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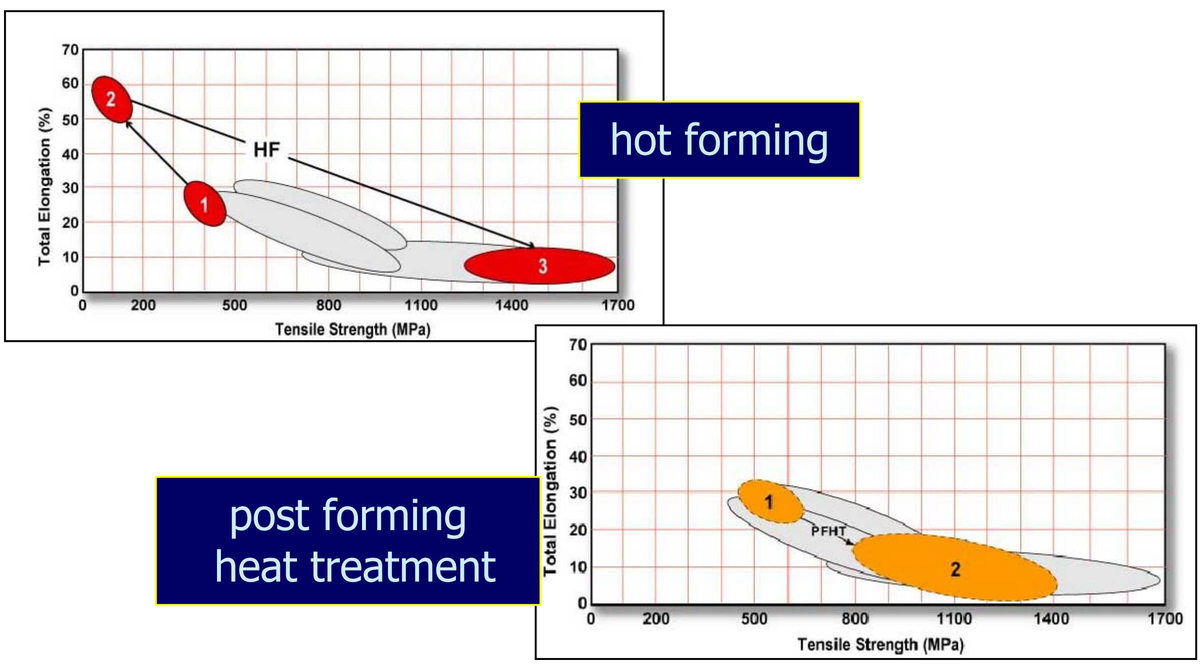
Material Comparison: Boron-Treated Steels

The automotive industry has adopted a strategy to implement Advanced High Strength Steel (AHSS) technology for vehicle frame and body structures, in response to market demands to reduce the weight of automobiles to improve fuel economy and occupant safety. Many car components and structural members can be made significantly lighter by using thinner gauge AHSS.

Generally speaking, as the strength of a steel sheet increases, its formability decreases, and to overcome this problem, various types of high-strength steel sheet products with controlled microstructures have been developed. In spite of these efforts, however, press forming complicated shapes is difficult when the strength of a steel sheet exceeds 1000 MPa.

However, several alternative methods, when combined with compatible materials, allow for complex components with strengths in excess of 1400 MPa: hot forming (press-hardening, hot stamping) and post-form heat treatment.



Two such compatible materials are martensitic stainless steels (i.e., type 410, type 420) and boron-treated steels (i.e., 22MnB5, USIBOR1500). The following tables list properties of two common types of these alloys, compared with other automotive steels:

Table 1: As-Delivered Tensile Properties

Alloy	Dir.	0.2%YS ksi(MPa)	UTS ksi(MPa)	%El (in 2")	Hard R_B	n-value
Type 410	L	42.2(291)	77.1(532)	32.7	79	0.196
(martensitic stainless)	T	44.2(305)	76.8(530)	31.1	--	0.194
HSLA350	L	57.9(399)	69.0(476)	26.1	75	0.136
	T	63.8(440)	70.8(488)	25.6	--	0.115
DP600	L	54.5(376)	96.3(664)	26.0	89.5	0.162
	T	57.5(396)	97.7(674)	26.0	--	0.160
DP780	L	69.5(479)	119.4(823)	20.4	97.3	0.143
	T	76.3(526)	125.3(864)	17.7	--	0.126
22MnB5	L	65.6(452)	84.8(585)	27.1	86	0.177
(boron-treated)	T	67.3(464)	86.1(594)	26.3	--	0.170

Results are average of duplicate tensile tests; courtesy of AK Steel Labs

Table 2: Tensile Properties after Heat-Treatment and Stress Relief

Alloy	Dir.	0.2%YS ksi(MPa)	UTS ksi(MPa)	%El (in 2")	Hard R_c
Type 410*	L	148.0(1020)	196.5(1355)	9.2	41.5
(martensitic stainless)	T	149.4(1030)	197.2(1360)	8.6	42.0
22MnB5	L	155.2(1070)	214.1(1476)	7.3	46.0
(boron-treated)	T	153.6(1059)	212.2(1463)	6.9	46.0

Results are average of duplicate tensile tests, courtesy of AK Steel Labs
*350°F/30min stress relief after hardening

While boron-treated steel can offer extremely high strengths, it requires a slightly-faster than air cooling quench rate to achieve maximum strengths. In practice, typical critical (minimum) quench rates are 20 to 40°C/s for boron- treated sheet steels.

Martensitic stainless steels, iron-chromium alloys containing 12-17% Cr, are considered "air-hardening" as an air quench is sufficient to develop a martensitic microstructure upon cooling. Typical critical (minimum) quench rates are 10 to 20°C/s for martensitic stainless sheet steels.

In hot-forming, the slower critical quench rate of martensitic stainless steels allows for more uniform part properties. This is most pronounced on deep-draw sections, where the heat transfer rate between the part and the die can vary significantly on non-normal contact faces.

The following table summarizes key thermal-processing parameters for the two alloys:

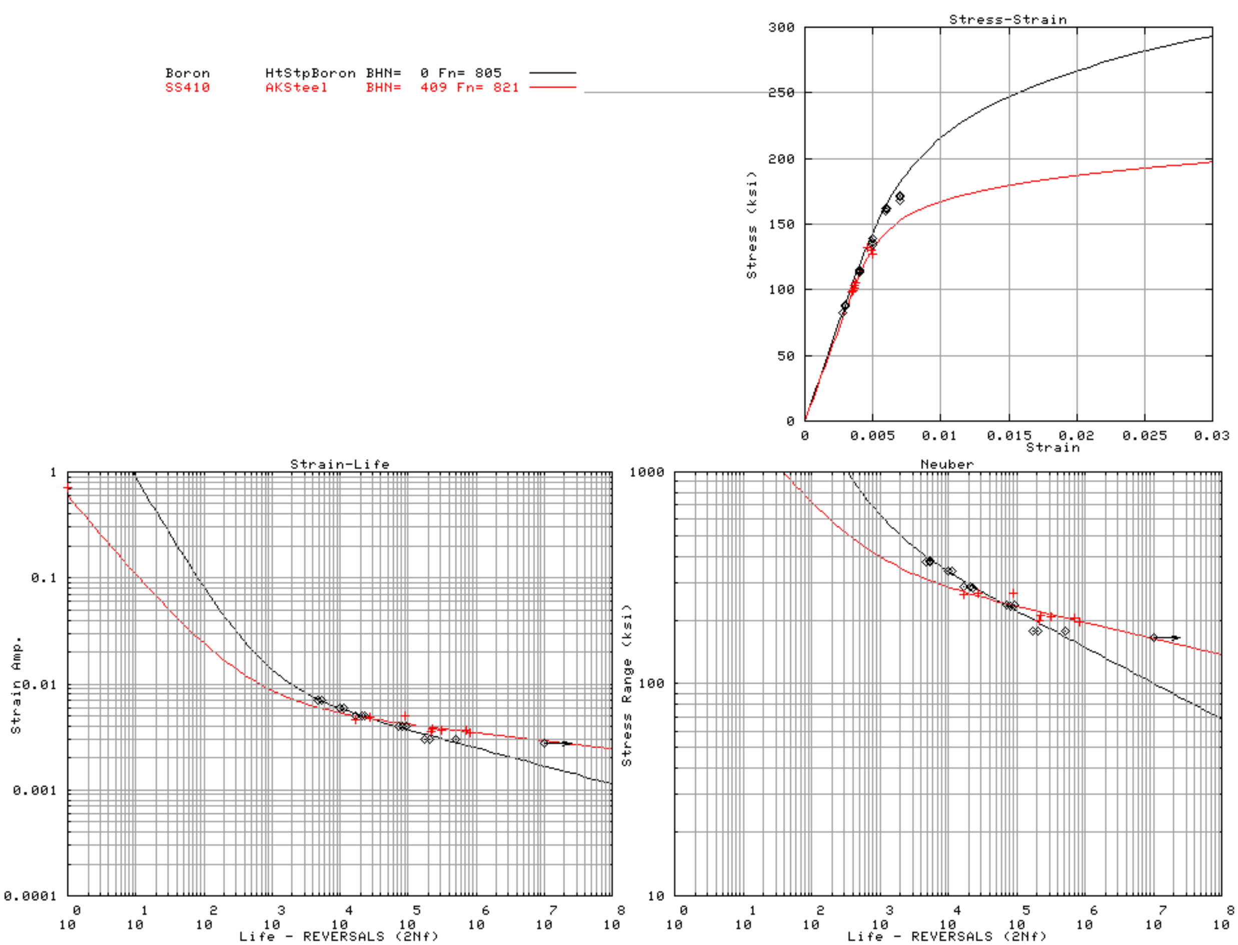
Table 3: Thermal Treatment Parameters

Alloy	Lower Critical Temp A_{C1} (°C)	Min. Austenitizing Temp A_{C3} (°C)	Critical Cooling rate approx (°C/s)
Type 410* (martensitic stainless)	675	960	10-20
22MnB5 (boron-treated)	750	860	20-40

Although martensitic stainless steel requires a higher austenization temperature, the lower critical temperature is lower. This allows for extra time transferring the heated sheets to the die, without worry of incomplete transformation and low hardness in the finished product.

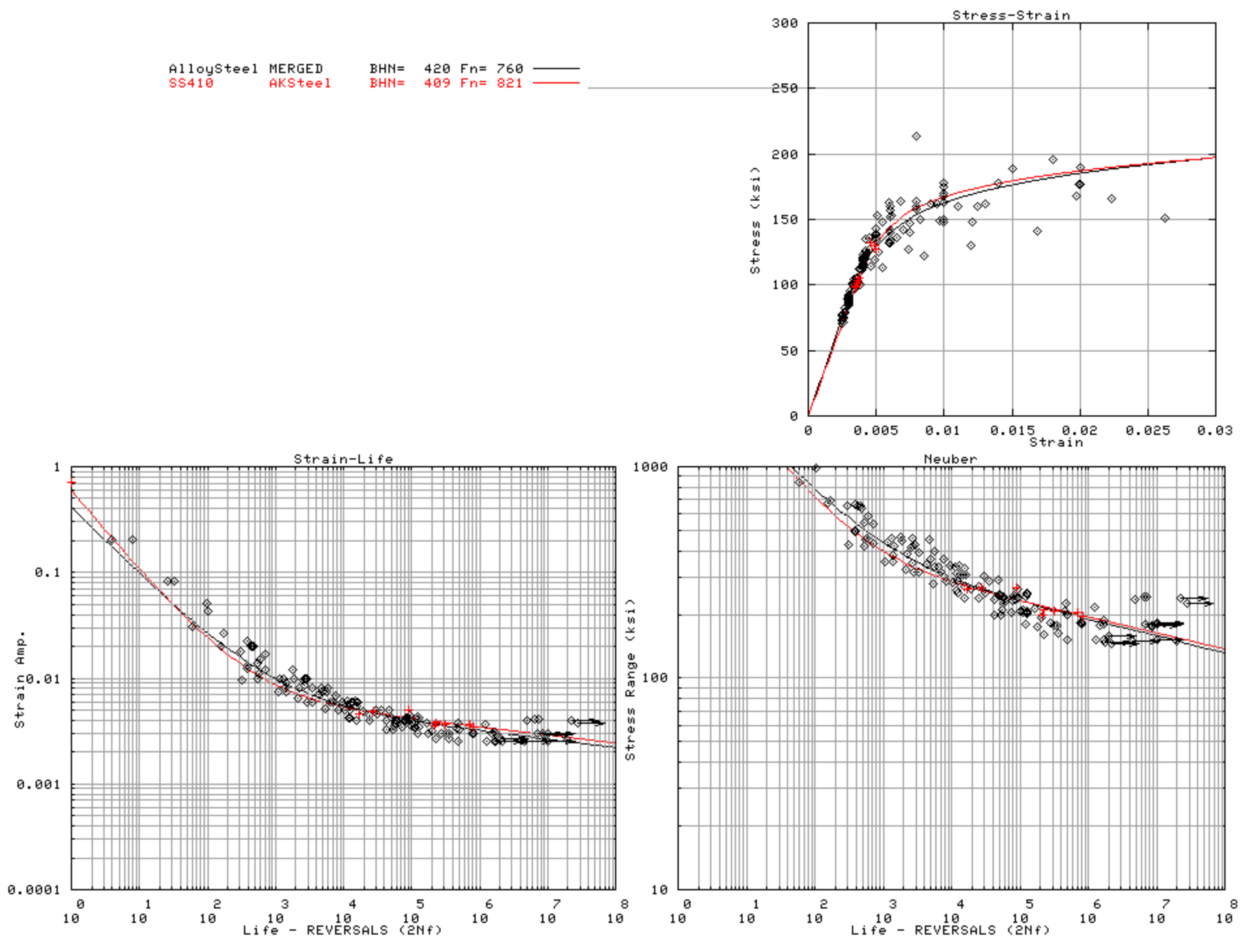
The following fatigue-life diagram compares the fatigue performance of the two alloys:

Fig. 1: Fatigue Life: Type 410 vs. 22MnB5 Boron-Treated Steel
(courtesy AK Steel Labs)



Additionally, the following figure compares many Alloy steels of similar ultimate tensile strength (Su= 200 to 249 ksi) and again the SS410 lies along the top of the scatter band for these types of steels.

Fig. 2: Fatigue Life: Type 410 vs. AHSS Alloy Steels
(courtesy AK Steel Labs)



The diagrams indicate:

- Type 410 stainless steel appears to have higher fatigue performance, in the long life region, than the test samples of 22MnB5 Boron-treated steel
- Type 410 Stainless Steel has similar fatigue properties to other alloy steels of similar ultimate strength.

There have been numerous studies sponsored by the American Iron and Steel Institute (AISI) and the Auto-Steel Partnership (A-S/P), such as the ULSAB (Ultra Light Steel Auto Body) that show, theoretically, how weight savings can be achieved by AHSS to various parts of a vehicle structure. Current trends, including the creation of the Heat Treatable Sheet Steel Group at the A-S/P, all point to an increasing awareness and implementation of high-performance materials such as martensitic stainless steels.