Weight reduction A

Weight Reduction in Rail Transport

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Metallurgical & Chemical (M&C) Directorate RDSO

- RDSO has various directorates for smooth functioning:
- M&C Directorate is involved in R&D activities related to Material development, Non-destructive testing, Corrosion Engineering, Fatigue, wear, Fracture mechanics studies, Welding technology, Failure investigation, Tribology, Polymer & Composite, Oils & Lubricants.
- It has 11 Labs altogether: Six in metallurgical group and five in Chemical Group

Vision

- Develop smarter, greener and safer Surface Transport System (s)
- Secure the leading role in the global market

Goals

- Higher speed
- Higher load carrying ability,
- Zero emission or neutral emission
- Cheapest mode among the contemporary mass transport system
- Higher reliability

Goal & Technical challenge

- Higher speed
- Higher load carrying ability,
- Zero emission or neutral emission
- Cheapest mode among the contemporary mass transport system
- Higher reliability & safety

- Light weighting
- Energy efficient
- Cost effective
- No compromise with safe design

Cost effectiveness of 1 Kg light weighting in Indian Railways

- Loaded Km per wagon per day = 146.2
- Increase in NTKM per day per wagon = 0.1462
- Increase in NTKM per year per wagon = 53.363
- Earning per NTKM of coal = Rs. 0.811
- Earning per year with 1 Kg light weighting = Rs.43.27
- SFC / GTKM = Rs. 0.0768
- Empty Km earning of wagon per day = 79.5
- Decrease in GTKM per day for I Kg light weighting = 0.0795
- Fuel cost saving per day = Rs.0.00611

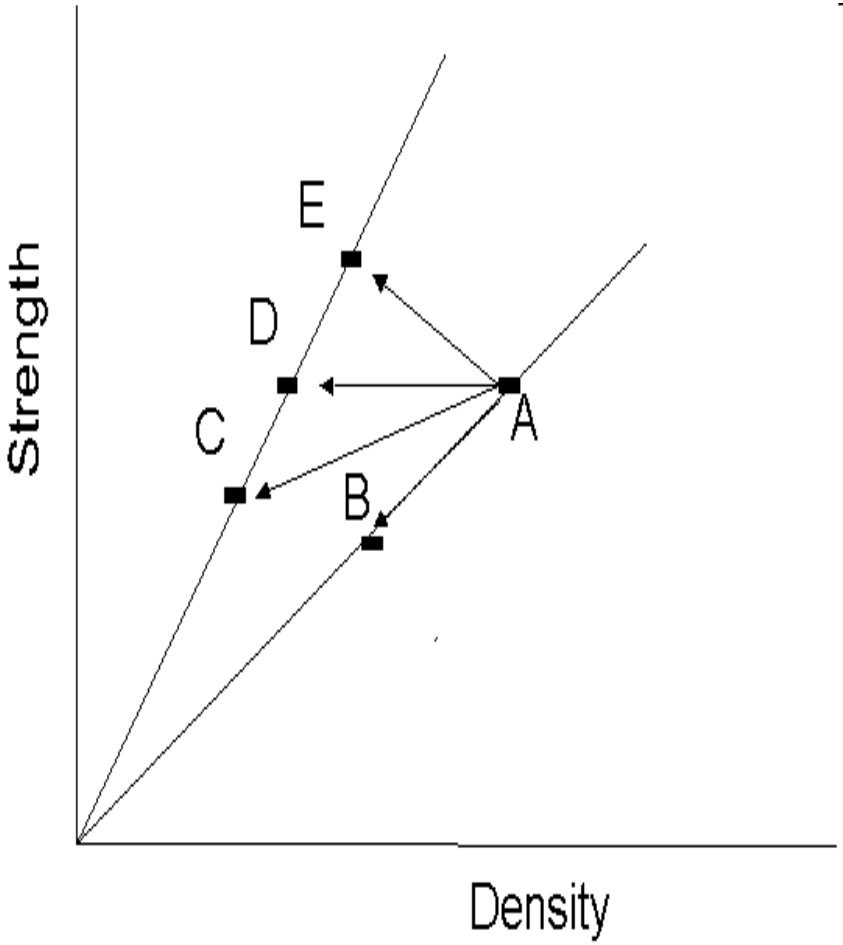
Cost effectiveness of 1 Kg light weighting in Indian Railways

- Saving in fuel cost per year for 1 Kg light weighting = Rs.0.00611 x 365 = Rs.2.23
- Total saving per year or 1 Kg light weighting = Rs.43.27 + Rs. 2.23 = Rs. 45.50
- Considering life of wagon as 20 years, total life time saving for 1 Kg light weighting can be

  Rs.45.50 x 20 = Rs. 814 = **Euro 15** = **22 US Dollar**
- it can be estimated that the value of lightweighting in aerospace industries is around €100 or Rs.5500 per kilogram of weight
- The operating cost benefits of lightweighting are perceived to be much lower in Rail transport. Costing in the rail industry is dominated by initial costs

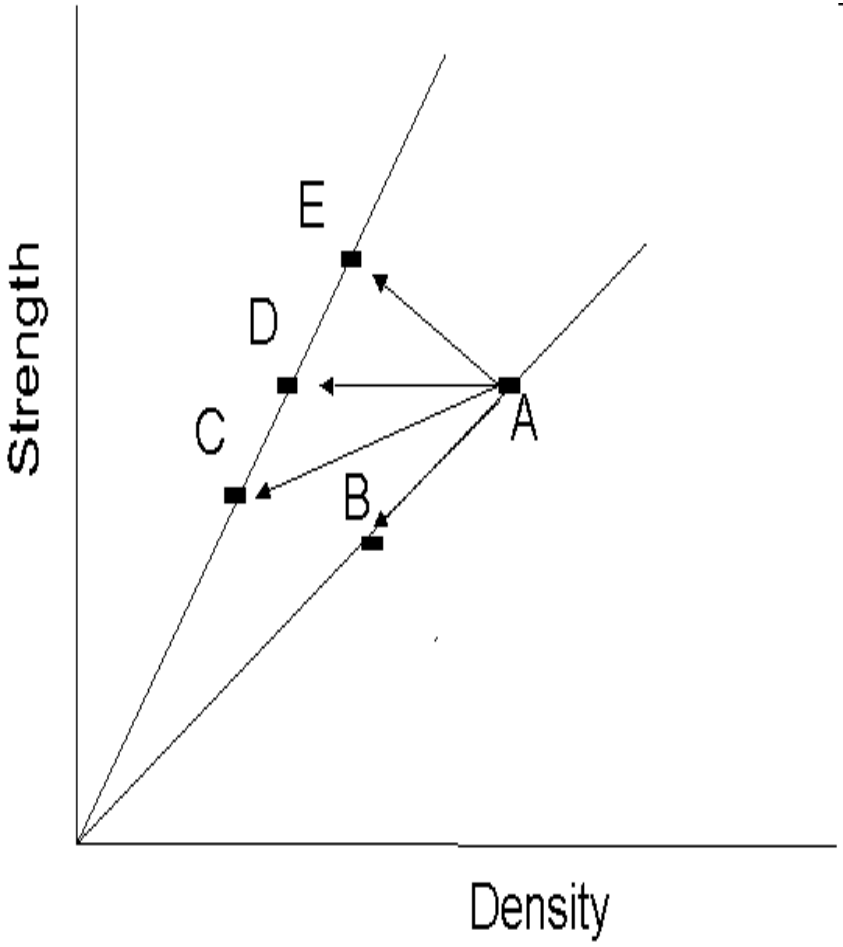
Options of Light weighting

- For same strength, we can have different material of different density
- Strength here is considered as Ultimate Tensile Strength of material
- The line at the left hand side represents light weighted material



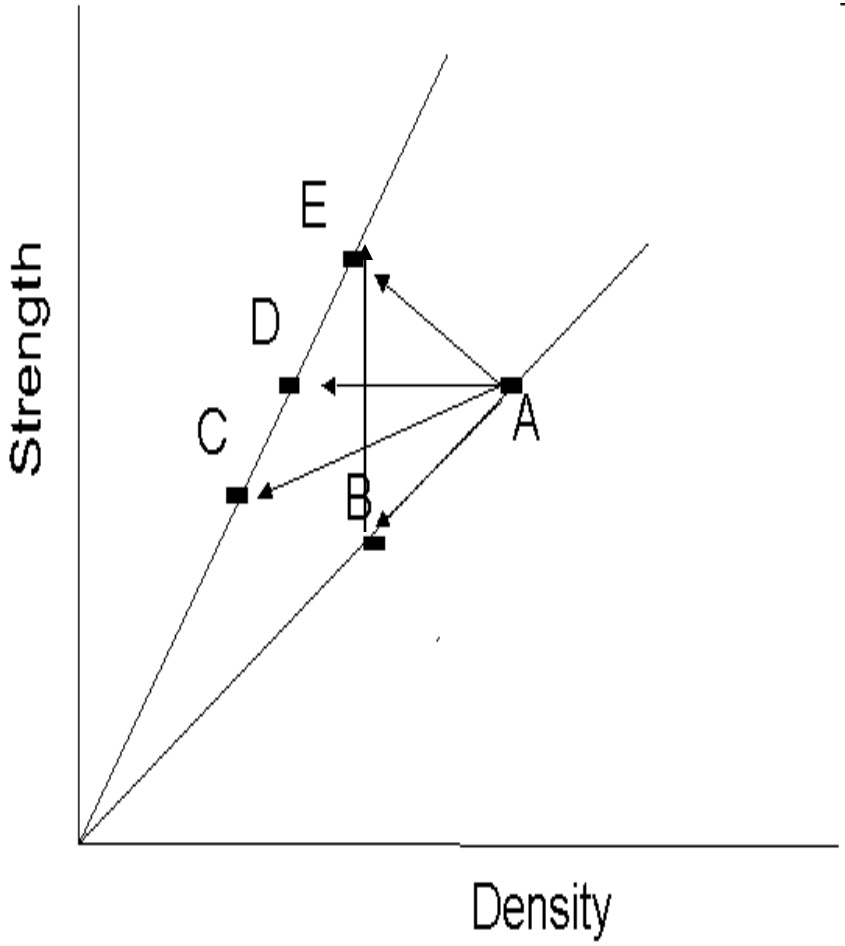
Options of Light weighting

- D & A both represents same strength but D is a lighter weighting material as density is less
- From A we can opt for E or D, if we do not want to compromise with strength
- If we can compromise with strength, we can opt for B or C also.



Options of Light weighting

- Selection of material is considered based on different other factors also, e.g. availability, formability, price, impact or fatigue value etc
- All the time lighter material options may not be suitable for application
- Option of increasing strength of a material (B E) will also push it towards lighter weighting material

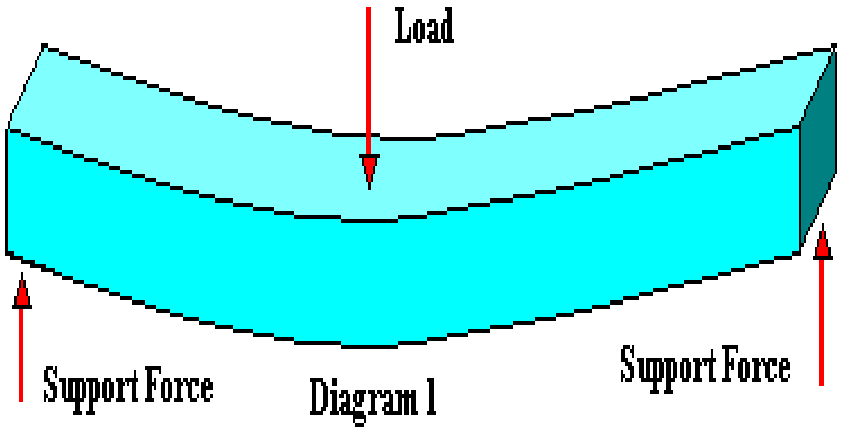


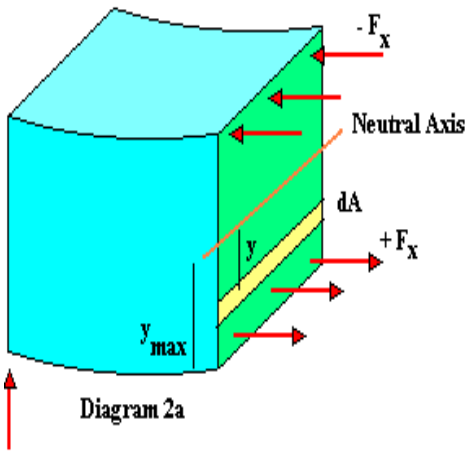
Bending stress

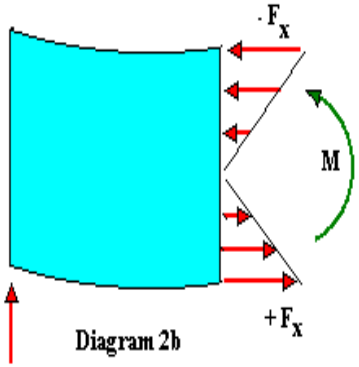
- Suppose we have a bar of rectangular cross-section subject to symmetrical three-point bend
- The maximum tensile stress at the bottom is

$$\sigma = 3FL/ 2BD^2$$

- If rectangular section is of width B and height D, F is the load and L is the length of the beam







Steel – the widely used material

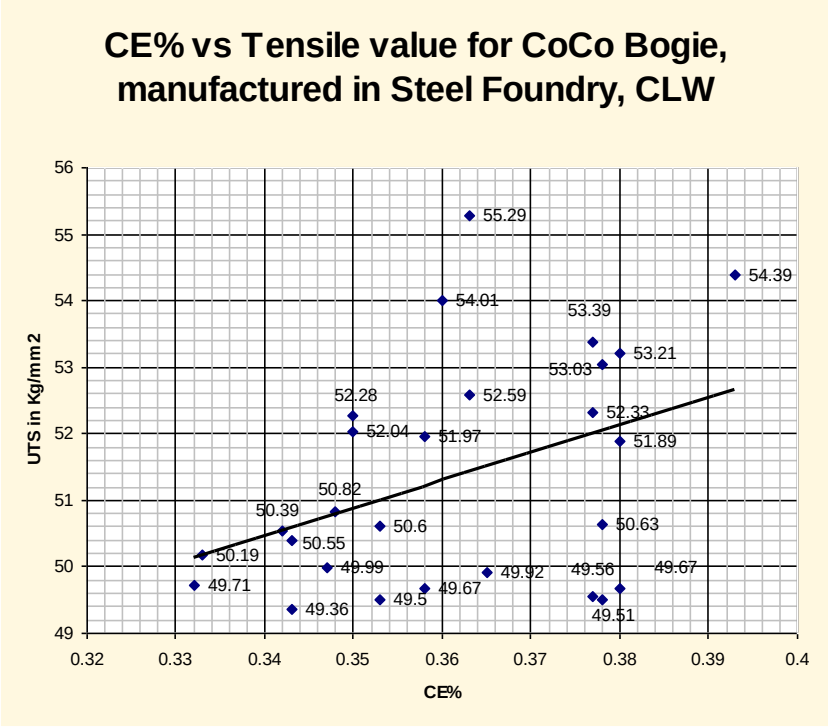
- Steel is the cheapest and the most widely used material at present.
- Steels are usually defined as alloys of iron and carbon, containing not more than 2% carbon, with or without other alloying elements.
- With more than 2% carbon, the material comes into another category called ‘cast iron’.

Steel – the widely used material

- As the carbon content in the steel increased, the hardness and tensile strength of the steel is increased.
- At the same time, the ductility of the steel decreases, with the increase of carbon
- Addition of other alloy elements like Mn, also acts to some extent in the same way in steel.
- In steel, the combined effect of carbon and Mn is called as carbon equivalent (CE) of the steel.
- CE% is generally stated as (C% + 1/6 Mn%)

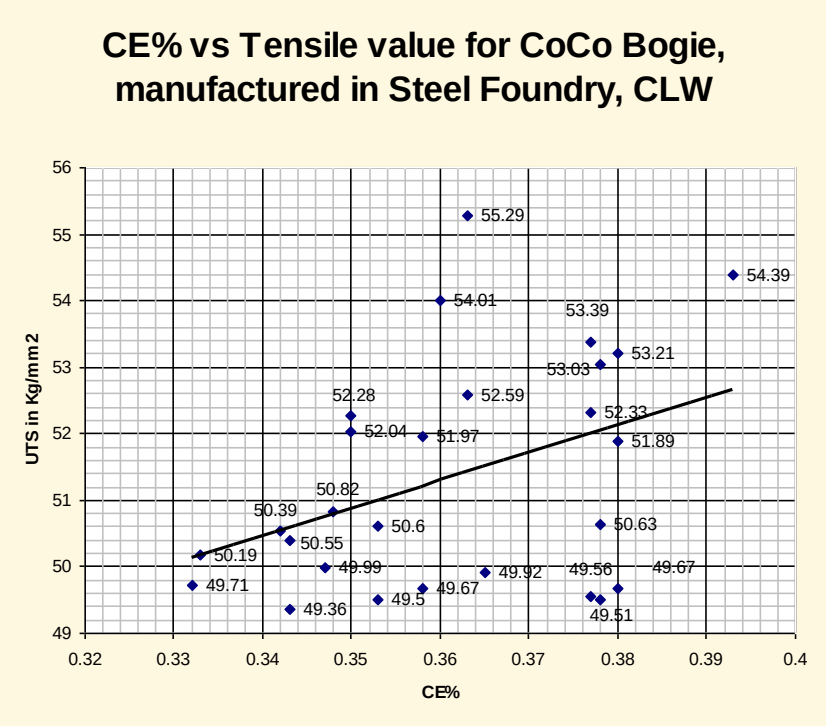
How to increase strength of steel?

- CLW has conducted a study on UTS against different CE% for 27 Bogies.
- A scattered diagram for UTS vs CE% has been plotted and statistical regression line or trend line for the relationship has been drawn



How to increase strength of steel?

- The trend line permits an appraisal of the closeness of the relationship between the CE% & UTS.
- The value of UTS increases with the increase of CE%.
- The UTS value of 500 Mpa comes around CE% 0.33% and UTS 518Mpa comes around at CE% 0.39.



Advantage & Limitation of high CE% steel

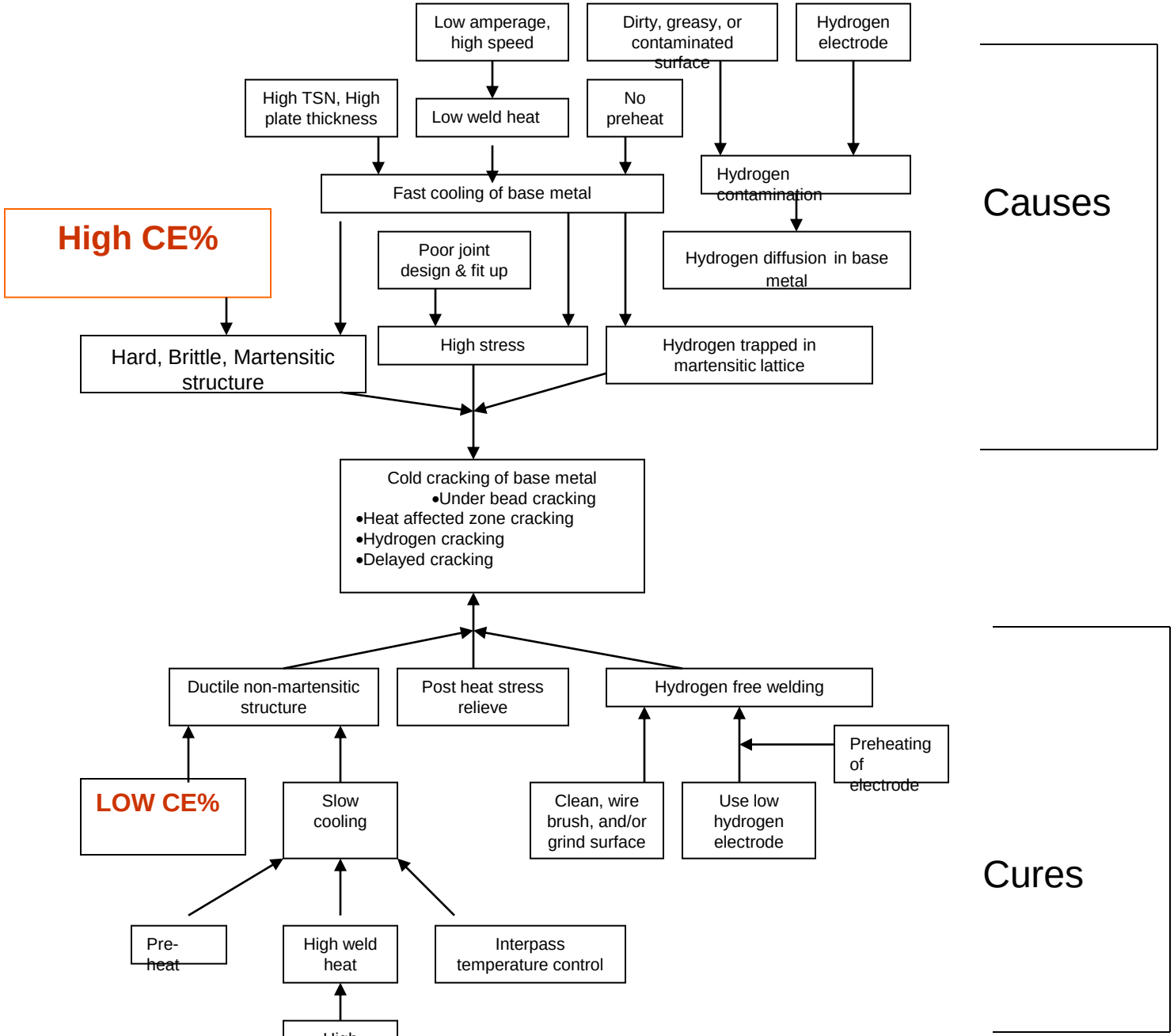
- Higher CE% makes the steel less ductile or brittle.
- They are not easy to cut, bend or machine
- When high CE% steel is quenched from a elevated temperature, they form a extremely brittle hardened structure, known as martensite.
- When martensite is heated at a lower temperature , a tougher & less britle structure is attained
- The process is called heat treatment

Advantage & Limitation of high CE% steel

- Heat treatment of steel gives rise to UTS upto level of 1000Mpa and above.
- Quenching without tempering gives rise to brittle structure.
- This property of higher CE% reduces weldability .
- Higher CE% steels are therefore not very welding friendly or fabrication friendly.

Weldability & CE%

- It is observed from above higher strength steels (with high carbon equivalent) are more susceptible to weld cold cracking than low strength steel (with low carbon equivalent)
- Steels that transform martensitically are particularly more susceptible to this kind of failure
- From design point of view, It is however always kept in the mind that for a given level of required strength, the steel with the lowest carbon equivalent should be considered for fabrication


Low amperage, high speed
Dirty, greasy, or contaminated surface
Hydrogen electrode
High TSN, High plate thickness
Low weld heat
No preheat
Hydrogen contamination
Fast cooling of base metal
High CE%
Poor joint design & fit up
Hydrogen diffusion in base metal
Hard, Brittle, Martensitic structure
High stress
Hydrogen trapped in martensitic lattice
Cold cracking of base metal
•Under bead cracking
•Heat affected zone cracking
•Hydrogen cracking
•Delayed cracking
Ductile non-martensitic structure
Post heat stress relieve
Hydrogen free welding
Preheating of electrode
LOW CE%
Slow cooling
Clean, wire brush, and/or grind surface
Use low hydrogen electrode
Pre-heat
High weld heat
Interpass temperature control
High amperage, Low speed
Causes
Cures

Micro-alloyed steel

- A micro-alloyed steel can be defined as a carbon-manganese steel containing deliberately added alloying elements totalling only 0.05 to 0.10%.
- Alloying elements which are effective in modifying steel properties when present in such small amounts include boron, vanadium and niobium
- Boron is used even in lesser amounts (0.005% /0.003%).

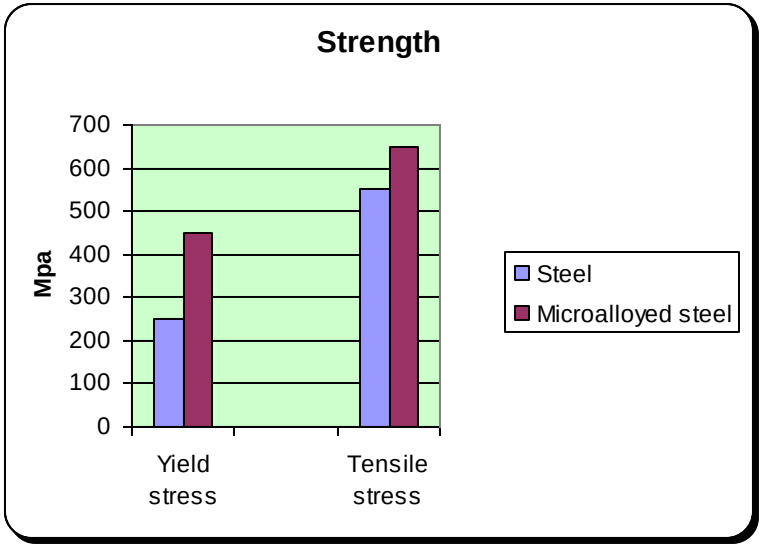
Micro-alloyed steel

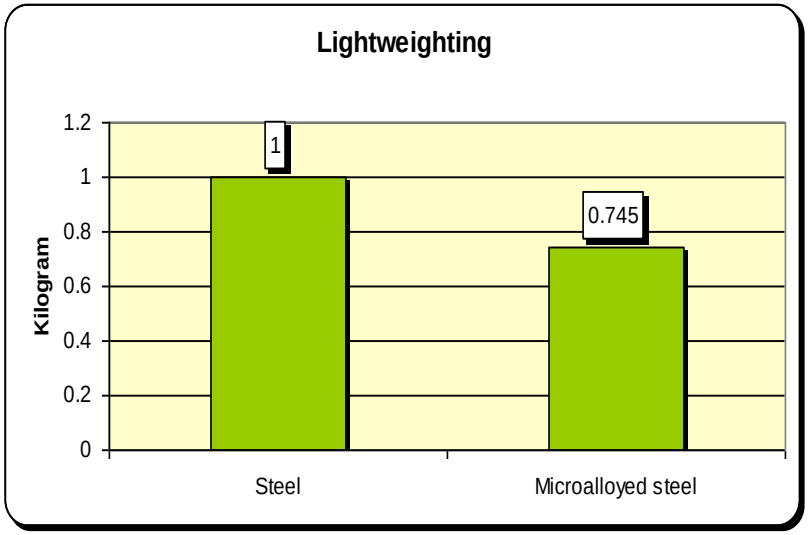
- These elements do not increase CE%, but increases strength of the steel dramatically
- **HSLA steel** (**h**igh **s**trength **l**ow **a**lloy steel) is a type of steel alloy that provides many benefits over regular steel alloys
- These added elements are intended to alter the microstructure of plain-carbon steels, which is usually a ferrite-pearlite aggregate, to produce a very fine dispersion of alloy carbides in an almost pure ferrite.

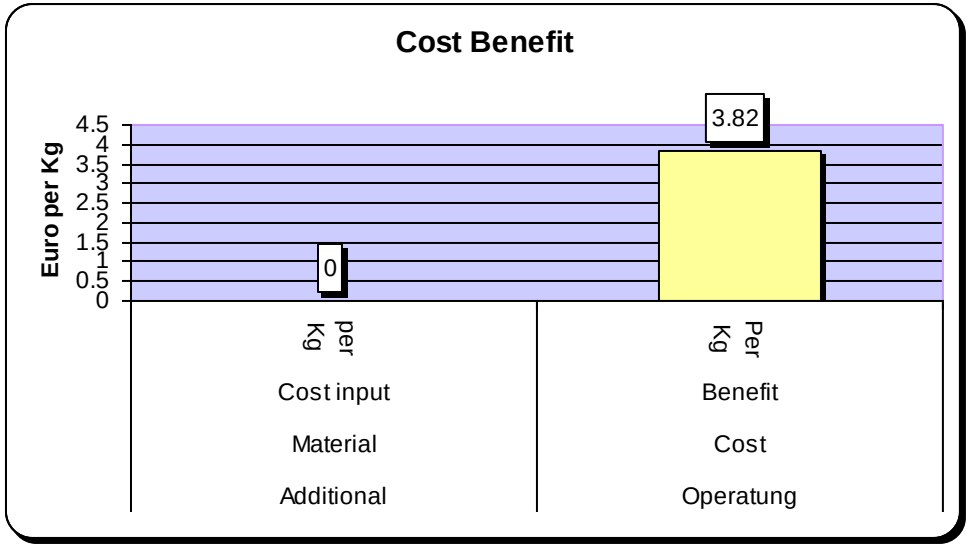
Micro-alloyed steel

- This increases the material's strength by precipitation strengthening and by refining the grain size
- Their yield strengths can be anywhere between 250–590MPa
- Precipitation hardening increases strength, but may contribute to brittleness.
- Grain refinement increases strength but also improves toughness
- HSLA steels usually have densities of around 7800 kg/m^3


Material cost
Euro per Kilogram
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.56
0.71
Steel
Microalloyed steel


Strength
Mpa
700
600
500
400
300
200
100
0
Yield stress
Tensile stress
Steel
Microalloyed steel


Lightweighting
Kilogram
1.2
1
0.8
0.6
0.4
0.2
0
1
0.745
Steel
Microalloyed steel

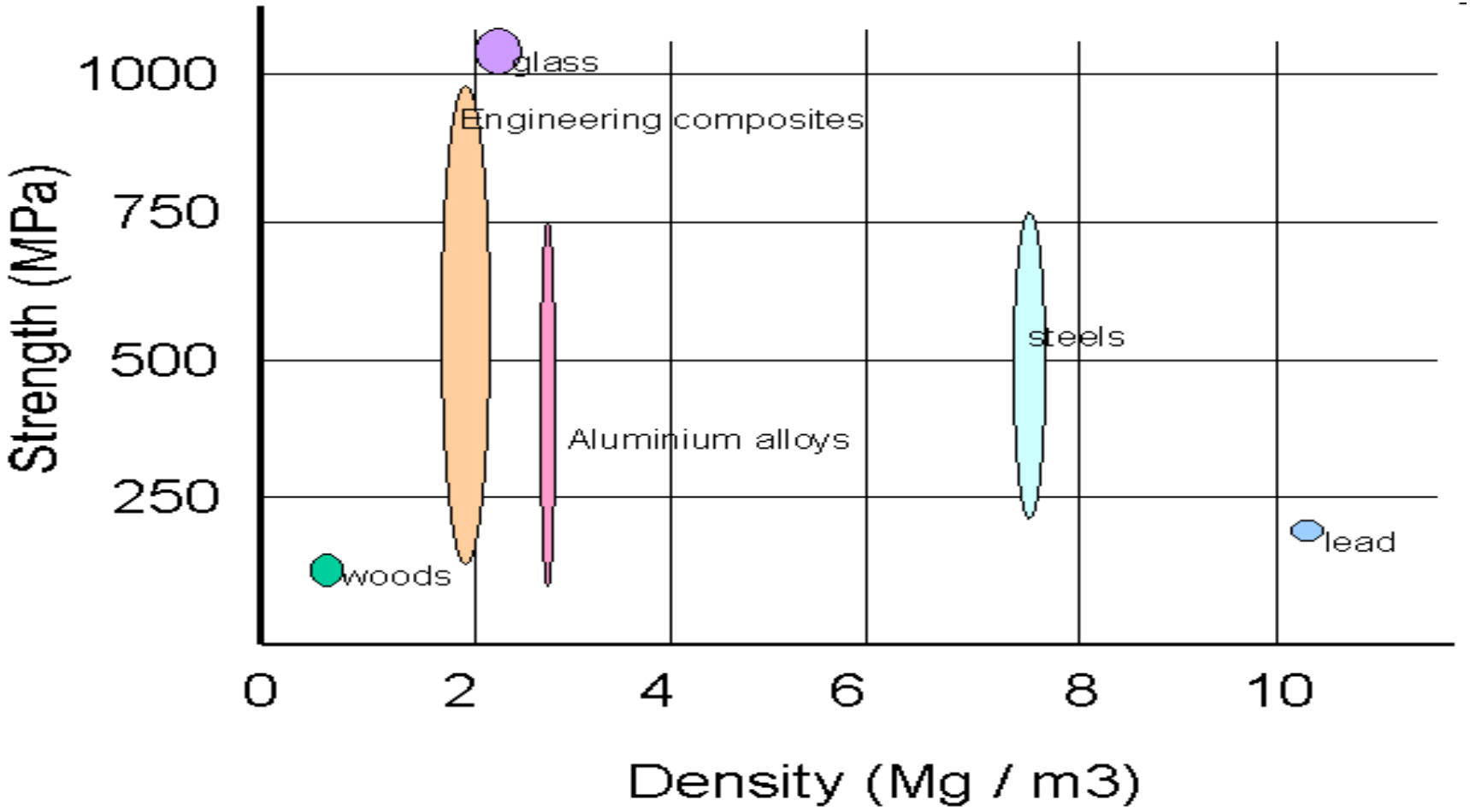

Cost Benefit
Euro per Kg
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
3.82
per Kg
Per Kg
Cost input
Material
Additional
Benefit
Cost
Operatung

Micro-Alloyed Steel

- Scope of light weighting is limited as density of the material remains same
- Corrosion is a significant phenomenon in the case of Ferrous materials
- Higher additional material is required to be designed to nullify corrosion effect

Different lighter density material options

Different light material options



Weight reduction II

Aluminium

Aluminium

- The potential of aluminium as a mass reduction material is clear when looking at its specific mass (2.7 g/cm3), which is almost one-third of that of iron (7.8 g/cm3)
- Many of the aluminium alloys belonging to 2000, 6000, 7000 series can give rise to tensile value & Yield value higher or equivalent to those of structural steel.

Aluminium

- But Modulus of elasticity of Aluminium, is around 10,000psi and that of steel is around 30,000psi
- For same stress, an aluminium beam will have almost three times more deflection than that of steel beam
- So as to nullify this effect, Aluminium beam has to be given certain extra material or thickness for having better stiffness.