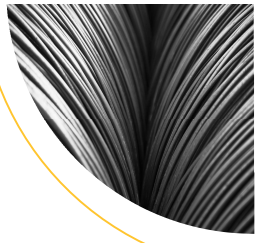
CHARTER STEEL

Choosing the Right Material for Your Application



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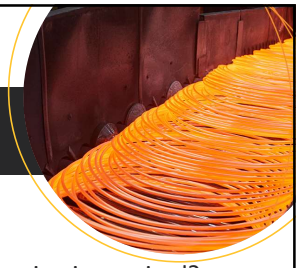

Some Things to Consider When Choosing the Proper Steel

Material Cost – Is there a lower cost option that would provide the same quality?

Formability – Can the material be easily formed based on geometry? What level of processing is required?

Hardenability – Can the material be properly heat treated based on size/geometry?

Compliance with Standards/Specifications – Does the material meet print requirements?

Tool Life/Tooling Costs – What are the indirect costs of using a less expensive material?

Machine Downtime/Set-up Time – What are the indirect costs of using a less expensive material?

Potential for Cracked/Scrapped Parts (Sorting) – What are the indirect costs of using a less expensive material?

Susceptibility to Quench Cracking – Large parts, sharp radii, thin sections, large volume transitions, etc.

Service Environment – Exposure to temperature, humidity, salt, etc.

2

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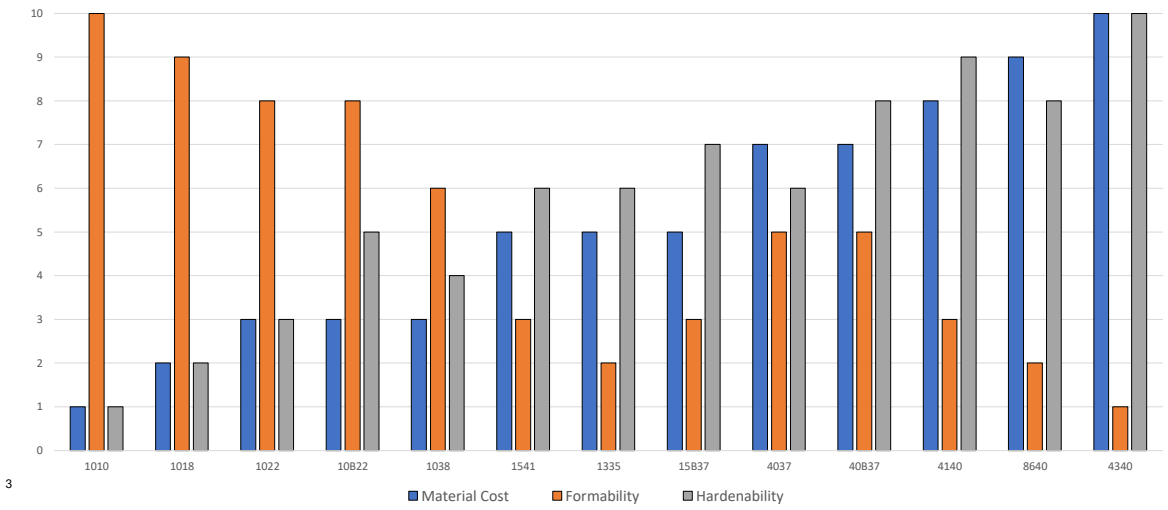
Relative Comparisons by Grade



3

3

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Additional Considerations/Options

Microalloys:

- Strength by work hardening (no heat treat required).
- Typically used on long parts with susceptibility to warping during heat treat.

PPAP's:

- Customer approval.
- Joint re-validation.

Head Marking:

- Some specifications require a special head marking (e.g. underline property class – "10.9") when using a lower carbon boron steel.

Special Applications:

- May have to avoid elevated service temperatures (e.g. above 500° F).
- May have to avoid extreme low service temperatures (impact strength). The ductile-to-brittle transition temperatures should be considered based on the specific application.
- Safety parts may have special material requirements (e.g. FMVSS).

4

4

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Hardenability

- Hardenability is the depth to which a steel is hardened after putting it through a heat treatment process.
- Generally speaking, the larger the component, the greater the material hardenability required.
- Hardenability can be measured using a jominy test (ASTM A255), or calculated based on material chemistry (CAT DI 1E0038).

5

5

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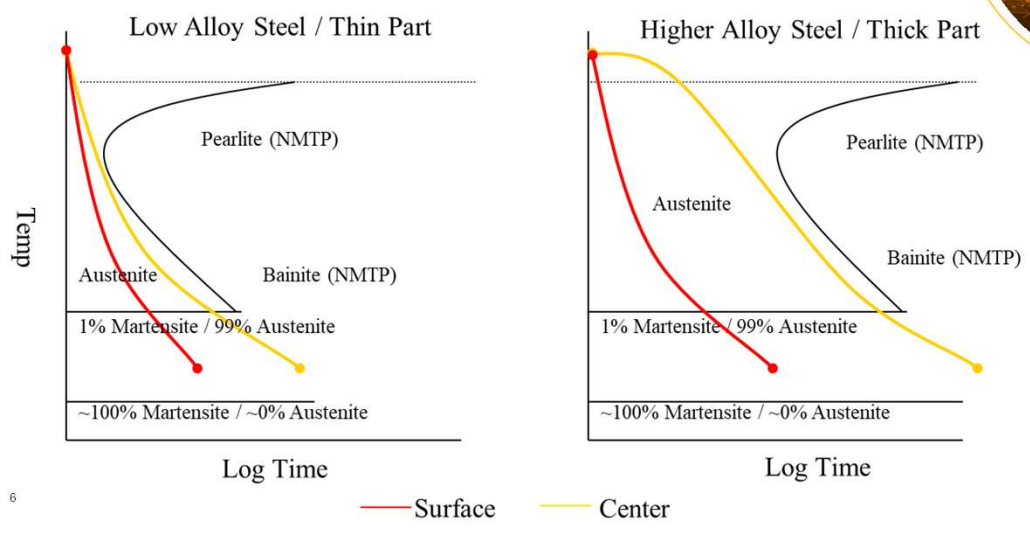
Hardenability (TTT Diagrams)



6

6

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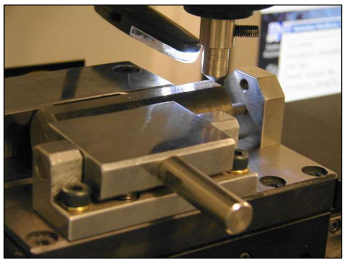
Jominy Test (ASTM A255)

- 1” diameter sample machined from billet / rolled stock.
- Sample is heated to a specific temperature (based on size and grade) for 35 minutes minimum.
- Sample is water quenched in a tank with standardized flow rate, water temperature, & distance.



7

7

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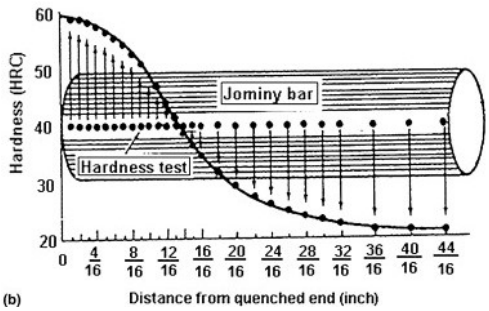
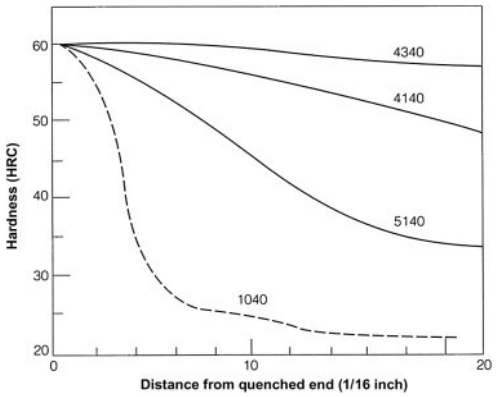
Jominy Test (ASTM A255)

- Flats are ground on opposite sides of the sample.
- Hardness testing performed at 1/16” increments from the quenched end on both sides.
  - 1/16” = J1, 2/16” = J2, etc.





8

8

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Hardenability Curves/Bands (H-Steels)

HARDNESS LIMITS FOR SPECIFICATION PURPOSES

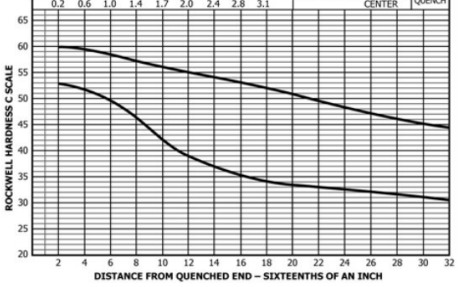
"J" DISTANCE SIXTEENTHS OF AN INCH	4140 H MAX.	4140 H MIN.
1	60	53
2	60	53
3	60	52
4	59	51
5	59	51
6	58	50
7	58	48
8	57	47
9	57	44
10	56	42
11	56	40
12	55	39
13	55	38
14	54	37
15	54	36
16	53	35
18	52	34
20	51	33
22	49	33
24	48	32
26	47	32
28	46	31
30	45	31
32	44	30

HEAT TREATING TEMPERATURES
RECOMMENDED BY SAE
*NORMALIZE 1600 °F
AUSTENITIZE 1550 °F
*For forged or rolled specimens only.

HARDENABILITY BAND 4140 H

C	Mn	Si		Cr	Mo	
0.37/0.44	0.65/1.10	0.15/0.35		0.75/1.20	0.15/0.25	

DIAMETERS OF ROUNDS WITH SAME AS QUENCHED HARDNESS	LOCATION IN ROUND	QUENCH
3.8	SURFACE	MILD WATER QUENCH
1.1 2.0 2.9 3.8 4.8 5.8 6.7	3/4 RADIUS FROM CENTER	
0.7 1.2 1.6 2.0 2.4 2.8 3.2 3.6 3.9	CENTER	
0.8 1.8 2.5 3.0 3.4 3.8	SURFACE	MILD OIL QUENCH
0.5 1.0 1.6 2.0 2.4 2.8 3.2 3.6 4.0	3/4 RADIUS FROM CENTER	
0.2 0.6 1.0 1.4 1.7 2.0 2.4 2.8 3.1	CENTER	



- H-steels (i.e. 4140H) are guaranteed by the supplier to meet established hardenability limits (ASTM A304).
- The H-band composition provides the melt shop with a somewhat wider chemical range.
- Today, most US mills melt to tighter chemistry limits and can meet H-band hardenability.
- Some customers call out specific jominy requirements such as a J1 minimum and a J5 maximum.

9

9

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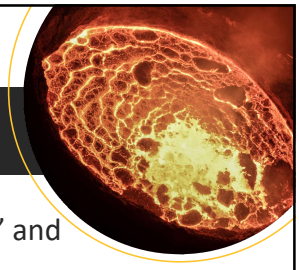
The Use of Boron in Steel



In Europe, a very high percentage of fasteners are produced from “Boron” and “Boron Alloy” steels:

- Class 8.8 to 10.9 fasteners and grade 10 nuts.
- Sometimes referred to as “Euro-Boron” or “Euro-Boron Alloy” steels.
- Grade designations such as 23MnB3 or 30MoB1 per specifications such as DIN EN 10263-4.

In the US, this percentage is lower due to:

- Perception (“boron steels are bad”).
- Resistance to change (alloys are “tried & true”).
- Joint relaxation at higher temperatures.
- Specification requirements/confusion.
- Grade designations such as 10B22 or 40B37.

10

10

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What Does Boron Actually Do?

- Added in small amounts (0.0008% to 0.003%) to significantly increase hardenability.
- An addition of 30 ppm (0.003%) gives a hardenability equivalent to 0.6% Mn, 0.7% Cr, 0.5% Mo or 1.5% Ni.
- Ti addition (0.01% – 0.05%) prior to boron addition (Ti ties up N - titanium nitrides).
- Boron goes into solution (active) instead of forming boron nitrides.
- Actual jominy (as opposed to calculated) is performed on all boron steels to verify boron effectiveness.

11

11

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Potential Advantages of Boron Steels

- Enhanced formability and tool life/lower tooling costs
  - Reduced alloy and carbon content
  - Reduced work hardening
  - Ti and B additions tie up nitrogen
  - Improved mechanical properties:
    - Lower tensile strength and hardness, higher reduction of area
- Potential reduction in material costs
  - Reduced alloy costs/surcharges
  - Somewhat offset by Ti and B additions
- Reduced susceptibility to quench cracking
  - Reduced alloy and carbon content

12

12

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Potential Disadvantages of Boron Steels

- Strength loss at high temperatures
  - Lower tempering temperatures may be required to achieve the same hardness as alloy steels (specification requirements).
  - Material can soften (e.g. lose strength/clamp load) at lower service temperatures than alloy steels.
- Compliance with standards & specifications
  - Chemistry requirements (< 0.25% C).
  - Minimum tempering temperature requirements.
    - To get to 36 HRC, 4037 requires ≈ 850° F temper while 30MoB1 requires ≈ 750° F temper.
  - Size requirements.
  - Test requirements.
  - Head marking requirements ("12.9" as opposed to "12.9").

13

13

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Example of Alternative Options

Characteristic	Current Grade	Alternative Option #1	Alternative Option #2	Alternative Option #3
Grade	4037	5135	15B37	10B22
Chemistry Difference (compared to 4037)		higher Cr, no Mo	B, higher Mn, no Mo	B, lower C, no alloys
Tempering Temperature (to hit approximately 36 HRC)	850° F	900° F	850° F	650° F
Hardenability	Fair to Good	Good	Good to Excellent	Good
Formability	Good	Fair	Fair	Good to Excellent
Susceptibility to Quench Cracking	High	High	High	Low

14

14

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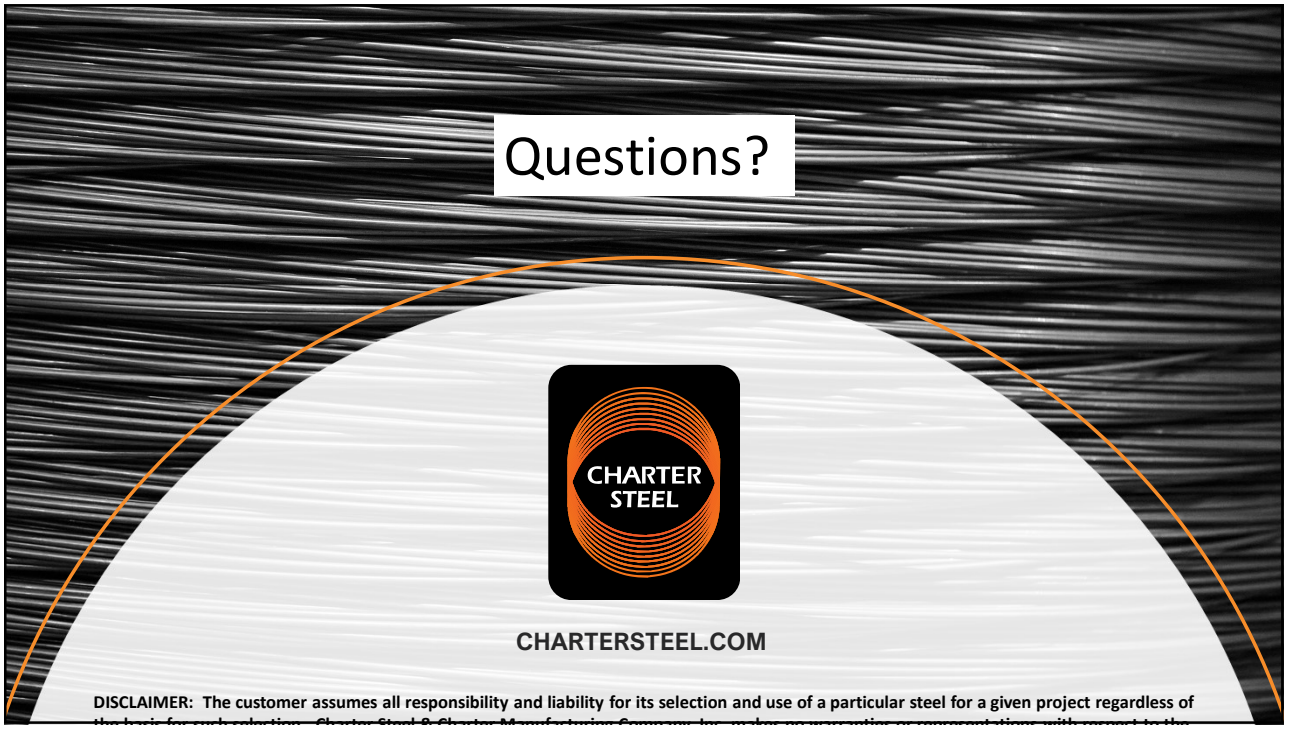
Summary and Conclusion

- There are numerous things to consider when choosing the right material for the job.
- Choosing the right material for the application is key to producing high quality parts and controlling both up-front (material) costs as well as indirect costs such as tool usage, downtime, sorting, etc.
- There are typically several options available when choosing material.
- Choosing the wrong material could potentially result in poor quality, excessive costs, excessive downtime, poor part performance, etc.
- Charter's Technical Service Engineers (TSE's) are always available as your ally to assist/advise in any raw material decisions.

15

15



16