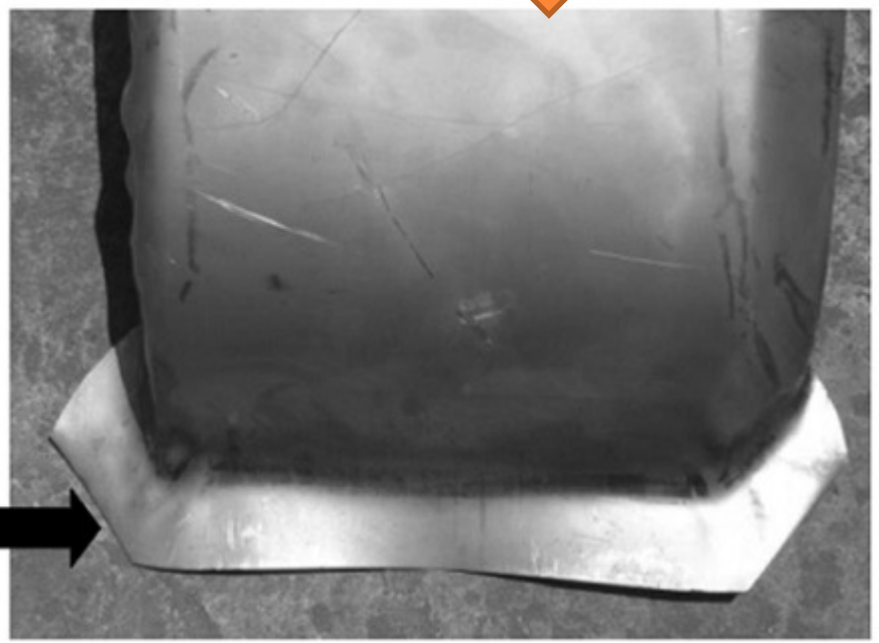


3mm EDD BUMPER

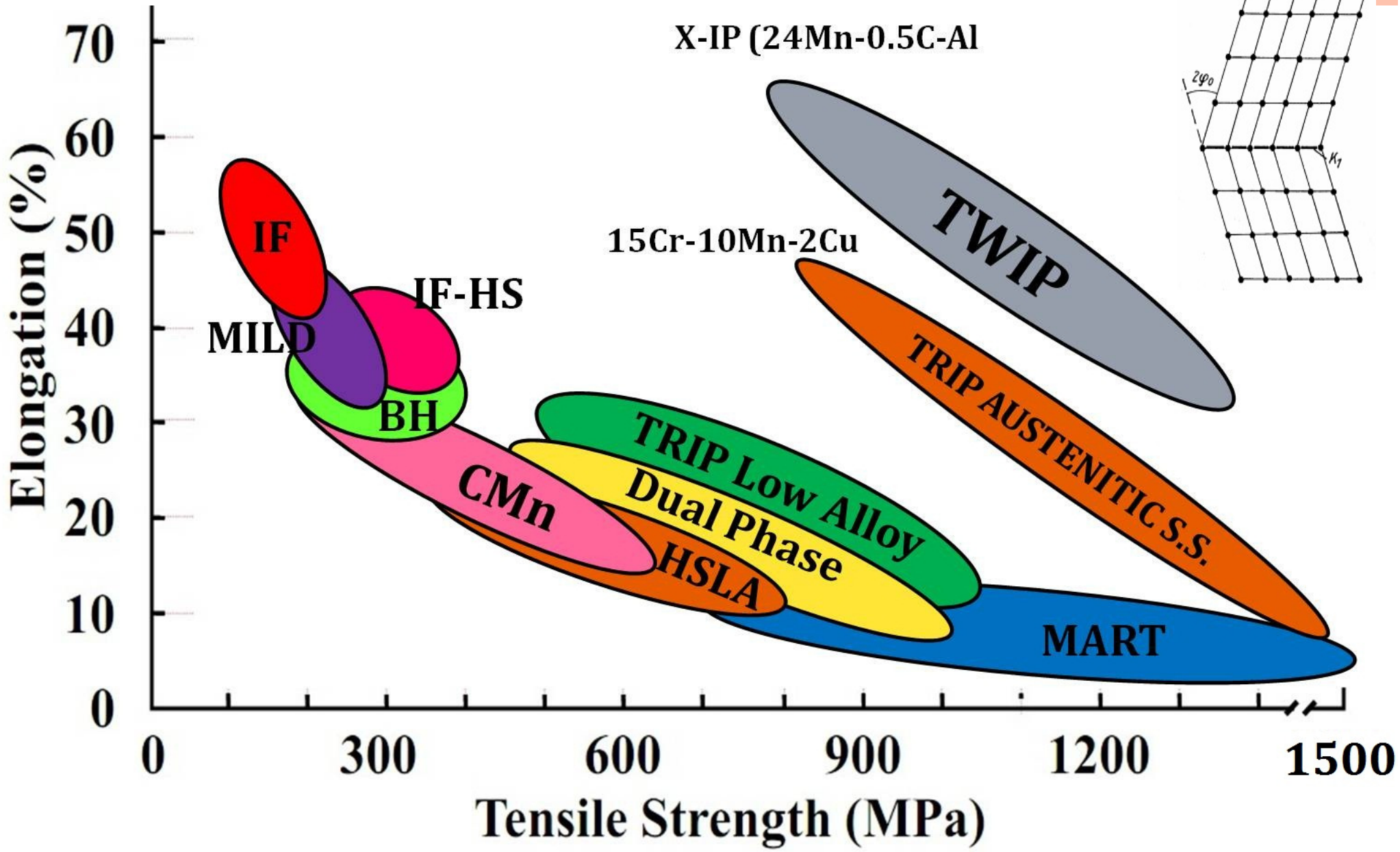
1.2mm JSLT BUMPER

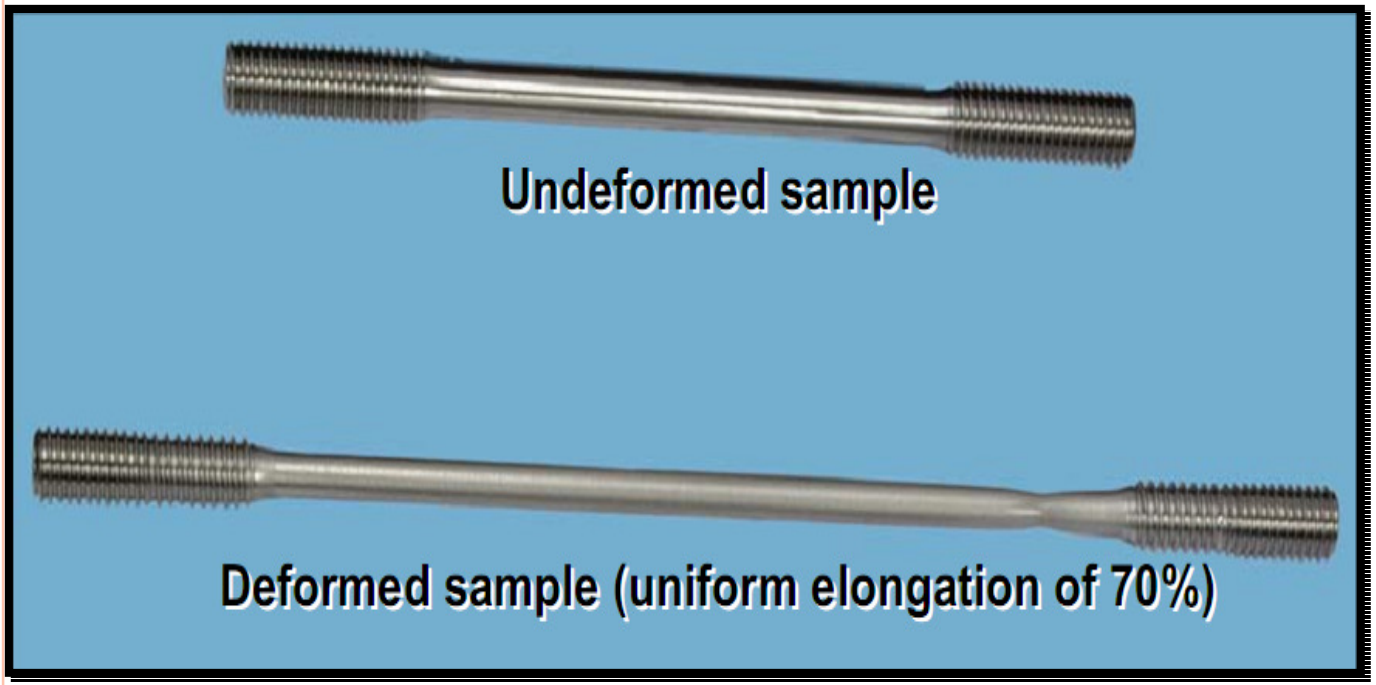
Thickness of Bumper Reduced @ASHOK LEYLAND



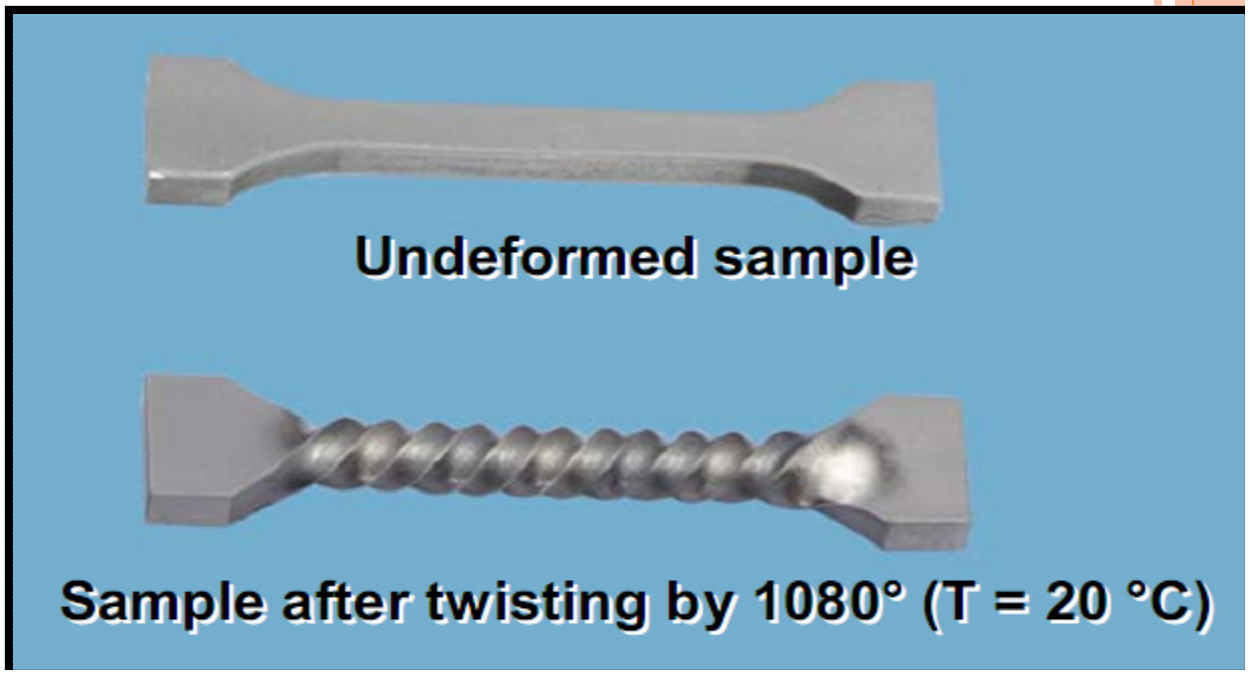


TWIP STEEL


X-IP (24Mn-0.5C-Al
15Cr-10Mn-2Cu
TWIP
TRIP AUSTENITIC S.S.
TRIP Low Alloy
Dual Phase
HSLA
MART
CMn
BH
IF-HS
MILD
IF
Elongation (%)
Tensile Strength (MPa)
0
10
20
30
40
50
60
70
0
300
600
900
1200
1500



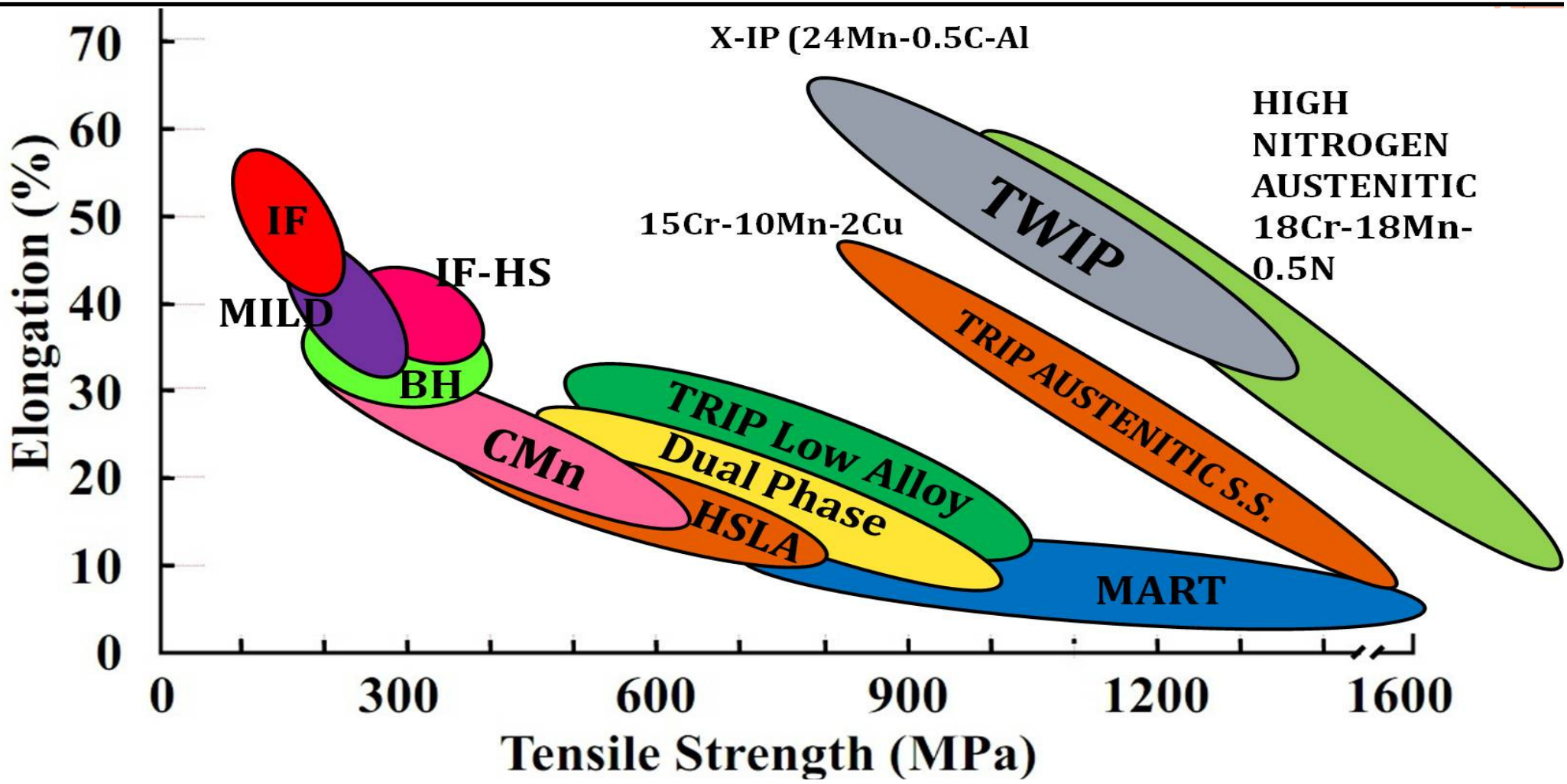
TWIP STEEL X5 MN AL SI 25 3 3



High Nitrogen Austenitic Stainless Steel

DIN 1.3816 -X8CrMnN18-18

C	Cr	Mn	N	Si	P	S	Fe
-	17.5	17.5	0.5	-	-	-	-
0.1	20	20	0.7	0.8	0.06	0.015	Bal



INTERSTITIAL FREE FERRITIC STAINLESS STEELS

Grade	%C	%Cr	%Ti/(Ti + Nb)	%Mo	%N
409L	0.01	11	~ 0.2	-	0.01
436L	0.01	16	~ 0.3	1	0.01
439	0.01	17	~ 0.3	-	0.01
441	0.01	18	~ 0.5	-	0.01
444	0.01	18	~ 0.4	~ 2	0.01
446	0.1	23	-	-	-

Ti, Nb or Ti+Nb stabilized grades

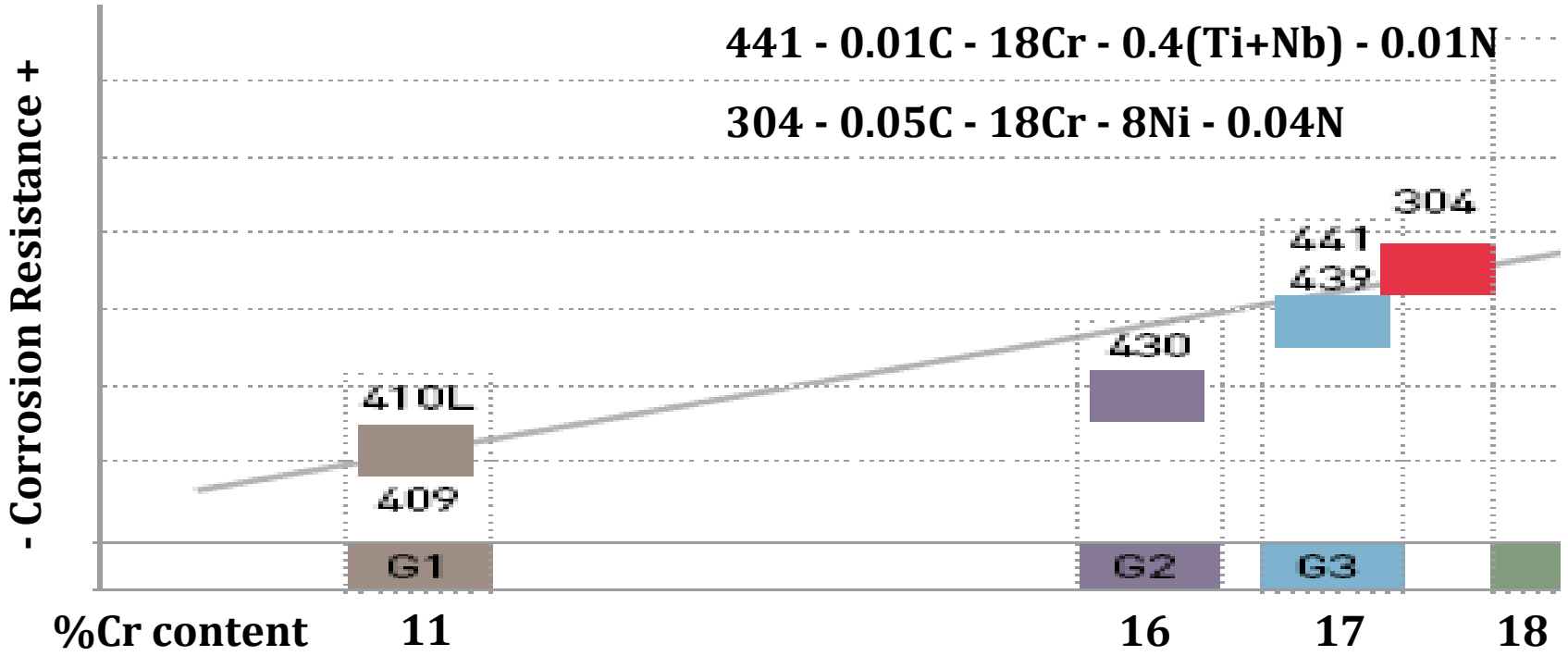
Advantage

- Improved Corrosion resistance
- Superior Formability
- Improved Weldability
- Superior Toughness
- Lower DBT Temp.

Low C, Low N Ferritic Stabilized with Ti/Nb

Finding increasing application due to

- **Comparable Corrosion Resistance 441 vs. 304 grade**
- **Superior Drawability : High r-bar value**
- **Good Ridging Resistance**
- **Superior Weldability in comparison to classical Ferritics**



Applications of 439

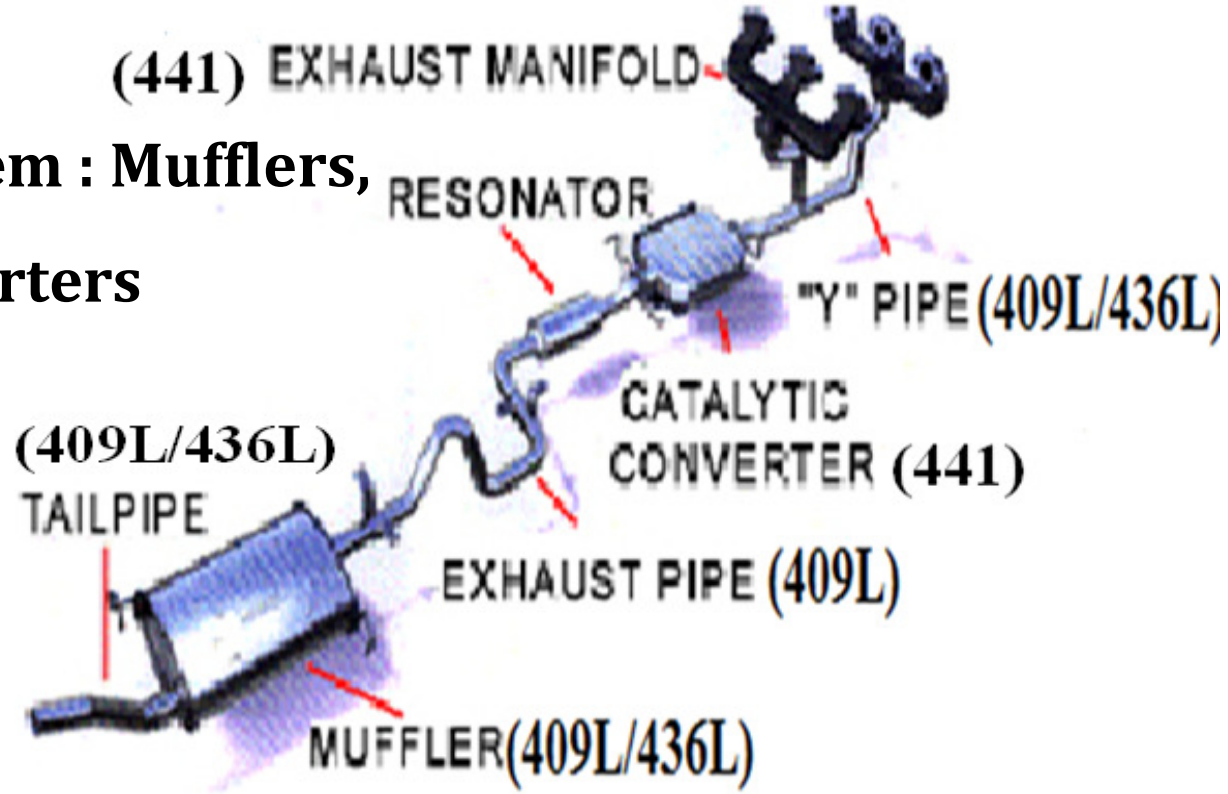
- Automotive exhaust manifolds and mufflers
- Direct fired hot water tanks
- Food equipments
- Lift panels
- Electrical appliances: Washing machine drum microwave ovens
- Sugar industry: Sugar-cane juice ducts, heaters, evaporators, crystallization units

Applications of 441

- Solar panel
- Solar hot water tank, Solar Collector
- Exchanger tubes: Sugar & energy industry
- Exhaust system: manifold, catalytic converter

Applications of 409L

- Automobile exhaust system : Mufflers, manifold, Catalytic Converters
- Fuel filters
- Refrigerated container
- LCD monitor frames



Applications of 436L

- Solar water heater
- Visible parts of exhaust systems
- Automotive trim and outdoor panels
- Communication-system shelter

SUPER FERRITIC STAINLESS STEELS WITH HIGH CORROSION RESISTANCE

	Grade	Cr	Mo	Ti
Super Ferritic Corrosion Resistant	44626	25-27	0.75-1.5	0.2
Super Ferritic Heat Resistant	44600	23-27	-	-

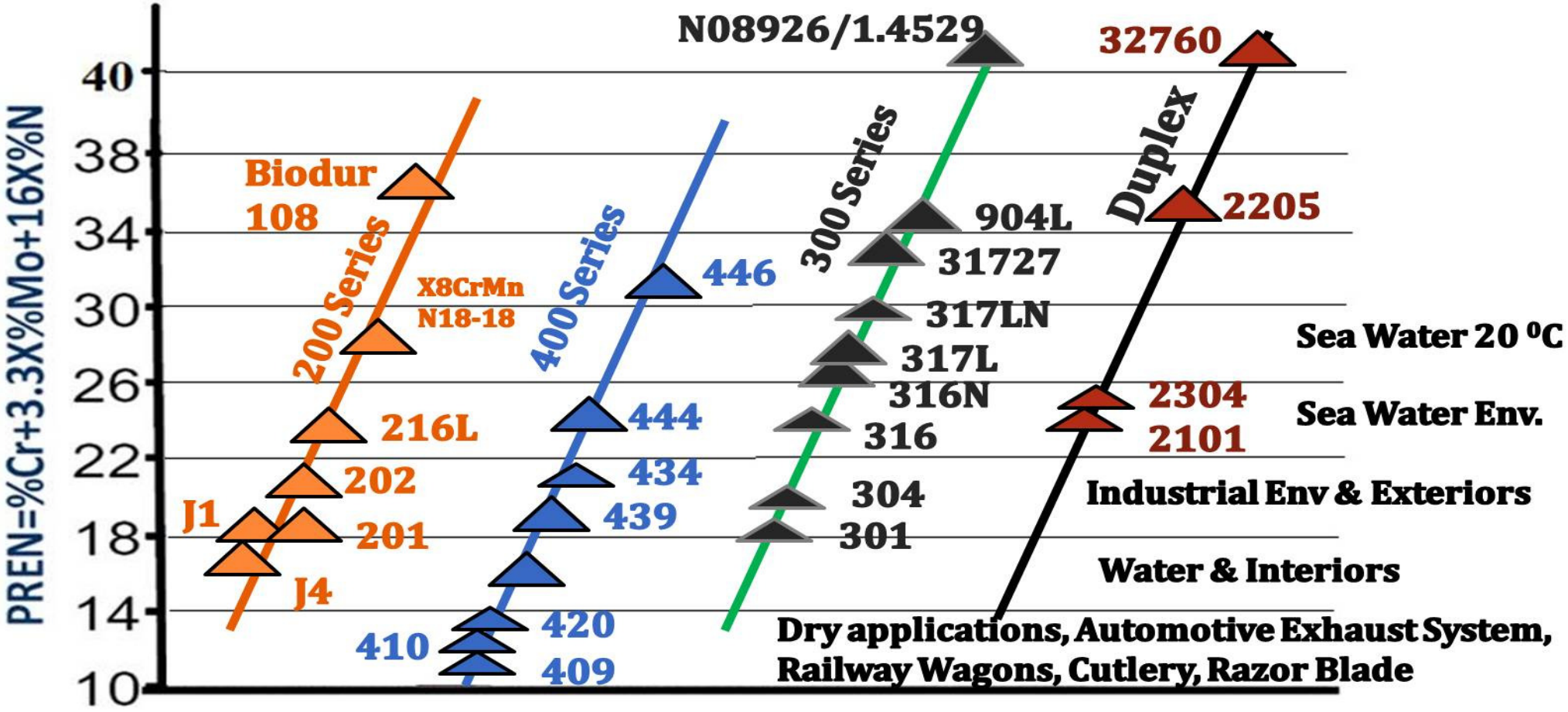
Applications

- Boiler tubes
- Cement kilns
- Waste heat boilers
- Salt baths
- Heat treating
- Incinerators

STAINLESS STEELS WITH HIGH CORROSION RESISTANCE

Benefits of Interstitial Nitrogen

- Improved Pitting Corrosion Resistance
- Improved Weldability
- Improved Formability–TRIP Optimization
- Reduced Material Cost
- Reduced Processing Cost



High Performance Austenitic Stainless Steels

Grade	C	Cr	Ni	Mo	Cu	N
31727/NAS 155N	0.02	18	15	4	3	0.2
Super Austenitic EN 1.4529/NAS 255NM	0.01	20	25	6	1	0.2

APPLICATIONS

31727	**Chimneys and dampers of high sulfur fuel**
	Dilute sulfuric acid tanks
EN 1.4529	**Pollution control**: Flue gas de-sulphurisation (absorber, ducts)
	Natural and treated seawater system, **desalination plants**
	Bleaching equipment for **pulp and paper industries**
	Chemical industries: **Phosphoric acid & Sulphuric acid plants**

CHIMNEYS

BLEACHING EQUIPMENT

Duplex & Super Duplex Stainless Steels

Low carbon and intentionally added nitrogen for:

- **Superior Inter-grannular corrosion resistance**
- **Higher pitting resistance**
- **Improved Weldability**

	Grade	C	Cr	Ni	Mo	N	W
Lean Duplex	**2101**	0.03	21	1.5	-	0.22	-
Duplex	**2205**	0.02	22	5	3	0.16	-
Super Duplex	**UNS 32760 (ZERON 100)**	0.02	25	7	3	0.25	0.5

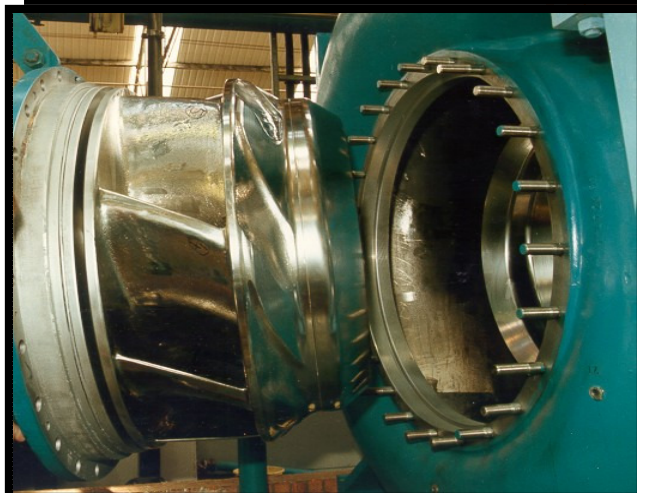
Nitrogen Alloying has made Duplex Stainless Steel Readily Weldable

APPLICATIONS

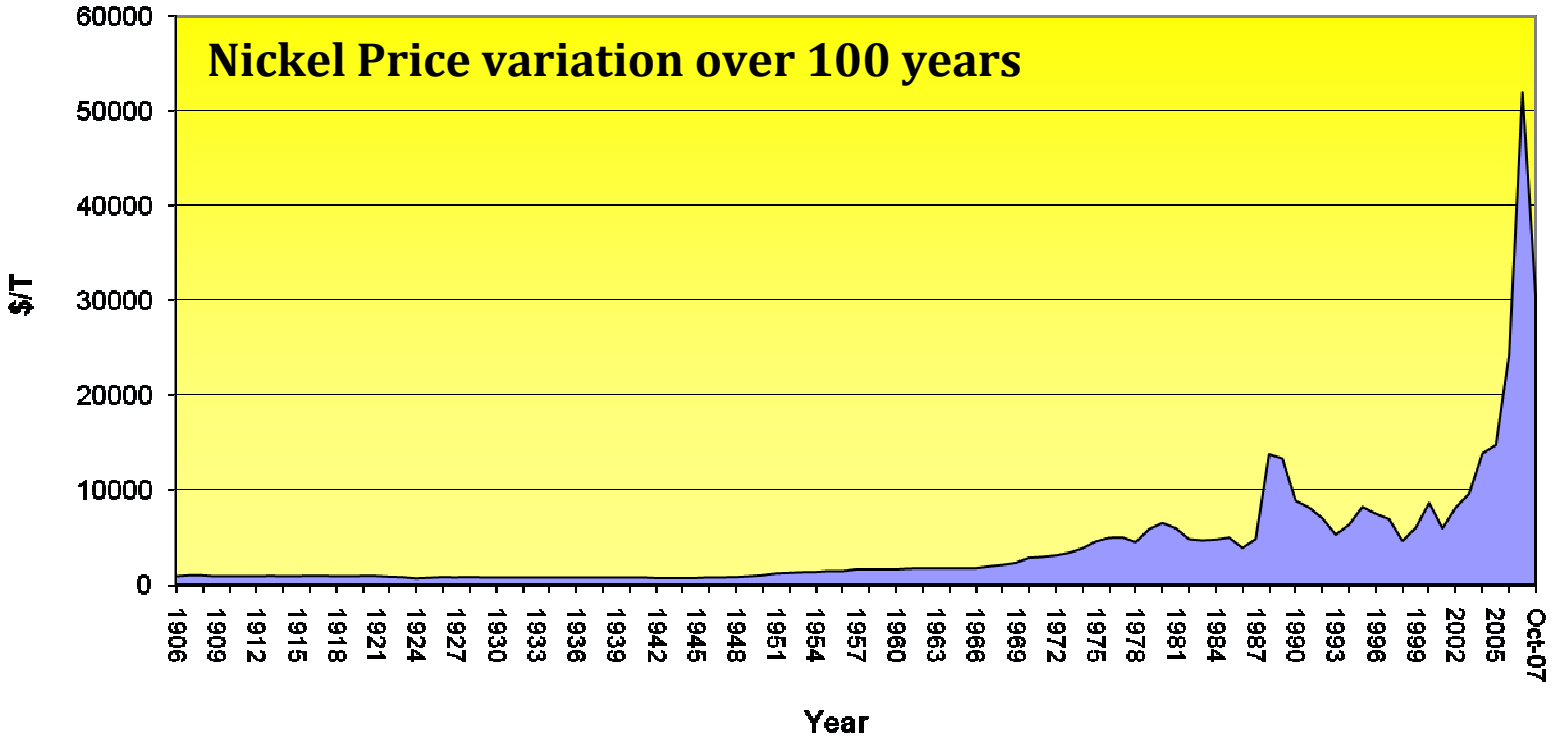
Lean Duplex 2101	**Tanks:** Palm oil, Wine, Marble slurry, Potable and Sewage water, Ethanol, Fruit juice, Biodiesel
	Infrastructure: Bridges, Sluice gates
Duplex 2205	**Chemical industry:** Sour gas piping, Heat exchanger, tanks and vessels for chloride-containing media
	Oil and Gas industry: Piping and process equipment, offshore structures
	Cargo tanks in ships for transport of chemicals
	Flue gas desulphurization systems, Electrostatic precipitators
	Pulp and Paper industry: Digester
Super Duplex 32760	**Sea water Desalination Plants**
	Sea water Pumps

TANKS

ROTARY PUMPS



IT IS AMAZING THAT STILL GRADE 304 (18Cr-8Ni) ACCOUNTS FOR 50% OF TOTAL S.S PRODUCTION WORLDWIDE



N added Stainless Steels

0.05N nearly replaces 1%Ni

Cost per Kg of Input Materials	
Steel Scrap	Rs 20
Cr (From HC Fe-Cr)	Rs 110
Mn (From HC Fe-	Rs 80
Nickel	Rs 1250

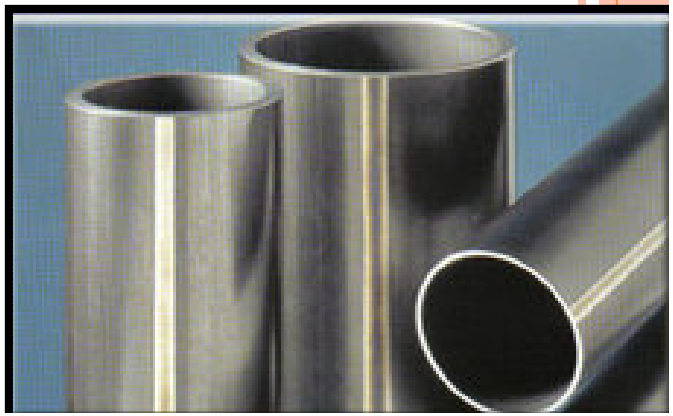
LOW COST ALTERNATIVES TO 18Cr-8Ni

REQUIREMENT	APPLICATIONS	SWITCH TO
UNWELDED APPLICATION	KITCHENWARE,WHITE GOODS, DECORATIVE WARES, WALL PANELS	**Cr 16⁺**

Grade	%C	%Cr
430	0.1	16

WELDED APPLICATION WITH CORROSION RESISTANCE SIMILAR TO 304	WELDED TUBES, TANKS, EXTERIORS	**439,441, 444**

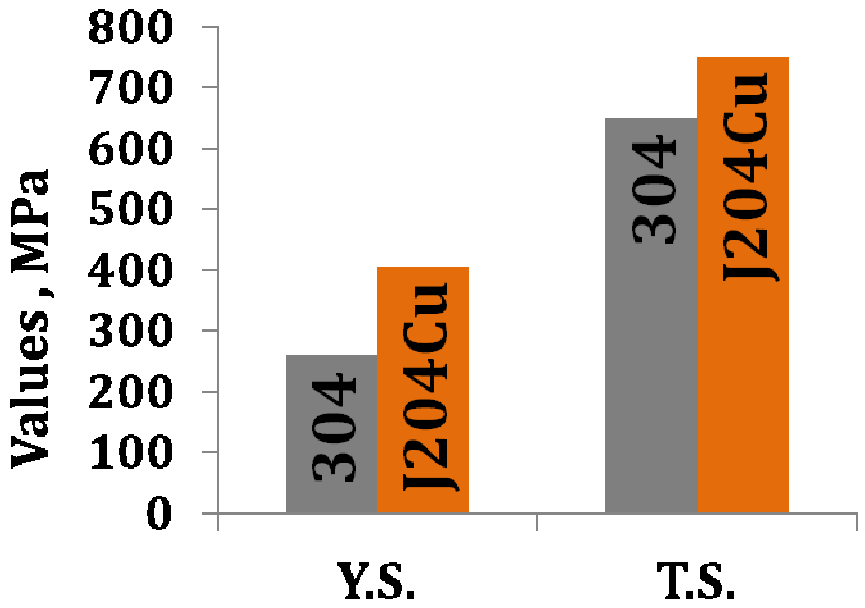
Grade	%C	%Cr	%Ti/(Ti + Nb)	%Mo	%N
439	**0.01**	**17**	**~ 0.3**	**-**	**0.01**
441	**0.01**	**18**	**~ 0.5**	**-**	**0.01**
444	**0.01**	**18**	**~ 0.4**	**~ 2**	**0.01**

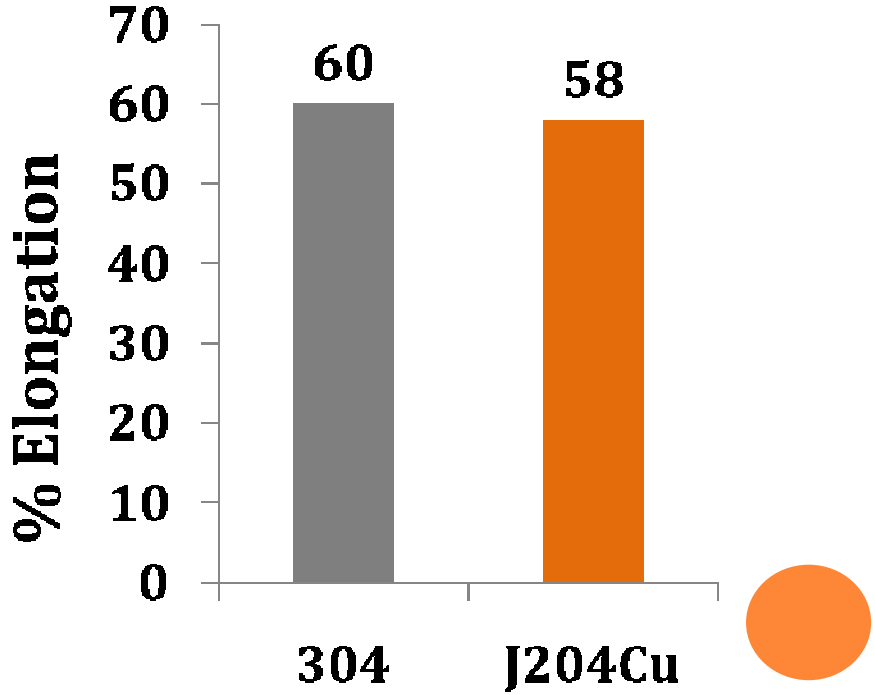


REQUIREMENT	APPLICATIONS	SWITCH TO
HIGH STRENGTH & HIGH FORMABILITY	DEEP DRAWN KITCHENWARE, SINKS, ELEVATORS, AUTOMOTIVE HOSE CLAMPS etc.	**204Cu**

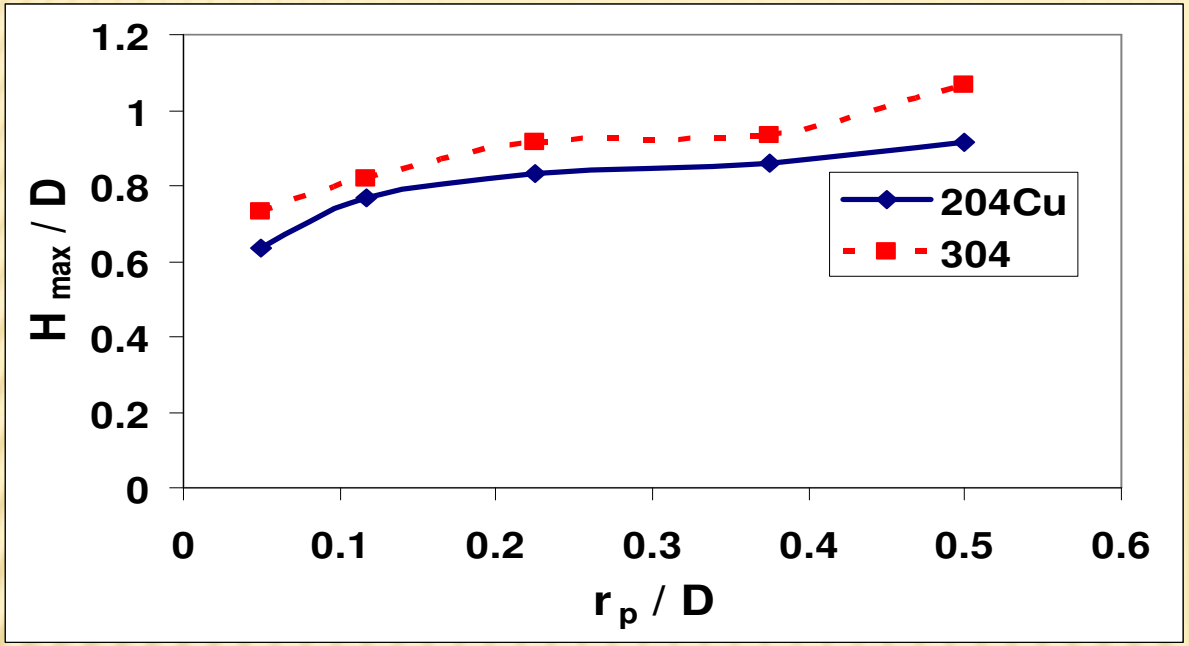
Grade	C	Cr	Mn	Ni	Cu	N
J204Cu (UNS S20430)	≤ 0.1	16.0-17.5	6.5-9.0	1.5-3.5	2.0-4.0	0.1-0.2

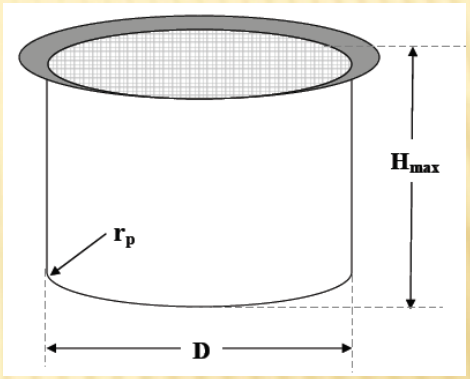
MECHANICAL PROPERTIES

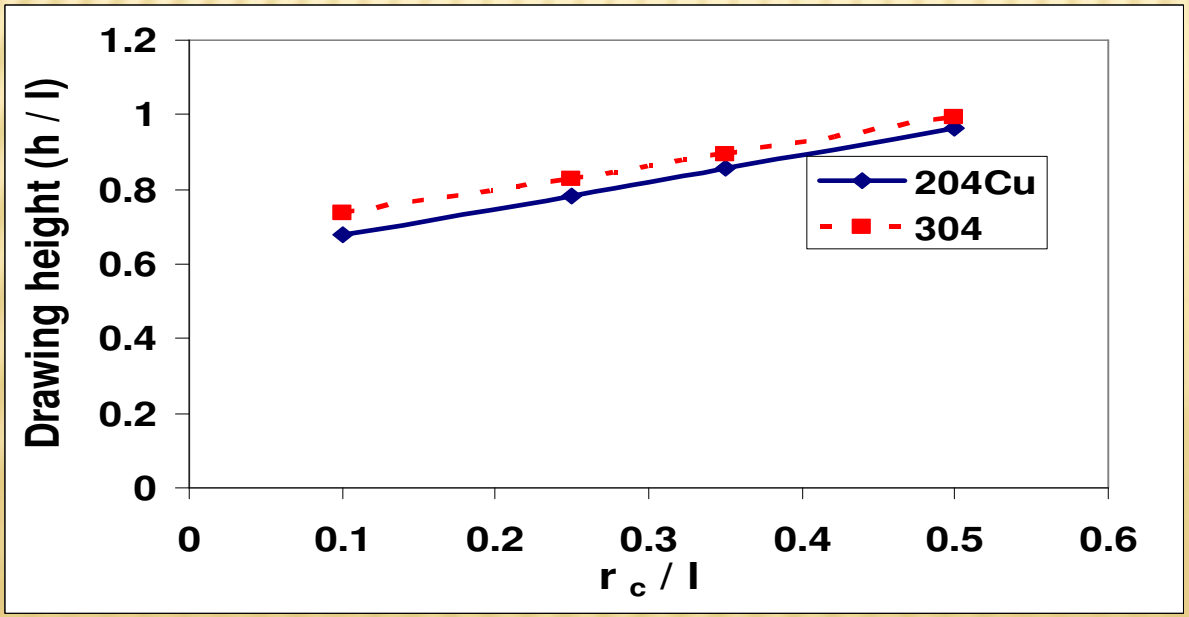


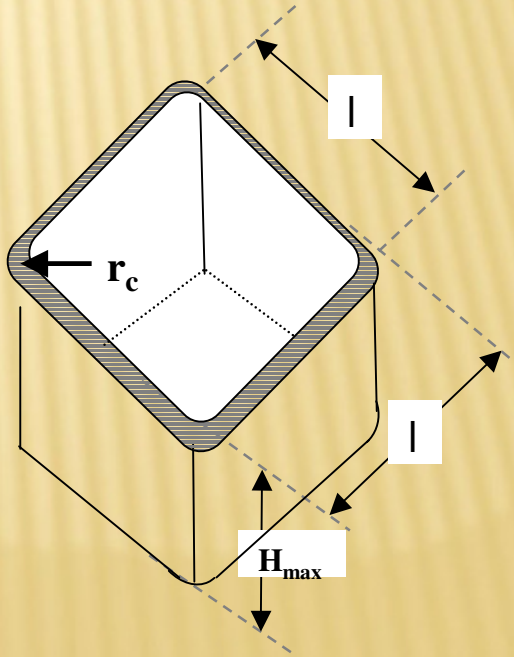


DRAWABILITY OF 204Cu:









APPLICATIONS OF 204Cu

Catering and food processing: Deep drawn kitchenware, cookware, milk cans

Architecture, building and construction: Handrails for staircase elevators, sinks

Consumer durables: Toasters, microwave ovens & washing machines outer body parts, mobile case/parts

Transport (Automotive): Hose clamps, safety belt anchors

SINKS

ELEVATORS

REQUIREMENT	SWITCH TO
HIGH STRENGTH & SUPERIOR CORROSION RESISTANCE	LEAN DUPLEX STAINLESS STEEL

	Grade	C	Cr	Ni	Cu	Mn	N
Low Ni Duplex	2101	0.03	21	1.5	-	5	0.22
Ni Free Duplex		0.03	21	0.3	1.5	5	0.22

Test Media (Boiling)	Duplex Ni Free	Duplex Low Ni	304	316L
1% Oxalic Acid	A	A	B	B
5% Acetic + 5% Formic	A	A	B	B
50% Nitric	A	A	B	B
1% H_2SO_4	B	B	E	C
5% H_2SO_4 + 20% $(NH_4)_2SO_4$	B	B	E	D

A < 0.1 mmpy
B - 0.1-1.0 mmpy
C – 1-3 mmpy
D – 3-10 mmpy
E > 10 mmpy

IT IS PERFECTLY FEASIBLE TO SWITCH TO MORE COST EFFECTIVE GRADES WITH HIGH FUNCTIONALITY

Conclusion:

- ***Continuous evolution of new attractive grades based on metallurgical concepts from interstitial free to high interstitial grades.***
- ***Trend towards leaner alloys with higher strength & enhanced formability for material conservation.***
- ***Thrust on controlled rolling & accelerated cooling to avoid expensive heat treatment.***